November 2020

Electricity Ten Year Statement

#ETYS2020

nationalgridESO

Foreword

As the Electricity System Operator for Great Britain we are in a privileged position. We sit at the heart of the energy system, balancing electricity supply and demand second by second. We keep the lights on and the electricity flowing directly to where it's needed. As well as day to day operation of the electricity system by our control centre, we play a central role within the energy industry, looking at what the future may bring and how the market needs to adapt to deliver a more affordable, greener future. We are facilitating the journey to net-zero by sharing insights and analysis, running world-first innovation projects, and communicating with the industry about how we need to plan and develop the electricity network.

Welcome to our Electricity Ten Year Statement (ETYS). This document sets out our current assessment of the future requirements of Great Britain's electricity transmission system. It highlights areas with uncertain future power flows and requirements which provide opportunities for system development and innovation.

It is our ambition to be able to operate a zero-carbon electricity system by 2025, a big milestone in the UK's journey to net-zero by 2050. The ETYS along with our other Electricity System Operator (ESO) publications, are key in helping us to achieve these goals, through encouraging innovation and informing development of the electricity network - so that together we can deliver a secure, sustainable and affordable energy future. The ETYS is a key input into our Network Options Assessment (NOA) process that makes recommendations for future investments and solutions. The ETYS and the NOA primarily focus on the bulk power transfer across major transmission boundaries in GB, however there are many other system requirements that are important for secure and efficient system operation.

We are in the midst of an energy revolution. The economic landscape, developments in technology, and consumer behaviour are changing at an unprecedented rate, creating more challenges and opportunities than ever for our industry. Our 2020 Future Energy Scenarios (FES), developed with stakeholder and industry input, informs decisions that will help us achieve carbon reduction targets and shape the energy system of the future. These scenarios are at the heart of the ETYS process in determining future transmission network needs.

The themes in this year's FES are negative net emissions from the power sector with about 40GW of new capacity connected to the system in the next 10 years. With a large amount of wind generation based in the north of the country and the demand being based in the south of the country, these changes are leading to high north-to-south transmission flows across Scotland. The number of interconnectors that are predicted to connect towards the South East of England also create potential overloads on the network and a key focus is to make sure that we can meet these needs. As a result of the future transmission needs we have identified in this document, the Transmission Owners (TO) alongside the Electricity System Operator (ESO) have provided development options for the Network Options Assessment (NOA) process. These options range from large asset builds through to smart grid management systems and new commercial products. The NOA aims to make sure that the transmission system is continuously developed in a timely, economic and efficient way, providing value for our customers. Using the results from ETYS 2019, the NOA 2019/2020 recommended £203 million of development spend on network reinforcements in 2020.

In line with our commitments in the ESO Forward Plan and the Network Development Roadmap, we are using our NOA pathfinder projects to assess a broader range of network issues and encourage options from a range of industry participants. This year we've improved our year-round probabilistic analysis and have presented additional studies that demonstrate how we are taking steps towards enhanced tools and analysis to improve our network planning. You can find further details about our enhanced role in network planning in the ESO Forward Plan. You can also find further details about the changes we are making to our methods in the Network Development Roadmap.

Thank you for your continued feedback on the ETYS process. It is vital that we share the right data in the right way to make this a useful document and a catalyst for wider debate. Please share your views with us; you can find details of how to contact us on our website [https://www.nationalgrideso.com/insights/ electricity-ten-year-statement-etys.](https://www.nationalgrideso.com/insights/electricity-ten-year-statement-etys)

Julian Leslie
Head of Networks, ESO

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Executive summary

Our Ambition

As the Electricity System Operator (ESO) for Great Britain, we are in a privileged position. We sit at the heart of the energy system, balancing electricity supply and demand second by second keeping the lights on and the electricity flowing directly to where it's needed.

Our ambition is to be able to fully operate Great Britain's electricity system with zero-carbon by 2025. We are already making great progress towards this, with record levels of renewable generation and periods of operating without using coal power. This means a fundamental change to how our system was originally designed to operate is needed, including integrating newer technologies right across the system – from large-scale off-shore wind to domestic scale solar panels – increasing demand-side participation, using new smart digital systems to manage and control the system in real-time.

We're already working with the industry to identify the systems, services and products needed to run a zero-carbon network and developing the new competitive market places needed to source these as efficiently as possible. We know the energy transition must be affordable and that competition is vital for encouraging innovation and keeping prices as low as possible.

Our 2030 mission is to enable the transformation to a sustainable energy system and ensure the delivery of reliable, affordable energy for all consumers. We have set some clear goals for 2025, we aim to have:

An electricity system than can operate carbon free

A whole system strategy that supports net zero by 2050

Competition everywhere

The ESO is a trusted partner

Key Messages

1. Power flows will become more variable with higher peaks

2. There is a growing need for network reinforcements in a number of regions

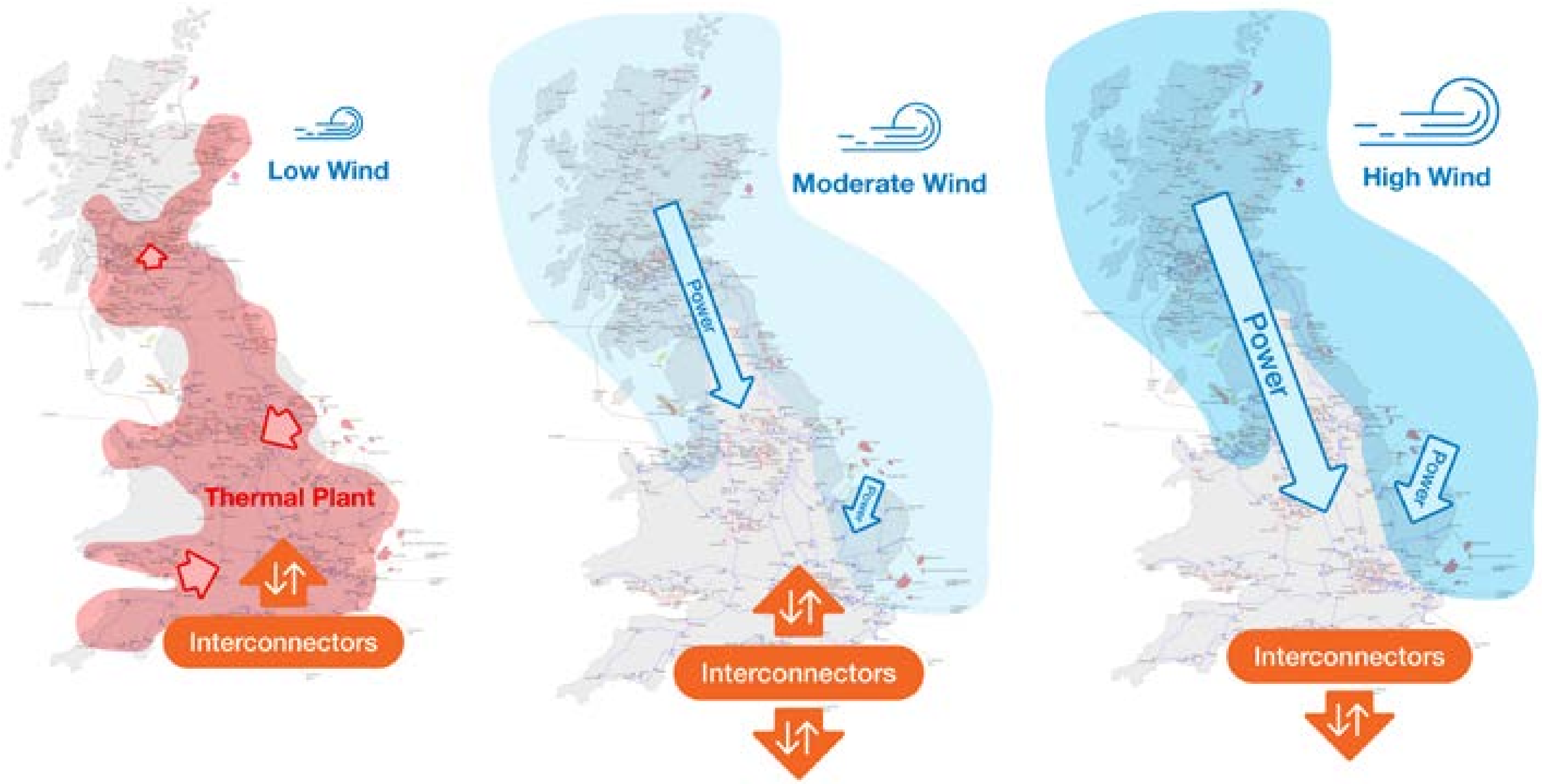
3. Network constraints expected to rise if no action is taken

Key Message 1

Power flows will become more variable with higher peaks.

Over the next 10 years, wind generation has been forecasted to increase in the north of the country. Demand is predominantly located in the south of the country leading to high north-south power flows with high variability.

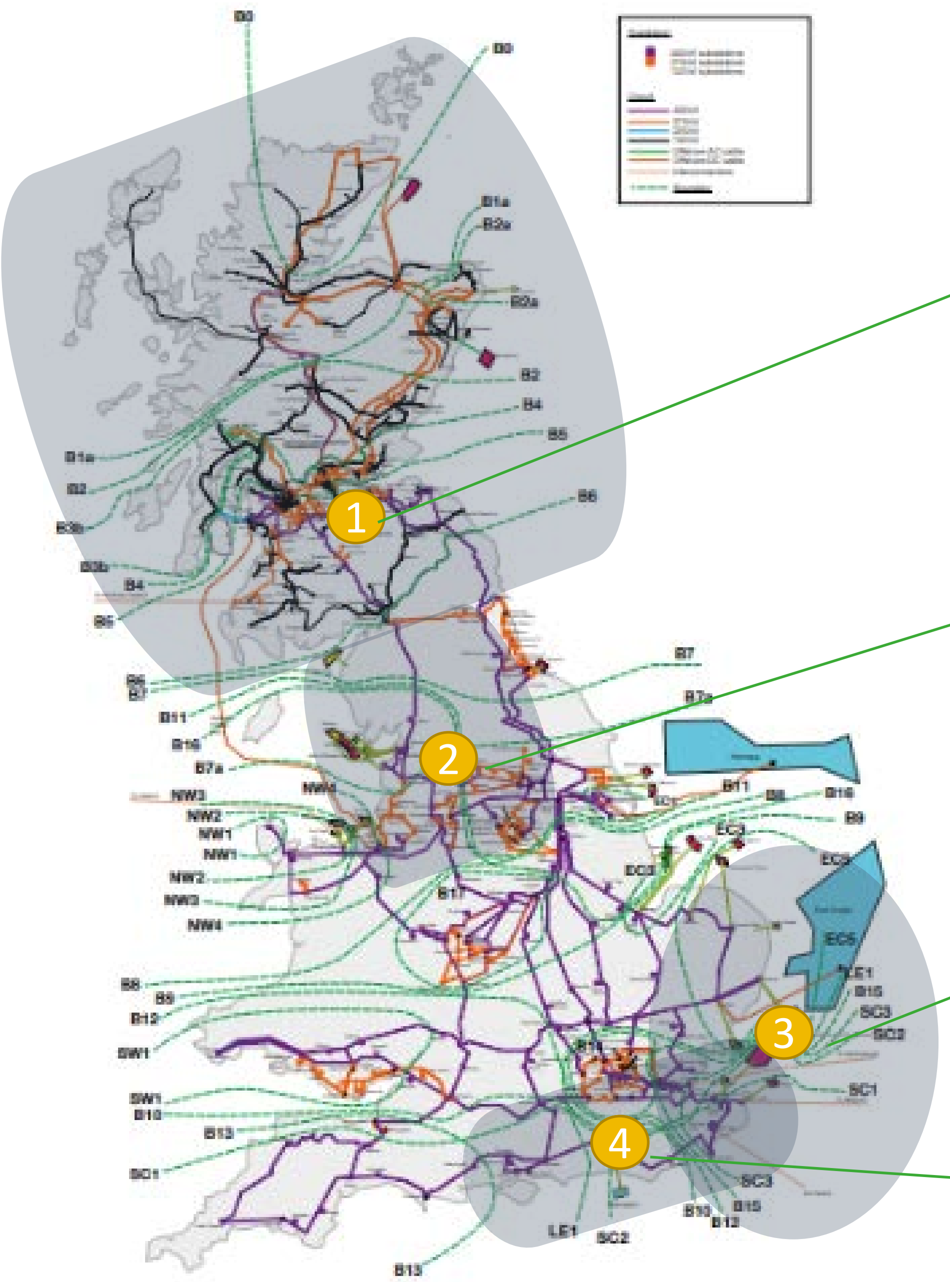
Interconnectors connect us to other European markets and either import or export power. As these flows change, it can require further transmission capability on the system to avoid constraints, especially when interconnectors export to Europe during significant periods of wind output.



Wind	Low	Medium	High
Conventional Plant	High	Medium	Low
Interconnectors	Typically Import	Variable	Variable with more export

Key Mesage 2

In the move to net-zero over the next decade, the GB Electricity Transmission System will face growing needs in a number of regions



Increasing quantities of wind generation connected across the Scottish networks more than doubling the north-to-south transfer

Additional 4GW of renewables expected compared to last year's scenarios requiring 18GW of requied transfers by 2040

A potential growth of over 6GW in low-carbon generation and interconnectors in the North of England combined with high Scottish generation will increase transfer requirements in the Midlands.

25% increase in expected requirements compared to last year's scenarios

10GW increase expected in generation coming from offshore wind on the east coast connecting to East Anglia, which will increase the need for reinforcement here

17% increase in expected generation between Two Degrees (FES 2019) and Leading the Way (FES 2020)

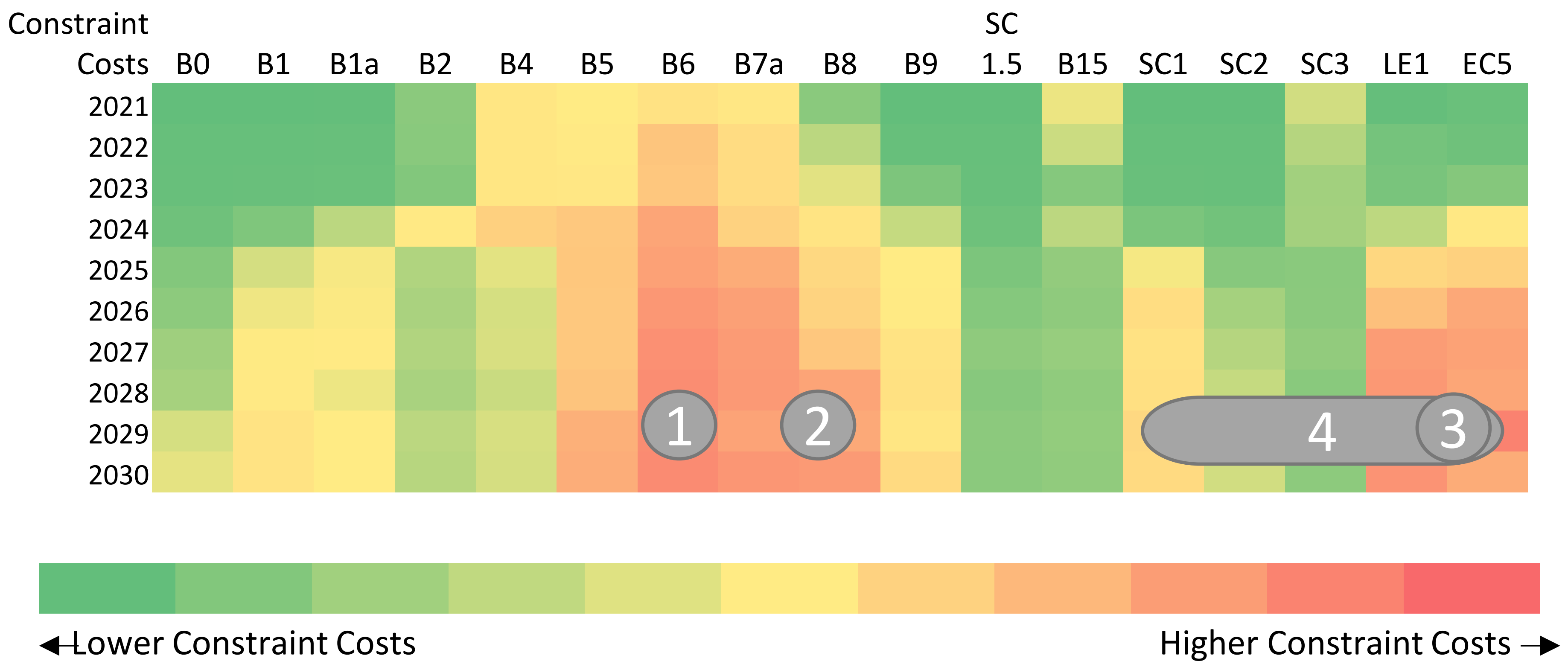
New interconnectors with Europe will place increased requirements on the transmission network.

London and Southern England need more reinforcement to enable future interconnection

Key Message 3

Constraint costs are expected to increase due to high flows across the transmission boundaries if no action is taken over the next ten years.

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 system 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 have to take actions to constrain generation, which can incur significant costs

The heatmap shows that if no reinforcements are made to the system (i.e. the system is the same as it is today, over the next 10 years), the network boundaries defined in the ETYS would lead to incurring significant network constraint costs due to the high flows from the increased generation capacity.

What is the ETYS?

What is the ETYS?

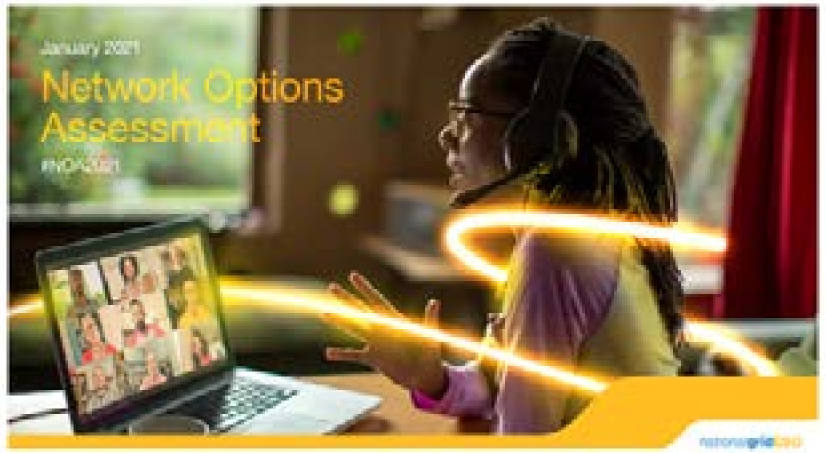
This is our annual view of what the transmission requirements and capability of GB NETS are over the next decade. The ETYS is key in helping us to understand what investment and development is needed to help us achieve our zero-carbon ambition.

Currently, the outcome of the planning process recommends investing **£203 million** this year to **42 projects** worth almost **£11.1 billion**. Details of the projects are shown in the 2019/20 NOA Report. The future is constantly changing so we update our view of the system needs and development projects annually.

! Hover over the covers to see more informaiton

Future of Energy Scenarios (FES)
July 2020
Range of credible pathways for the future of energy from today to 2050.

Electricity Ten Year Statement
November 2020
The likely future transmission requirements on the electricity system.



Network Options Assessment
January 2021
The options available to meet reinforcement requirements on the electricity system.

ETYS in the European Scene

Like the FES and the ETYS process in Great Britain, the European Network of Transmission System Operators for Electricity or ENTSO-e also assess the network capability of the European grid. This involves looking at a pan-European approach to simulate cross-border power transfer between GB and its neighbouring countries.

Together the ETYS and NOA consider cross-border electricity transmission networks (including interconnections with mainland Europe). European transmission developments are described in the Ten Year Network Development Plan (TYNDP) http://tyndp.entsoe.eu/.

The TYNDP is similar to the ETYS and NOA but covers all European Transmission System Operators (TSOs). It is published every two years with TSOs' input in accordance with Regulation (EC) 714/2009. The next publication is due in Q4 2020. Although TYNDP, ETYS and NOA all highlight future network developments, there are important differences:

- TYNDP is produced every two years, whereas the ETYS and NOA are produced annually. So information included in the TYNDP usually lags the ETYS and NOA.
- A different set of energy scenarios are used for the TYNDP compared to the FES that informs ETYS and NOA.
- The TYNDP focuses mainly on pan-European projects that meet European Union objectives, such as cross-border trade and European environmental targets.

The future for ETYS and the Network Planning Process

This year, for the first time, we have released a web version of the ETYS online. We believe this more interactive version of the ETYS will make it more accessible, clearer and easier than ever to read. Please let us know your thoughts on this new format and how we can enhance your experience.

The Network Development Roadmap sets out our ambitious commitments to transform our network planning and deliver greater value for consumers. We detailed how we are going to:

- drive greater consumer value by considering a range of solutions from different providers, to identify the best ways to meet transmission network needs
- enhance our analytical capabilities to ensure we plan the right level of investment for an increasingly complex network.

Since the update to the Network Development Roadmap in January 2020, we have been providing further updates through the website and newsletters.

In our incentives framework, we publish an annual Forward Plan where we set out timeframes for delivering roadmap commitments. We are still committed to facilitating whole system outcomes and supporting competition in networks.

The ETYS and NOA, in line with our licence obligations, are part of our baseline delivery against these roles. There are other commitments to transform our approach too throughout ESO.

The changing nature of the electricity system means it is increasingly important to study the transmission network needs beyond that of winter peak. The level of uncertainty throughout a year of operation has increased due to a significant increase in intermittent renewables and interconnectors.

This year we have improved our probabilistic analysis and optimised our post fault actions to better replicate real world events. We have summarised our results across a range of the GB network boundaries, and have identified the next steps for the analysis in chapter 4.

We are extending our network planning to address regional voltage and stability challenges through our pathfinder projects. We are taking the lessons learnt from them to help us identify further system needs and develop the tools and processes to assess voltage and stability challenges This is a part of our long-term planning. We have provided updates to the ongoing voltage year-round assessments in the Pennine regions in chapter 5.

Our NOA stability pathfinder project is exploring the benefits and practicalities of applying a NOA-type approach to the operability aspects of system stability. This is in response to the decline in transmission connected synchronous generation over the next decade. Further detail on our pathfinder projects is available on our Network Development Roadmap website.

We are also aiming to expand the NOA process to allow network and non-network solution providers across distribution and transmission to submit options to meet transmission network needs. Our pathfinder projects will help ensure the right balance between operational and network investment solutions and will increase the value of ETYS and NOA for consumers.

Finally, we are taking steps to clearly communicate our analysis of the transmission network needs to new audiences. For the second year now, we have made the System Requirements Form publicly available but we would welcome feedback on how this ETYS document and the way we set out transmission network needs can be more accessible.

Improving your experience

We hope you find the ETYS 2020 and our other ESO publications such as the NOA, FES and SOF useful in your future decision-making. We are keen to hear your views whether there are options to help resolve the problems identified, feedback on the new format or views on our analysis.

Following our last stakeholder survey, you asked us to describe transmission system needs more clearly and precisely. We are using our ongoing pathfinder projects to explore how we can better communicate system needs such as voltage and stability.

We will use learning from these projects to shape the ETYS in the future. We continue to review our information and processes, including the System Requirements Form (SRF), to make them more accessible to a broader range of participants. We welcome your ideas and how we can improve this.

We welcome any feedback you may have on this year's document, as it will assist us in the development of future publications. Please feel free to share any views or ideas you may have with us via transmission.etys@nationalgrideso.com


Network
Development
Inputs

Introduction

To identify the future transmission requirements of the National Electricity Transmission System (NETS), there are several inputs that feed into the planning process at various stages. They are checked with the Security and Qualtiy of Supply Standards (SQSS) to ensure that the network will remain secure and compliant.

The flow chart summarises this process to provide more clarity on the various stages before the network capabilities can be determined.

1. Future Energy Scenarios

We use the scenarios in the FES to determine the peak demand and generation capacity in various regions within the different scenarios.

2. Apply dispatch criteria to set the background

Dispatch the generation and interconnectors from the FES to balance with the peak demand (from step 1) to determine network power flows.

3. Apply the NETS SQSS planning criteria

Simulate network behaviour using the FES dispatched network model and NETS SQSS planning conditions.

4. Prepare the Network Model

Apply the dispatch background to complete models of the GB NETS so circuit loading and conditions can be simulated.

5. Determine network capability

Adjust boundary power transfers using the model until the limit of network capability is found within the SQSS limitations.

Future Energy Scenarios (FES)

Future Energy Scenarios (FES) represent a range of different, credible ways to decarbonise our energy system as we strive towards the 2050 target.

To help us plan for an uncertain future, we develop a range of scenarios reflecting a number of credible energy futures, which helps us to better understand the uncertainties facing the energy industry.

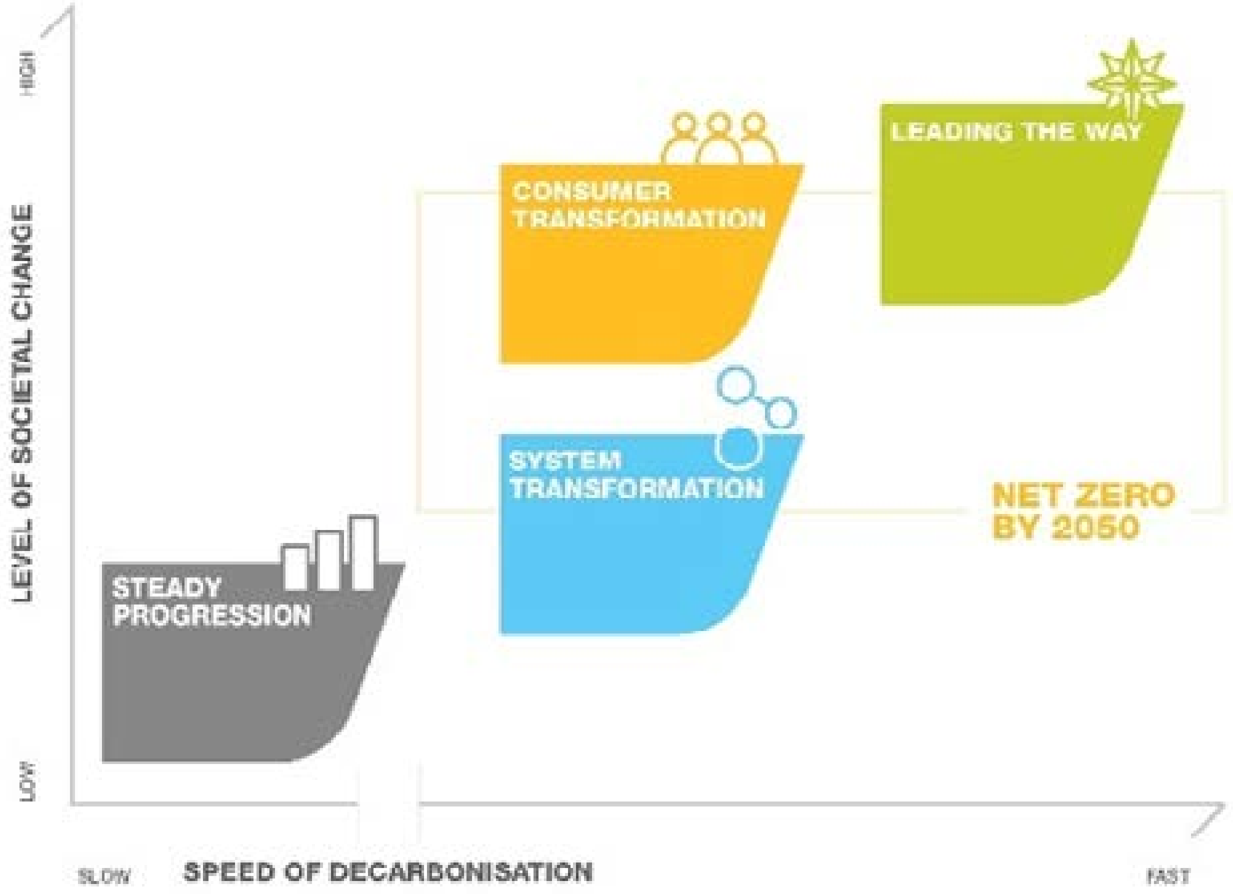
This year there are four scenarios aligned to the following axes:

- speed of decarbonisation – combines policy, economics, and consumer attitudes.
- level of societal change - allows us to explore different solutions for decarbonisation of heat (e.g. electrification vs low carbon gas) alongside changes in consumer engagement, levels of energy efficiency and a ‘supply-led vs demand-led’ approach.

All scenarios show progress towards decarbonisation from today, with the scenarios in the centre of the matrix meeting the net zero target in 2050 as legislated by the government, and those on the right and left representing the credible range of decarbonisation progress by meeting the target early and missing the target respectively.

Scenarios close to the bottom of the axis involve lower levels of energy efficiency improvements, less change of heating technology (including continued use of the gas network) and lower levels of consumer engagement in flexibility services. Scenarios closer to the top of the axis involve greater impact on consumers, with greater changes in heating systems and insulation and more consumer appetite for participation in provision of flexibility to help manage peak demand and intermittent generation.

In the ETYS, we use the generation and demand based on the assumptions in the scenarios to develop a range of credible power flows on the network. This is fed into our network model as the background to analyse the capability of the NETS.



You can find more information about FES 2020 on our website.

National Electricity Transmission System (NETS)

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

1 Scottish & Southern Electricity Networks

2 SP ENERGY NETWORKS

3 nationalgrid

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

The ‘transmission’ classification applies generally to assets at 132kV or above in Scotland or offshore, but in some cases includes other lower voltage assets.

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

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

The offshore transmission systems are also separately owned. There are seventeen licenced offshore transmission owners (OFTOs) that have been appointed through the competitive tendering process administered by Ofgem. They connect operational offshore wind farms that were given Crown Estate seabed leases in allocation rounds.

Together with the transmission owners, the ESO works to make sure that the assumptions made in the analysis are acceptable and any changes in their respective networks are reflected correctly in the network models. This is done to make sure that the ETYS portrays an accurate representation of the current transmission capabilities and identifies any future requirements.

Boundaries

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.

When we assess future requirements, we need to bear in mind that we have many signed contracts for new generation to connect to the NETS. In addition, the development of interconnectors connecting Great Britain to the rest of Europe will have a big impact on future transmission requirements.

We do not know precisely how much new generation there will be, and where it will connect, or when existing generation will shut down. We use our FES to help us decide on credible ranges of future NETS requirements and present capability. This is done using the system boundary concept. It helps us to calculate the NETS's boundary capabilities and the future transmission requirements of bulk power transfer capability.

The transmission network is designed to make sure there is enough transmission capacity to send power from areas of generation to areas of demand.

Limiting factors on transmission capacity include:

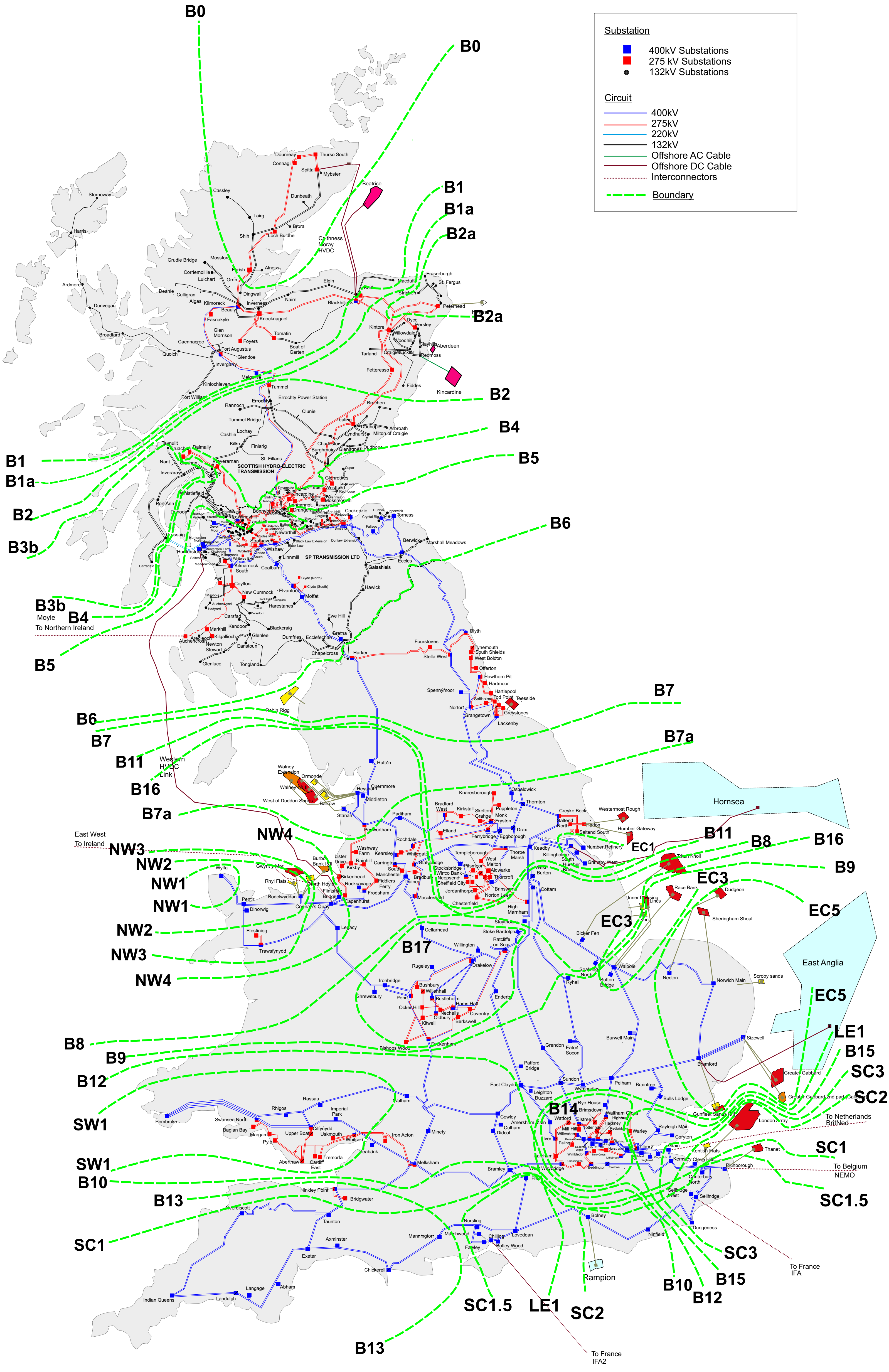
- thermal circuit rating
- voltage constraints
- dynamic stability

From the network assessment, the lowest known limitation is used to determine the network boundary capability.

The base capability of each boundary in given in Chapter 3 of this document. This will be used in the NOA 2020/21, to help us assess the reinforcement options that will address the potential future NETS boundary needs.

Defining the NETS boundaries has taken many years of experience in planning and operating the transmission system.

When significant transmission system changes occur, new boundaries may be defined and some existing boundaries either removed or amended (an explanation will be given for any changes). Some boundaries are also reviewed but not studied because of no significant changes in the FES generation and demand data of the area from the previous years. For such boundaries, the same capability as the previous year is assumed.



Determining the present capability and future requirements of the NETS boundaries

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

Local boundaries

Encompass small areas of the NETS with high concentration of generation. These small power export areas can give high probability of overloading the local transmission network due to coincidental generation operation.

Wider boundaries

Split the NETS into large areas containing significant amounts of both generation and demand. The SQSS boundary scaling methodologies are used to assess the network capability of the wider boundaries. These methodologies consider both the geographical and technological effects of generation. This allows for a fair and consistent capability and requirements assessment of the NETS. The NETS SQSS defines the methodology to assess boundary planning requirements, based on:

The security criterion

The boundary transfer requirements of the NETS to satisfy demand without relying on intermittent generators or imports from interconnectors. (The methodology for determining the security needs and capability are as per the SQSS Appendices C and D).

The economy criterion

The boundary transfer requirements of the NETS when demand is met with high output from intermittent and low-carbon generators and imports from interconnectors. This ensures that transmission capacity is adequate to transmit power from the highly variable generation types without any network constraint. The methodology for determining the economy needs and capability are as per SQSS Appendices E and F.

> “Over the years, we have continuously developed the transmission network to ensure there is sufficient capacity to transport power efficiently and economically across the country.

Electricity Transmission Network

Introduction

The GB National Electricity Transmission System must continue to adapt and be developed so power can be transported from source to demand, reliably and efficiently.

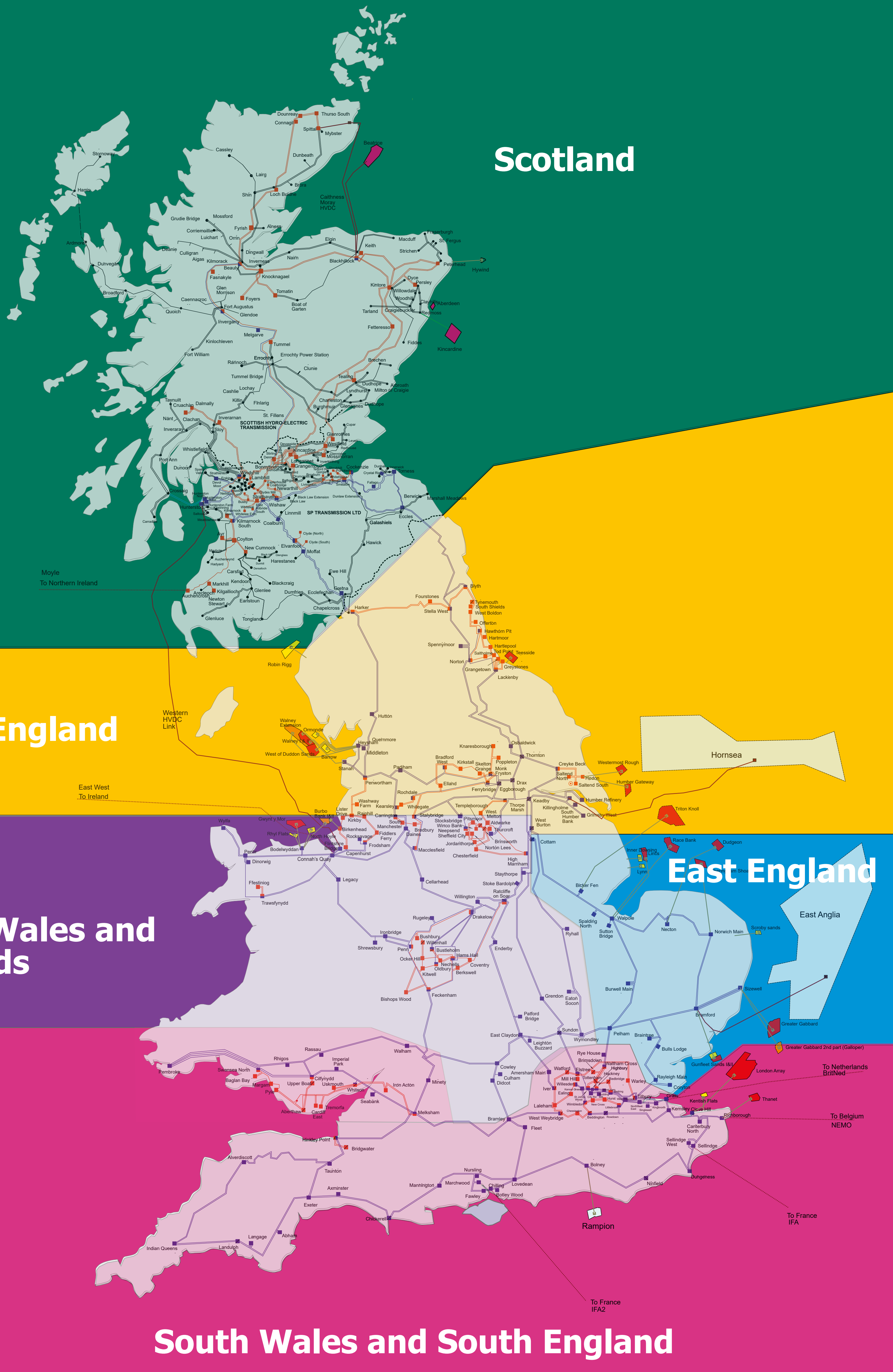
The results presented in this chapter will be used in the NOA 2020/21 to present an assessment of the ESO's recommended reinforcement options to address the potential future NETS boundary needs.

In this chapter, we:

- describe the NETS characteristics.
- discuss each of the NETS boundaries, grouped together as regions, to help you gain an overview of the total requirements, both regionally and by boundary.
- provide analysis to show how, and when, in the years to come, the NETS will potentially face growing future network needs on a number of its boundary regions.

The chapter is broken into regions and the regions are shown on the next page.

Regional split of the transmission network



How to interpret the boundary graphs?

The graphs show a distribution of power flow for each scenario, 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 chapter 2), we determine:

- the economy criteria - solid coloured line
- security criteria - dashed coloured line
- current boundary capability – solid black line

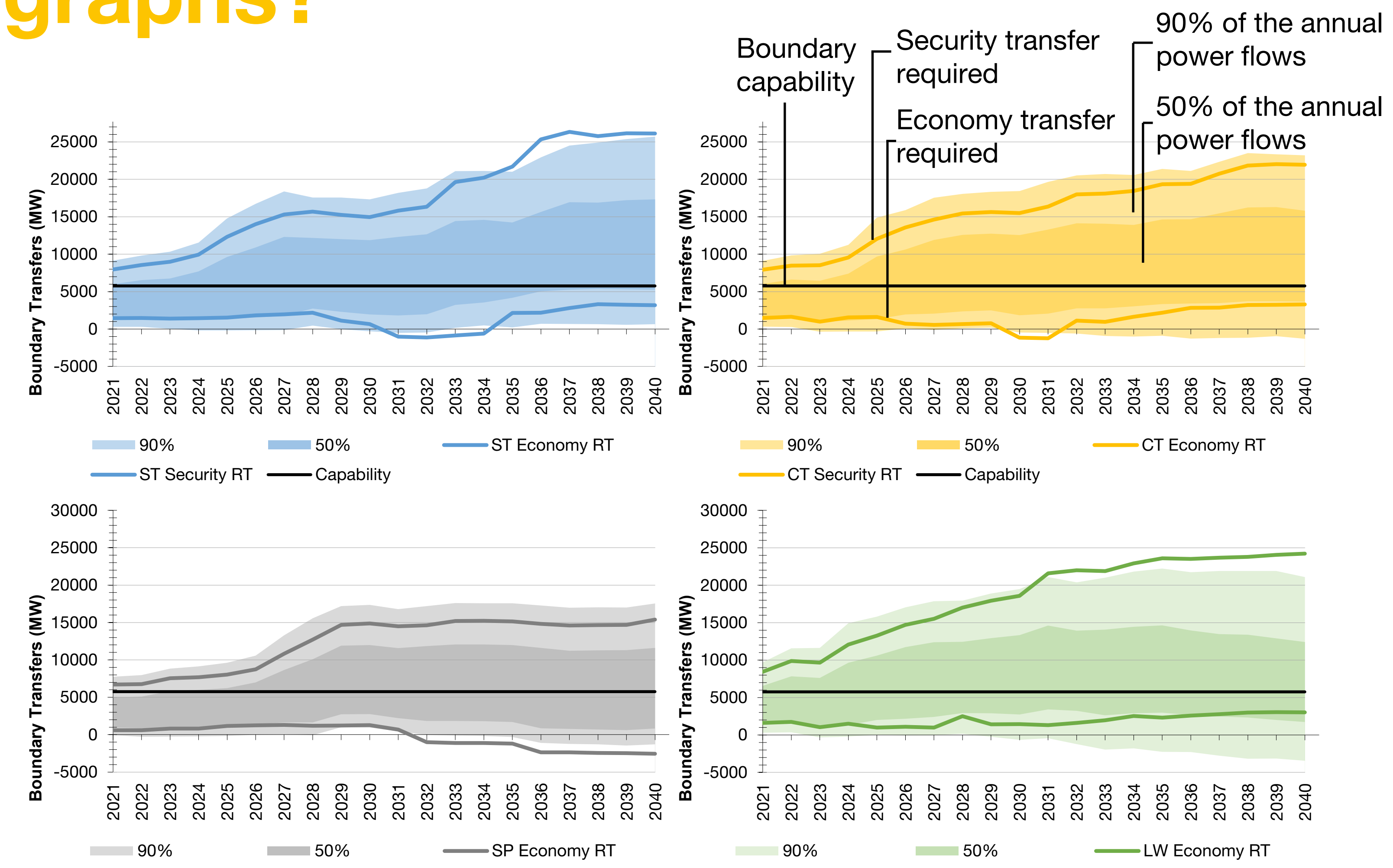
The current boundary capability is expected boundary capability for the coming 2020/21 year's winter peak study. This will change over time as the network, generation, and demand change, all of which are uncertain and so a straight back line shows the present capability.

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 free market power flows in comparison with boundary capability.

Using the B6 boundary charts as an example below, there are four charts – one for each of the scenarios in the FES.

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 the lighter region



- 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 (black 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 (black line).

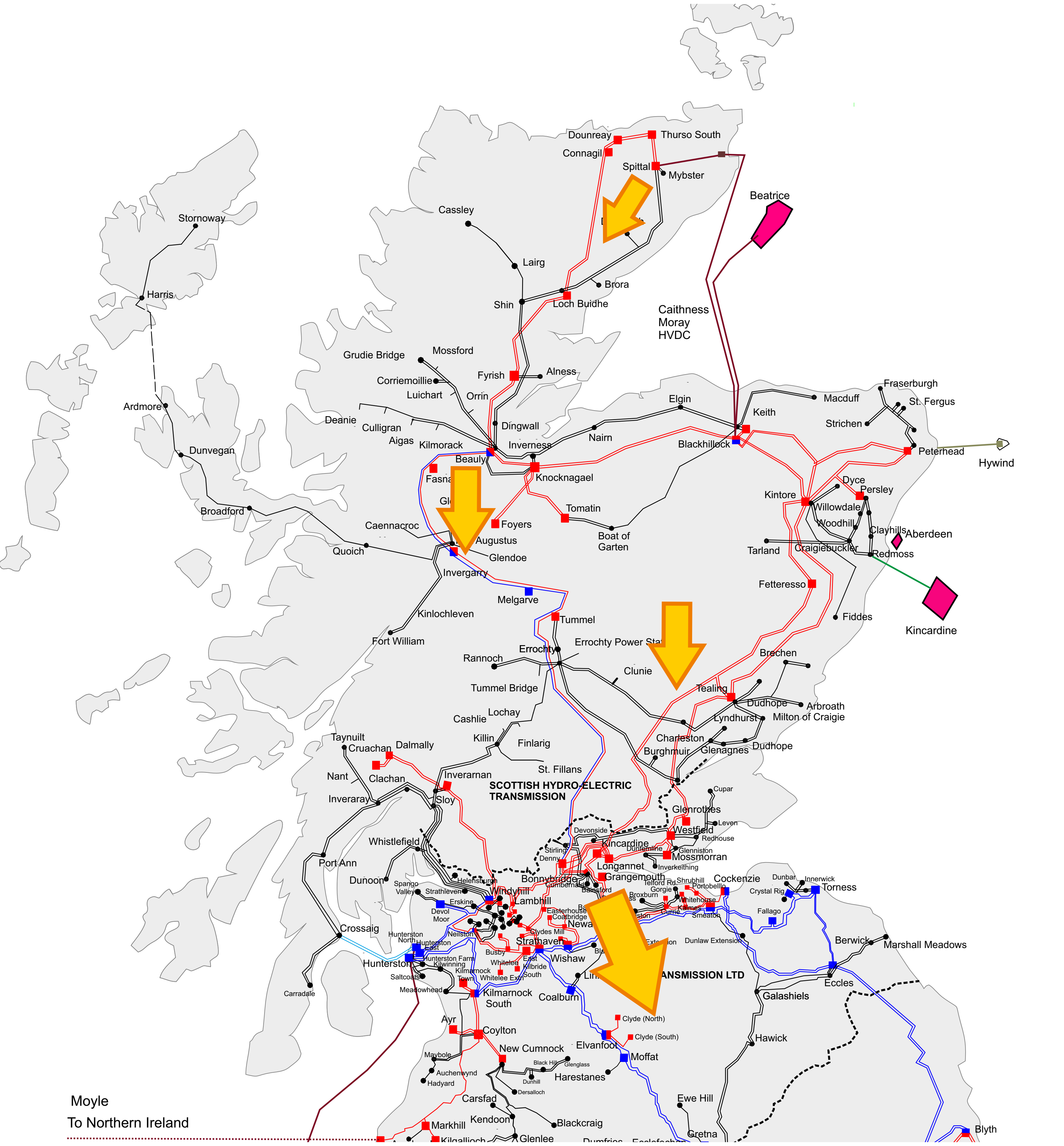
Scottish boundaries

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

The Scottish NETS is divided into 7 boundaries –

- B0 – Upper North SHE Transmission
- B1a – North West SHE Transmission
- B2 – North to South SHE Transmission
- B3b – Kintyre and Argyll SHE Transmission
- B4 – SHE Transmission to SP Transmission boundary (shared by SHE 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 figure below shows the general pattern of power flow directions expected to occur most of the time in the years to come up to 2030, i.e. power will generally flow from north to south.



The arrows in the diagram illustrate power flow directions and are approximately scaled relative to the winter peak flows.

Regional Drivers

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

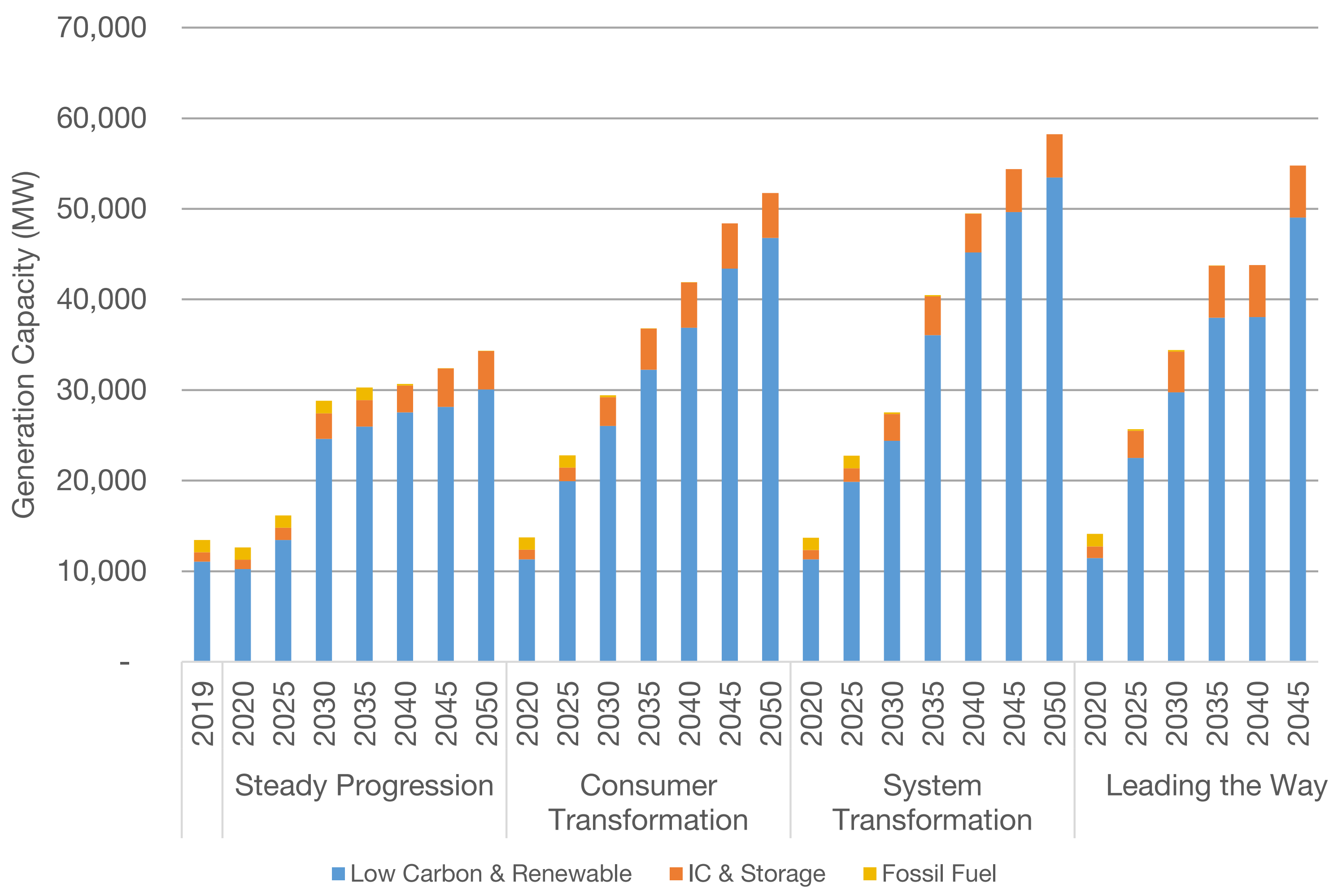
Over the next 10 years, Scotland is going to be experiencing a rapid growth in renewable generation capacity, mainly wind. This is going to increase the network reinforcement needs in some areas.

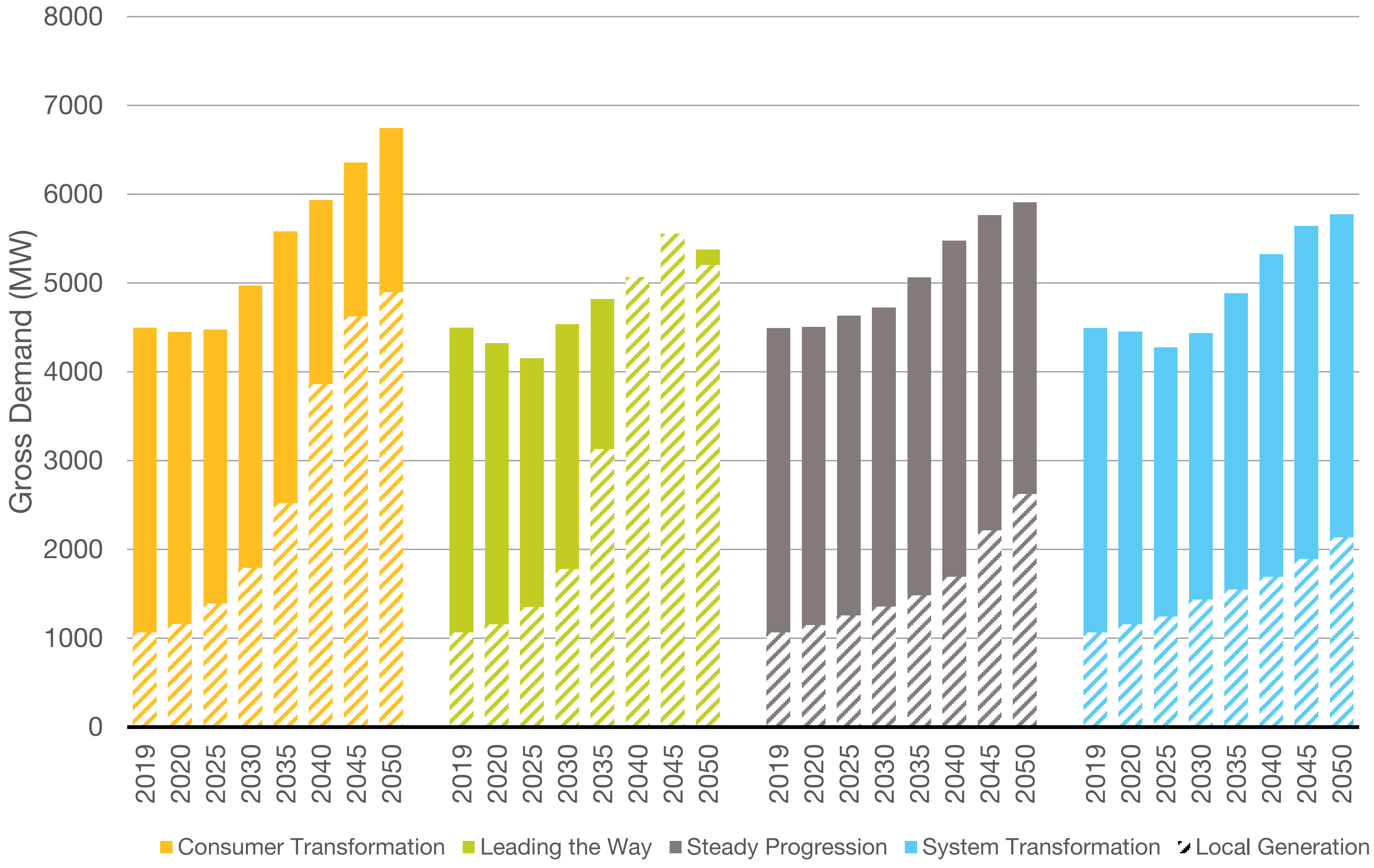
Across all the scenarios in the FES, the fossil fuel generation capacity in Scotland reaches nearly zero. By 2030, all scenarios show an increase in interconnector and storage capacities. By 2035, the scenarios suggest a total Scottish generating capacity of between 18 and 38GW.

The reduction in synchronous generation could lead to challenges with reduced short circuit levels and inertia. This potentially leads to increasingly dynamic Scottish network behaviour depending on factors such as weather conditions and price of electricity.

With gross demand in Scotland not expected to exceed 6GW by 2040, which is much less than the Scottish generation capacity, Scotland will be expected to export power into England most of the time.

At times of low renewable output, Scotland may need to import power from England. In a highly decentralised scenario like Leading the Way, local generation capacity connected at the distribution level in the Scotland region could reach more than 13GW by 2040.





Of that capacity, the total embedded generation output will average at around 7GW. This will vary depending on factors like wind speeds, and how other local generators decide to participate in the market.

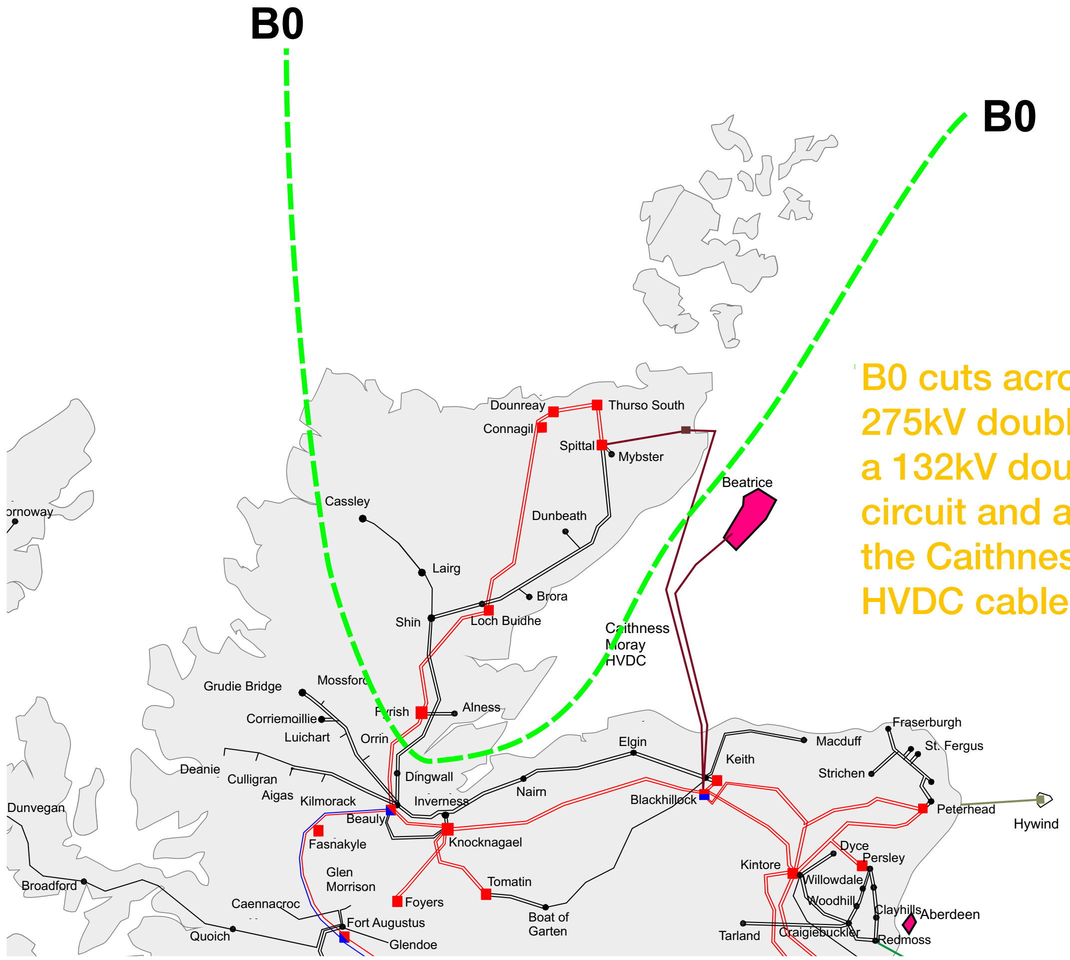
The anticipated increase in renewable generation in Scotland is increasing power transfer across the Scottish boundaries. On a local basis, with the anticipated generation development in the north of Scotland, including generation developments on the Western Isles, Orkney and the Shetland Islands, there may be limitations on power transfer from generation in the remote Scottish NETS locations to the main transmission routes (B0, B1a).

As generation within these areas increases over time, due to the high volume of new renewable generation seeking connection, boundary transfers across the Scottish NETS boundaries (B0, B1a, B2, B3b, B4 and B5 and B6) increase.

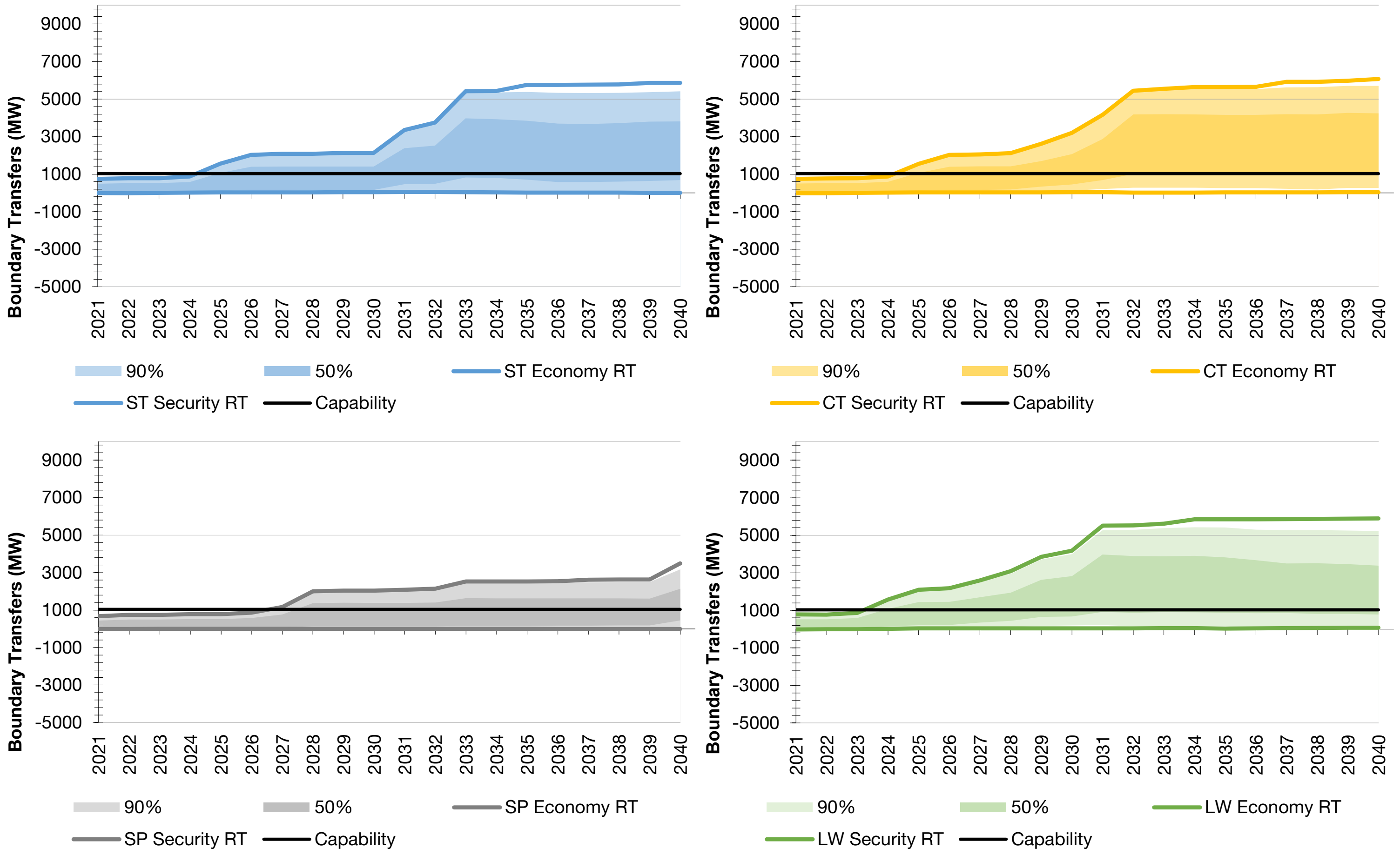
The need for network reinforcement to address the above-mentioned potential capability issues will be evaluated in the NOA 2020/21 CBA. Following the evaluation, the preferred reinforcements for the Scotland region will be recommended.

Boundary B0 – Upper North SHE Transmission

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



B0 cuts across a 275kV double circuit, a 132kV double circuit and across the Caithness–Moray HVDC cable.



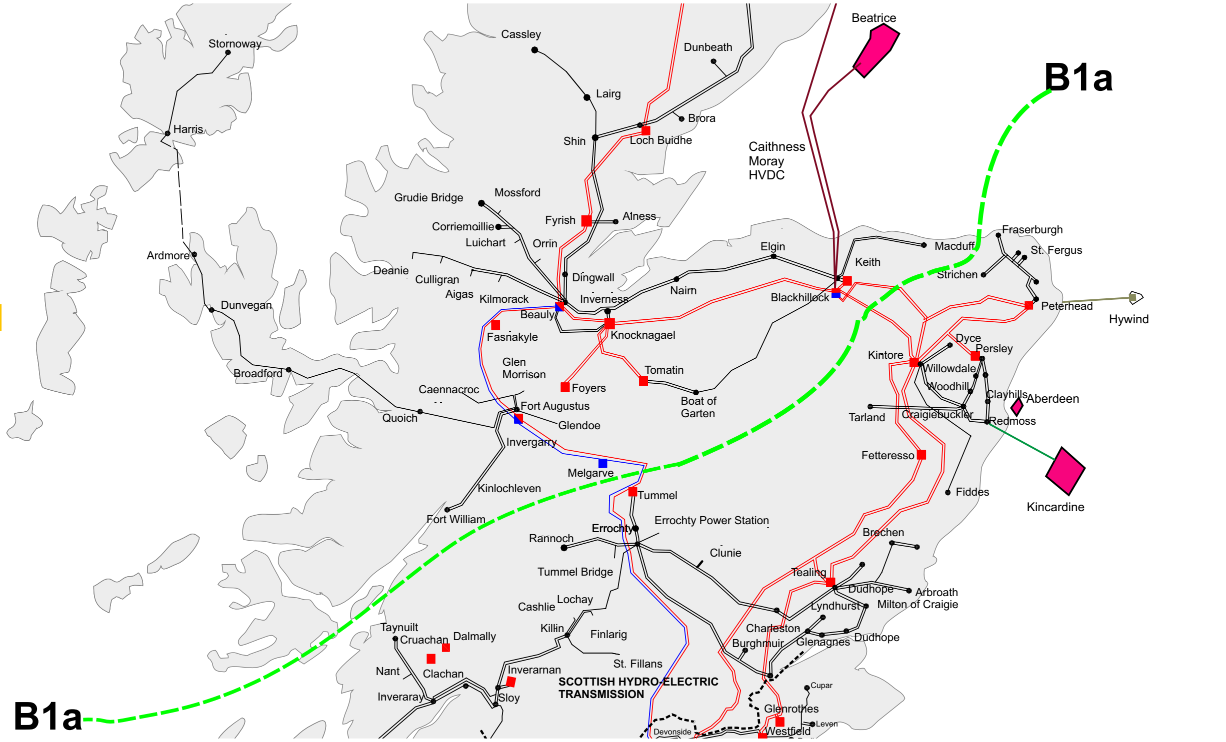
The power transfer through B0 is increasing due to the substantial growth of renewable generation north of the boundary. This generation is primarily centred around both onshore and offshore wind. There is also the prospect of new marine generation resource in the Pentland Firth and Orkney waters in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

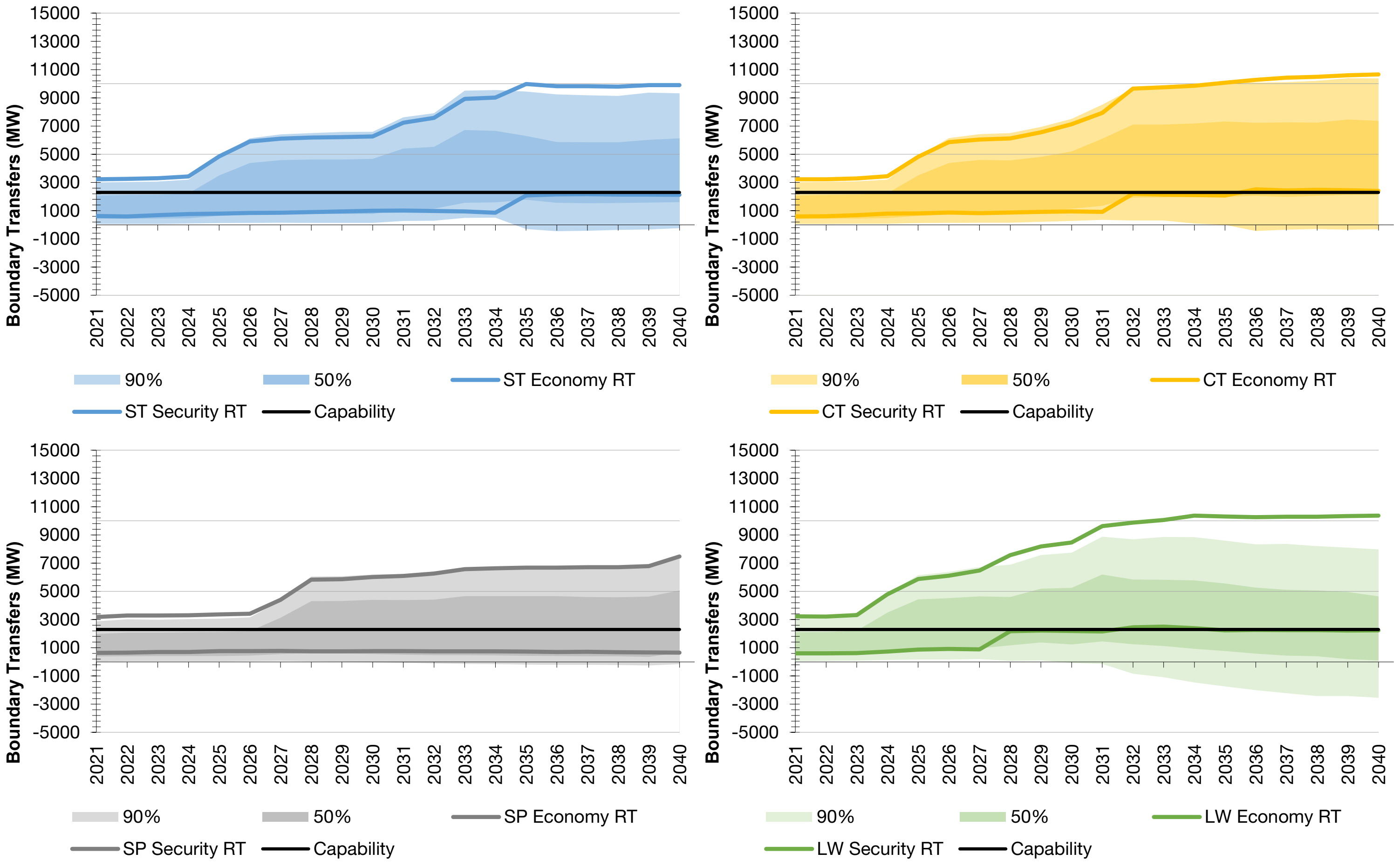
The current boundary capability is limited to around **1.0GW** due to a **thermal constraint**

Boundary B1a – North West SHE Transmission

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

B1a crosses two 275kV double circuits and a double circuit with one circuit at 400kV and the other at 275kV.





New renewable generation connections north of the boundary are expected to result in a significant increase in export requirements across the boundary. All generation north of boundary B0 also lies behind boundary B1a.

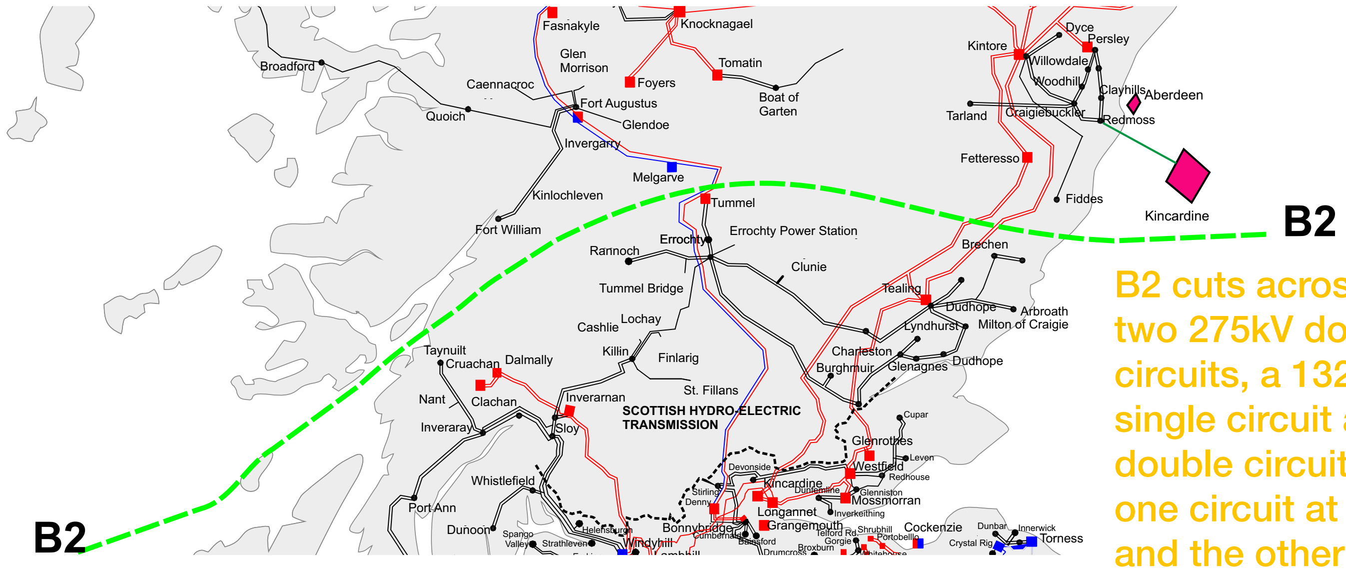
In all the future energy scenarios, there is an increase in the power transfer through B1a due to the large volume of renewable generation connecting to the north of this boundary. Although this is primarily onshore wind and hydro, there is the prospect of significant additional wind, wave and tidal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

A large new pump storage generator is also planned in the Fort Augustus area. Some marine generation is also expected to connect in this region during the ETYS period. This is supplemented by existing generation, which comprises around 800MW of hydro and 300MW of pumped storage at Foyers.

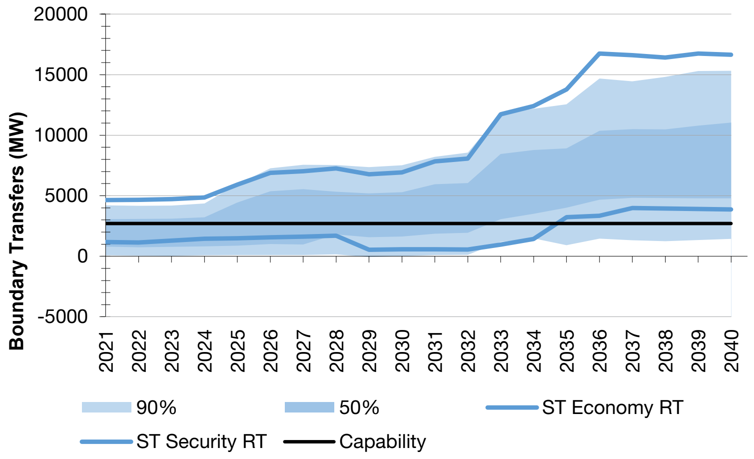
The current boundary capability is limited to around 2.5GW due to a thermal constraint

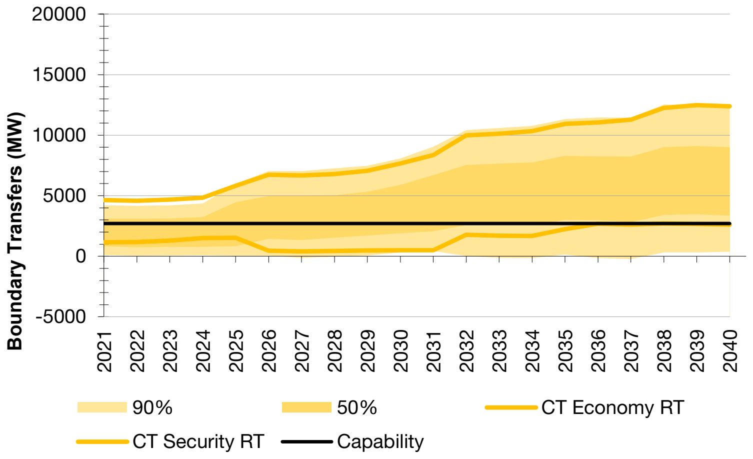
Boundary B2 – North to South SHE Transmission

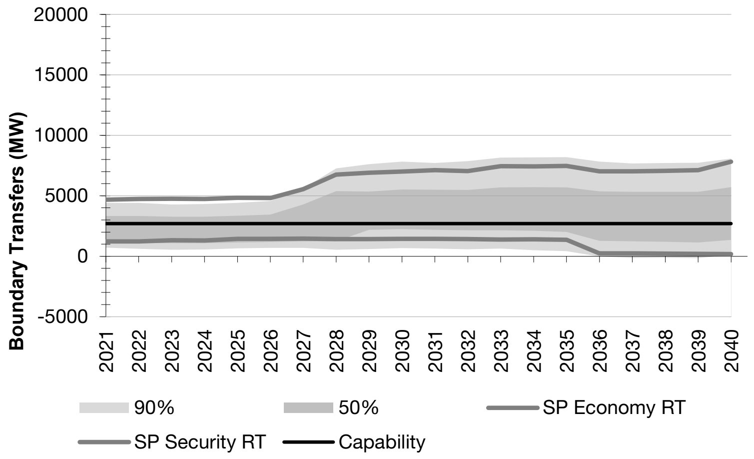
Boundary B2 cuts across the Scottish mainland from the east coast between Aberdeen and Dundee to near Oban on the west coast crossing the main north-south routes from the north of Scotland.

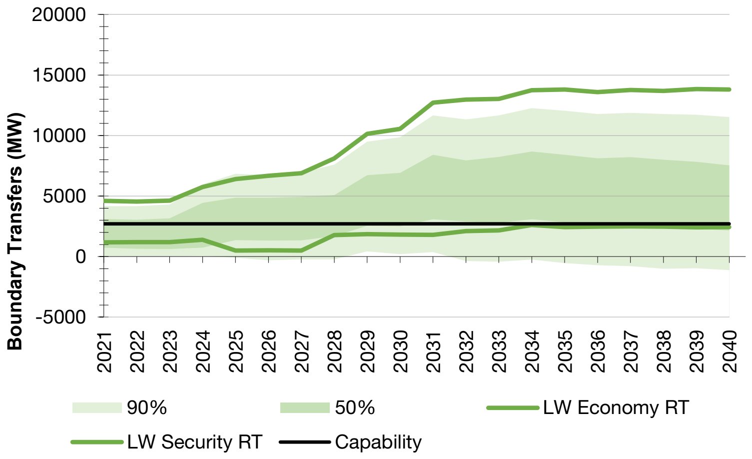


B2 cuts across two 275kV double circuits, a 132kV single circuit and a double circuit with one circuit at 400kV and the other at 275kV.









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.

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

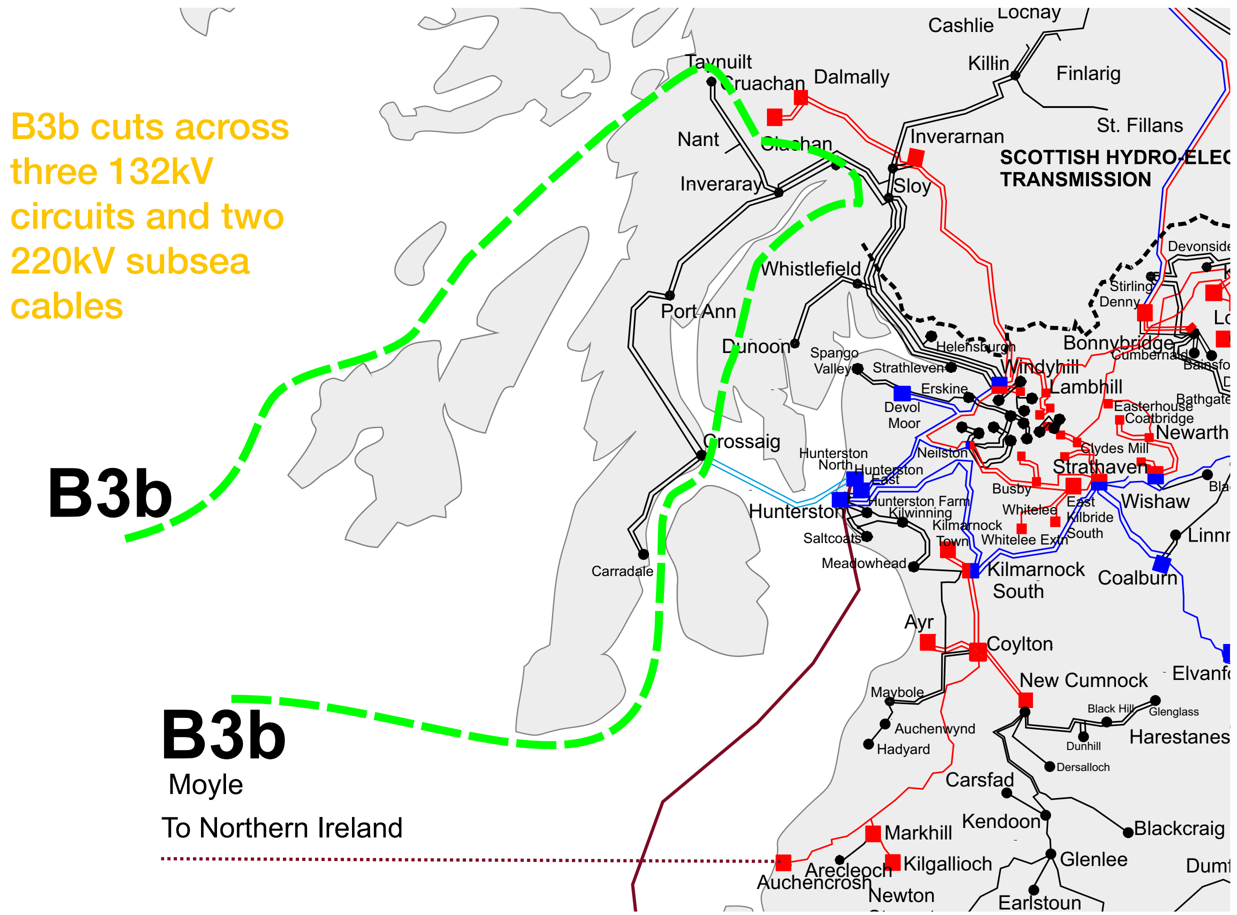
The generation behind boundary B2 includes both onshore and offshore wind, with the prospect of significant marine generation resource being connected in the longer term.

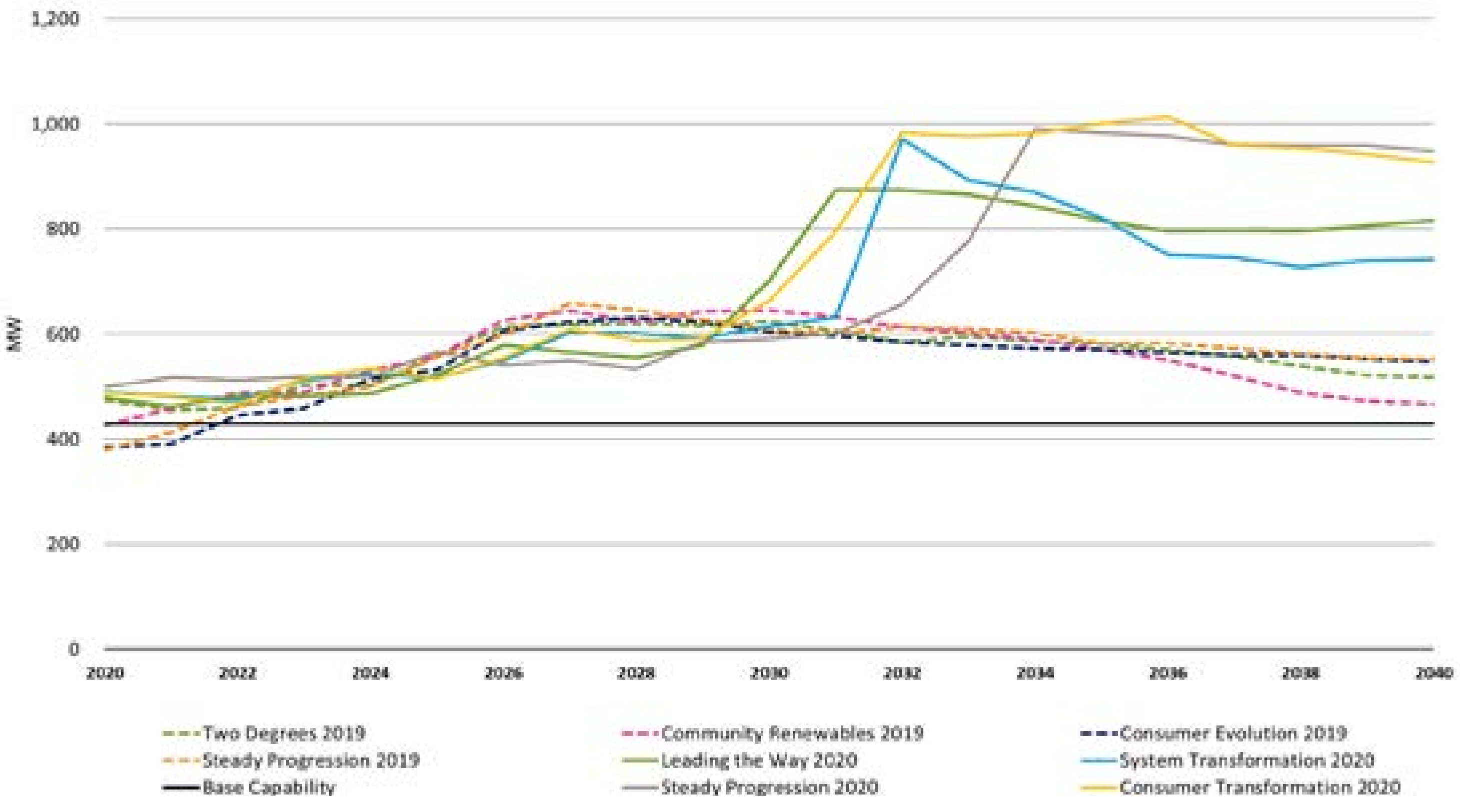
There is also the potential for additional pumped storage plant to be located in the Fort Augustus area. The thermal generation at Peterhead lies between boundaries B1a and B2, as do several offshore windfarms and the proposed future North Connect interconnector with Norway.

The current boundary capability is limited to around 2.8GW due to a thermal constraint

Boundary B3b - Kintyre and Argyll SHE 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.





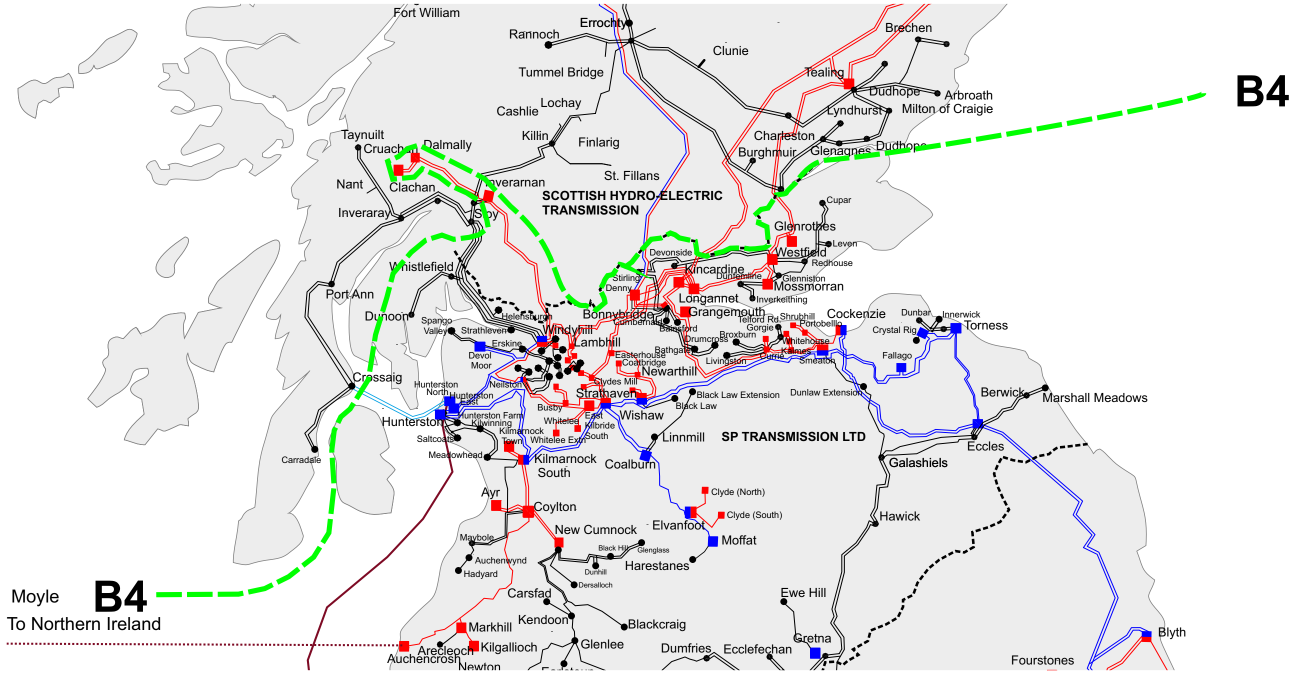
The generation within boundary B3b includes both onshore wind and hydro generation, with the prospect of further wind generation resource and the potential for marine generation being connected in B3b in the future, triggering the requirement for future reinforcement of this network.

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

The current boundary capability is limited to around 0.43GW due to a thermal constraint

Boundary B4 – SHE Transmission to SP Transmission

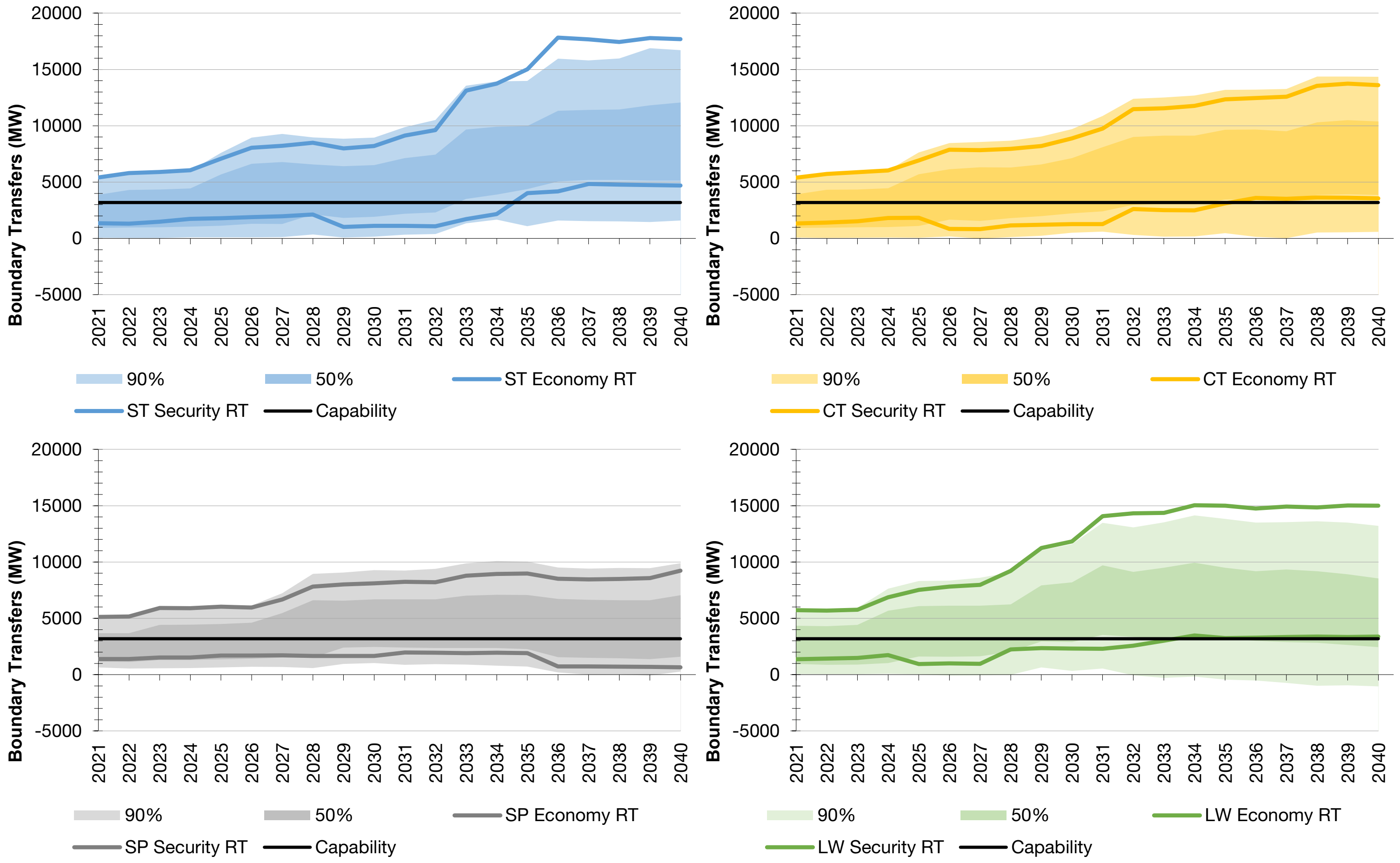
Boundary B4 separates the transmission network at the SP Transmission and SHE Transmission interface running from the Firth of Tay in the east to the north of the Isle of Arran in the west.



B4 cuts across two 275kV double circuits, two 132kV double circuits, two 275/132kV auto-transformer circuits, two 220kV subsea cables between Crossaig and Hunterston substations, and a double circuit with one circuit at 400kV and the other at 275kV.

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

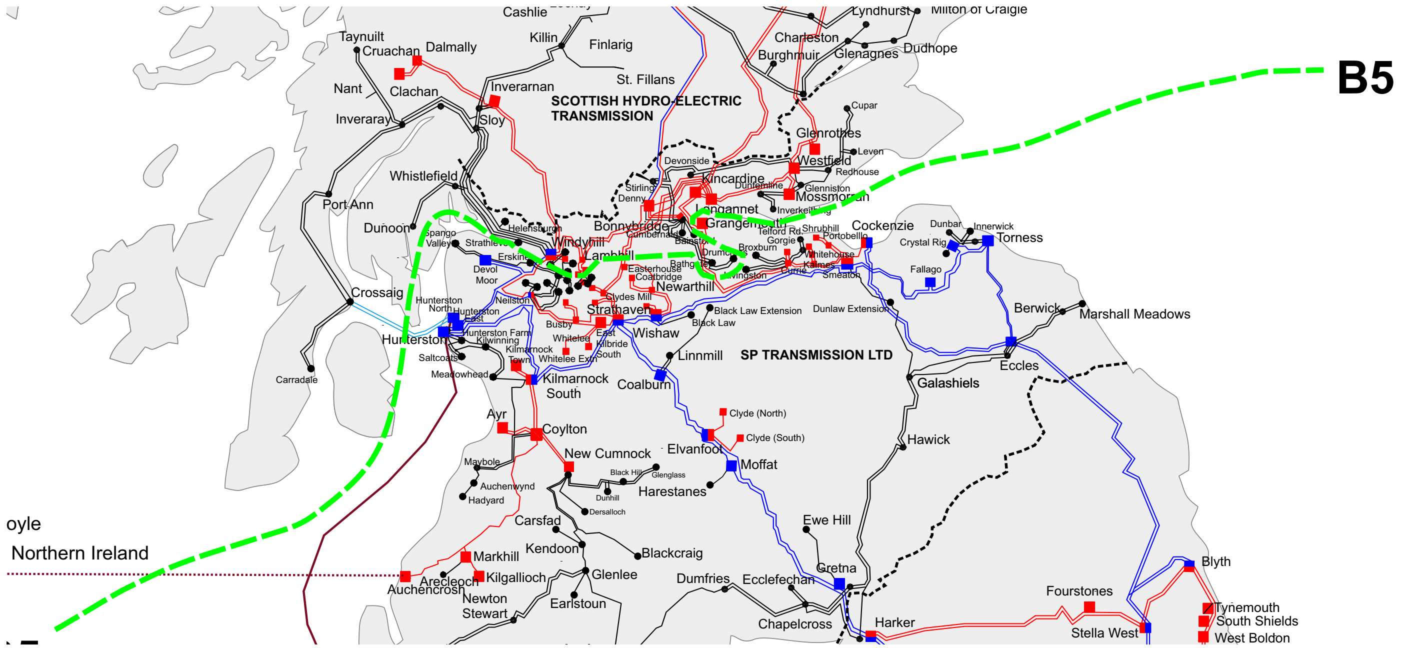
In all scenarios in the FES, the power transfer through boundary B4 increases because of the significant volumes of generation connecting north of the boundary, including all generation above boundaries B0, B1a, B2 and B3b. This is primarily onshore and offshore wind generation, with the prospect of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



The current boundary capability is limited to around **3.2GW** due to a **thermal constraint**

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.

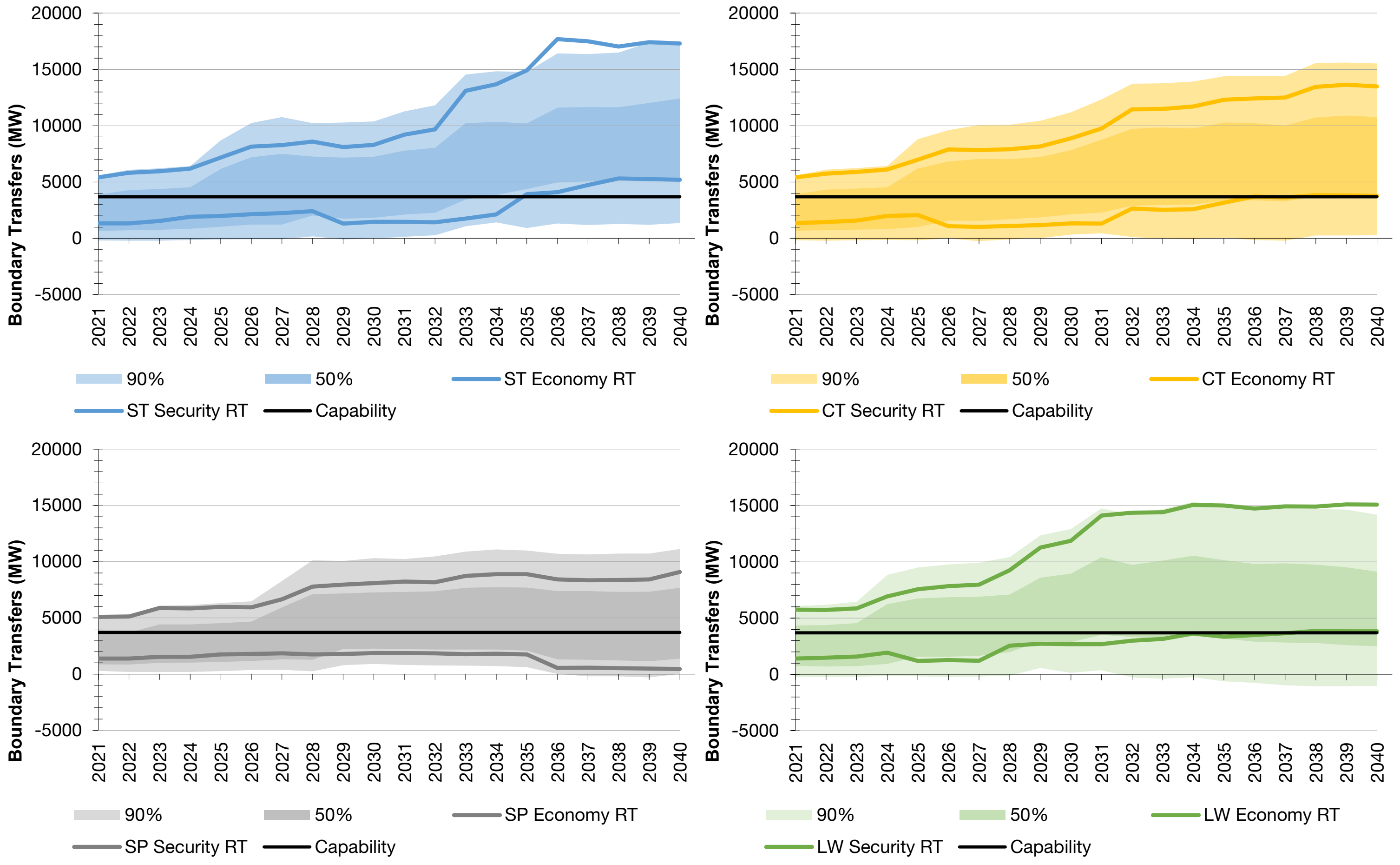


B5 cuts across three 275kV double circuits and a double circuit with one circuit at 400kV and the other at 275kV. The Kintyre–Hunterston subsea link provides two additional circuits crossing B5.

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

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

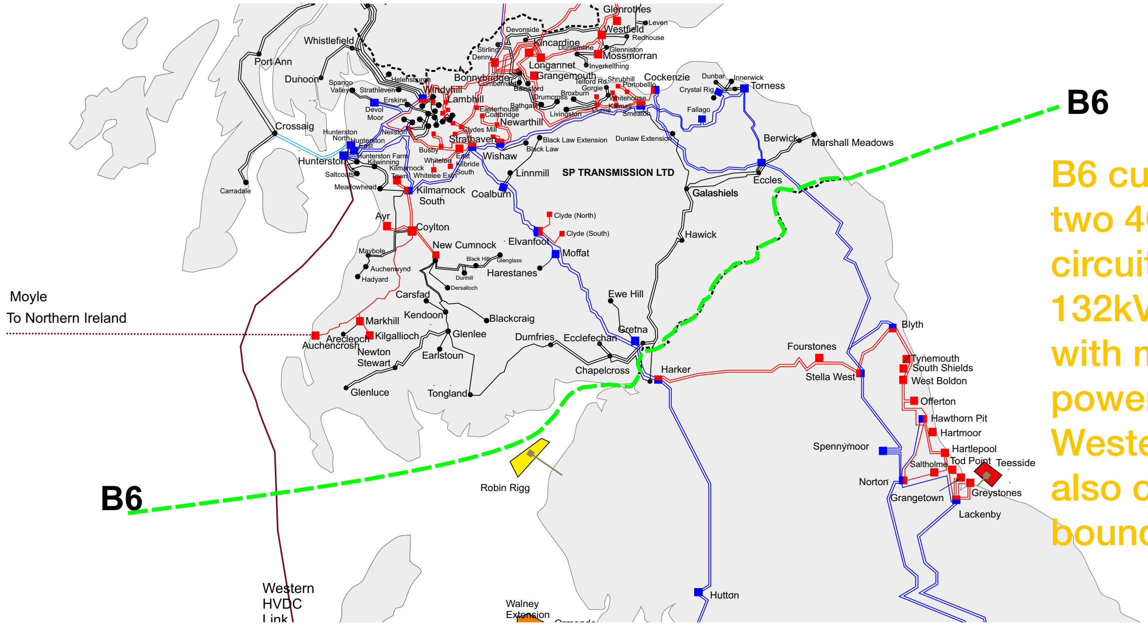
This is primarily onshore and offshore wind generation.



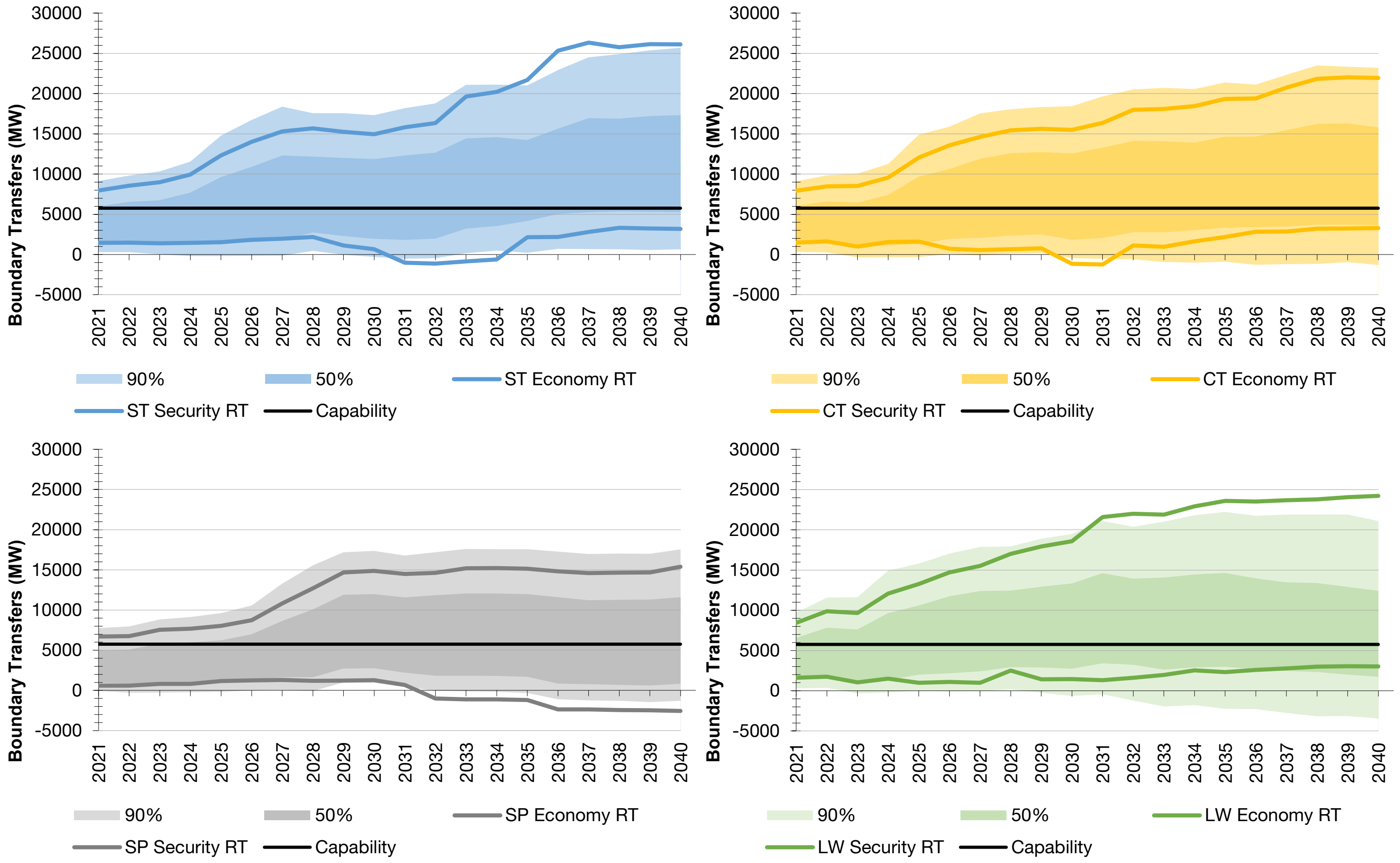
The current boundary capability is limited to around 3.7GW due to both thermal and voltage constraints

Boundary B6 – SP Transmission to NGET

Scotland contains significantly more installed generation capacity than demand, increasingly from wind farms. Peak power flow requirements are typically from north to south at times of high renewable generation output.



B6 cuts across two 400kV double circuits and two 132kV circuits with much smaller power flows. The Western HVDC link also crosses the 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. This generation increase is partially offset by the expected closure of nuclear plants, the timing of which varies in each scenario.

With the FES including many wind farms in Scotland, the spread of boundary power flows is very wide due to the intermittent nature of the wind. With 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 should be sufficient to support those conditions.

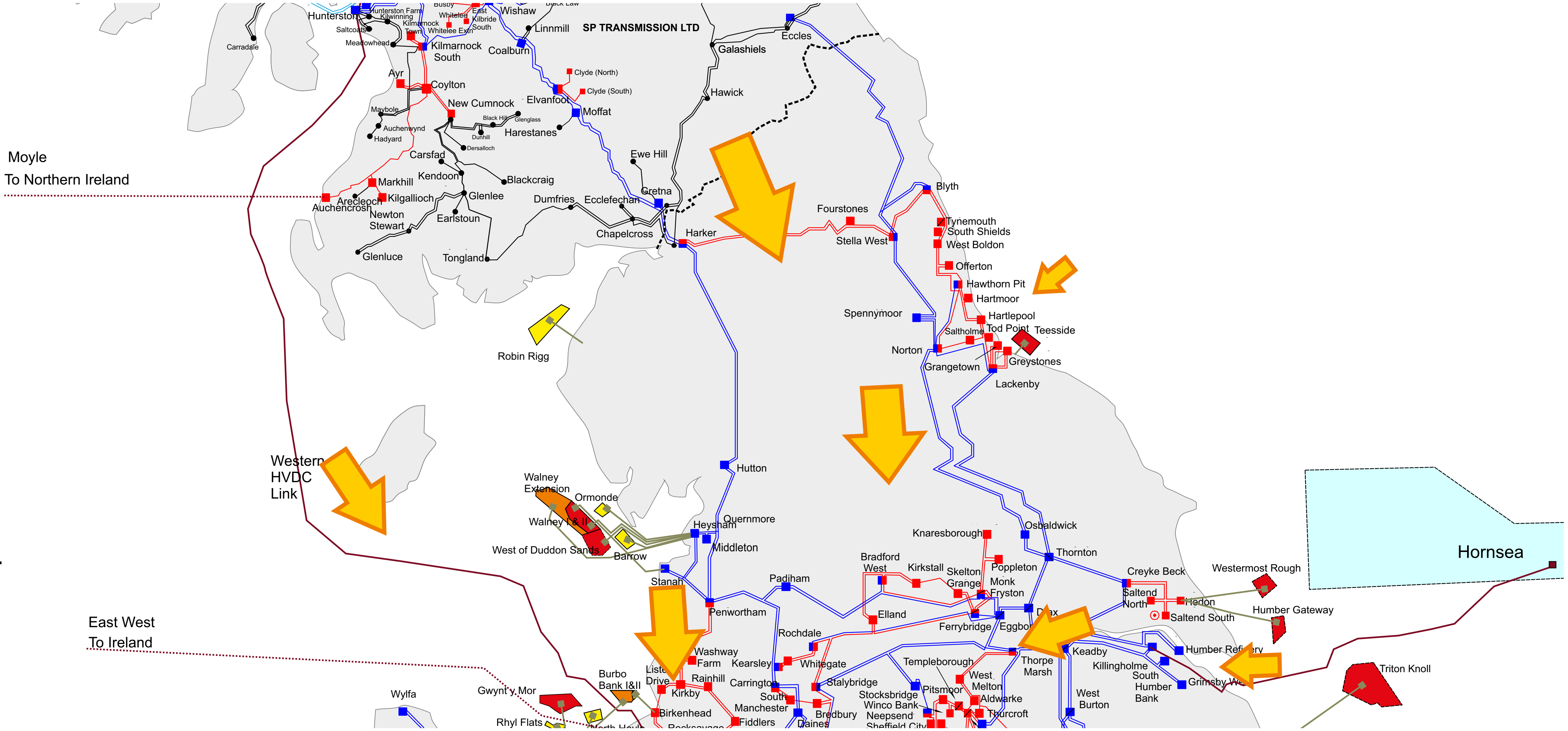
While the south to north transfer capability is enough to meet demand in Scotland, it is still necessary for conventional synchronous generation to remain in service in Scotland to maintain year-round secure system operation.

The current boundary remains at 5.7GW with the limit being the post-fault rating of transformers at Harker

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 B7, B7a and B8. The figure below shows likely power flow directions at system winter peak



Regional Drivers

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

The future energy scenarios suggest the northern transmission region could see a range of changes as shown in the graph.

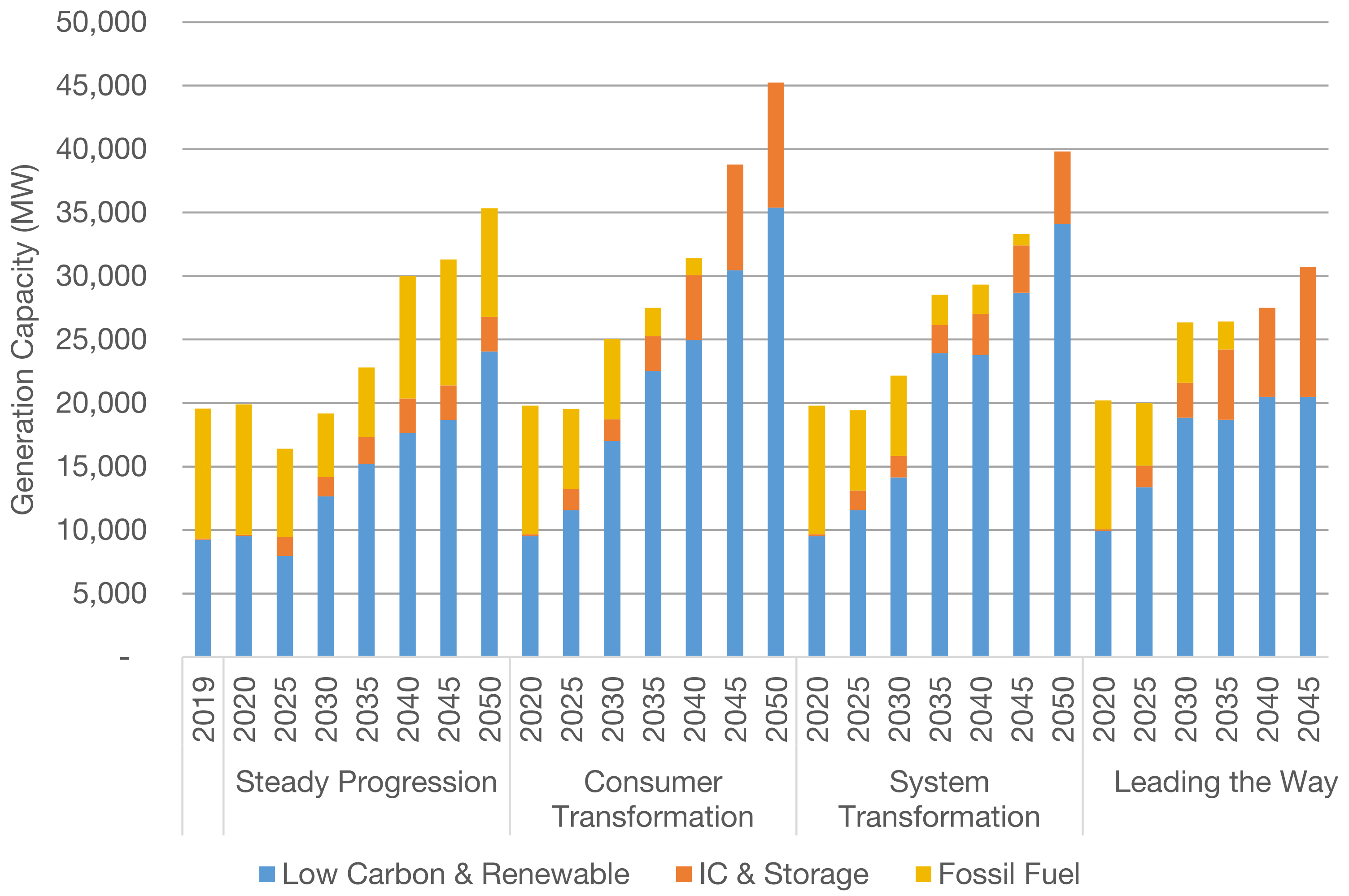
All four scenarios suggest growth in low-carbon and renewable generation, in addition to new storage and interconnector developments. The connected fossil fuel generation could see sustained decline in all but the Steady Progression scenario.

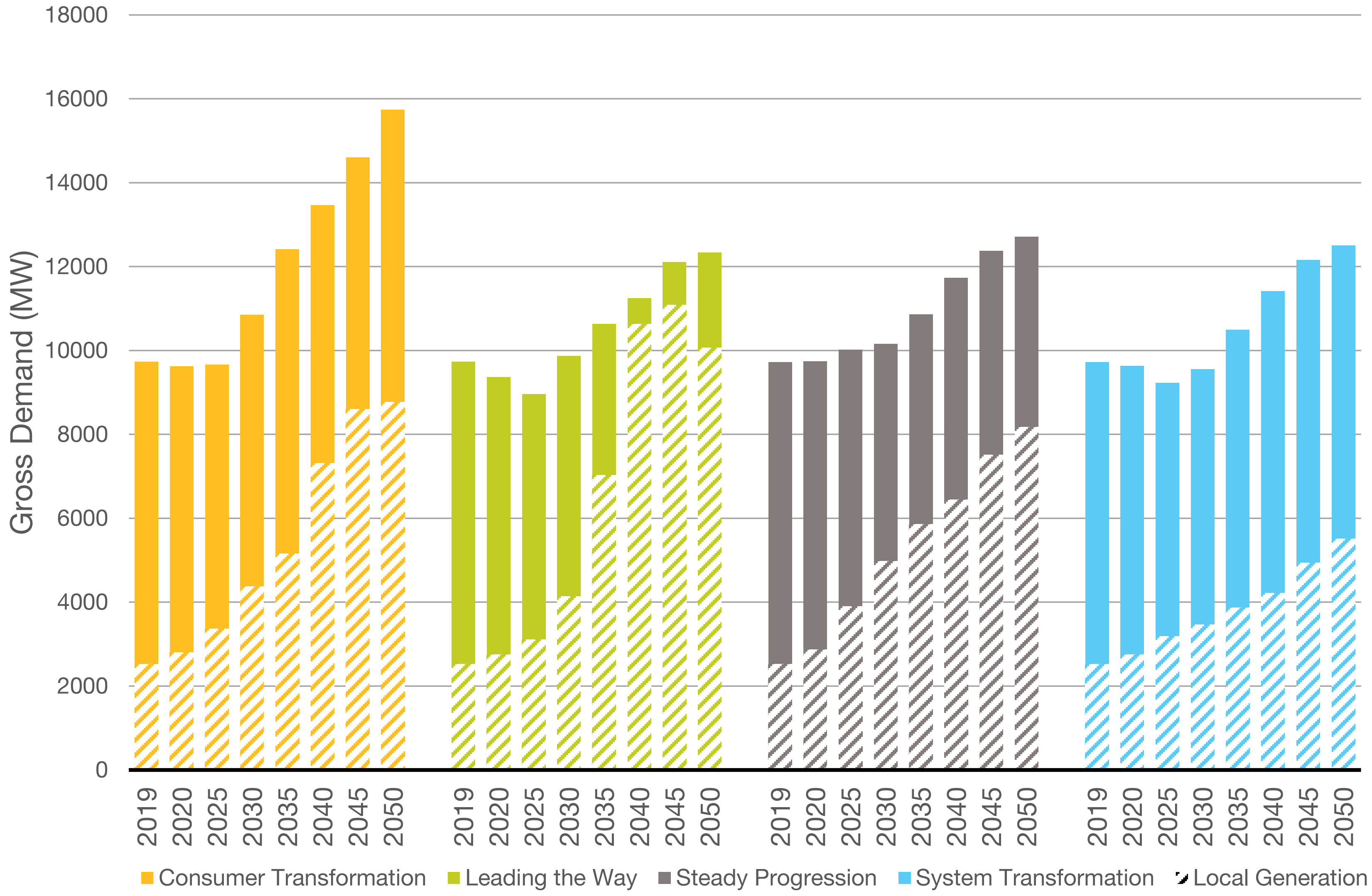
Large connections could cause network issues if connected to the north region.

Presently, most of the northern transmission network is oriented for north-south power flows with connections for demand and generation along the way. At times of high wind generation, the power flow will mostly be from north to south, with power coming from both internal boundary generation and generation further north in Scotland.

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

The highly variable nature of power flows in the north presents challenges to voltage management, and therefore automatic reactive power control switching is utilised. This helps to manage the significant voltage drop due to reactive power demands which arise at times of high levels of power flow on long circuits.





Operational reactive switching solutions are also used to manage light loading conditions when the voltage can rise to unacceptable levels. The high concentration of large conventional generators around Humber and South Yorkshire means that system configuration can be limited by high fault levels. Therefore, some potential network capability restrictions in the north can be due to the inability to configure the network as desired due to fault level concerns.

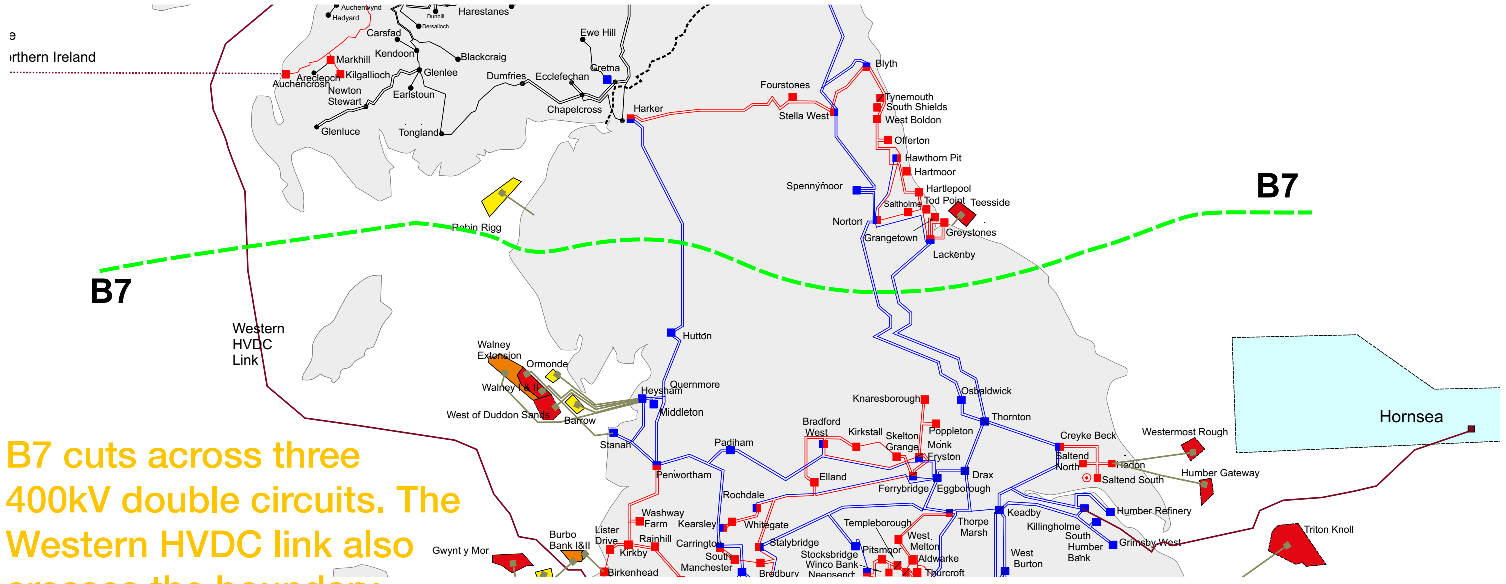
As the potential future requirement to transfer more power from Scotland to England increases, B7 and B7a are likely to reach their capability limits and may need network reinforcement. The potential future restrictions to be overcome across B7 and B7a are summarised:

- Limitation on power transfer out of north east England (boundary B7) is caused by thermal limitation for a fault on the double circuit between Harker–Hutton.
- At high power transfer, thermal limitations occur on a number of circuits within the north east 275kV ring.
- Limitation on power transfer from Cumbria to Lancashire (boundary B7a) occurs due to thermal limitation at Padiham–Penwortham circuit.

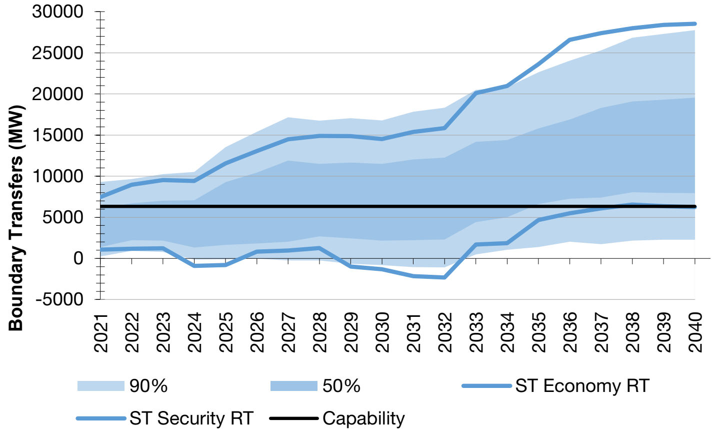
The need for network reinforcement to address the above-mentioned potential capability issues will be evaluated in the NOA 2020/21 CBA.

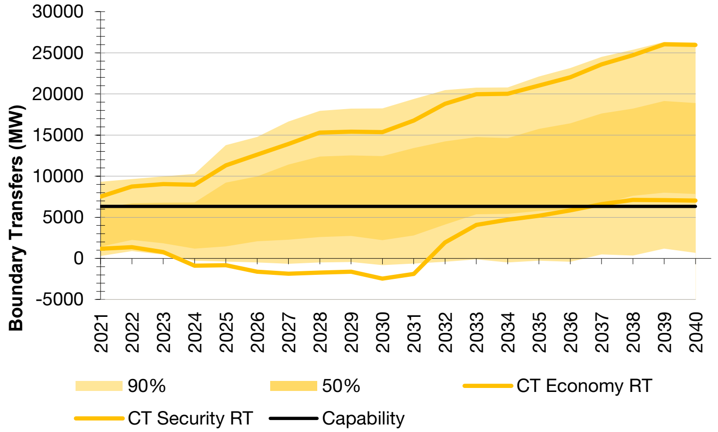
B7 – Upper North of England

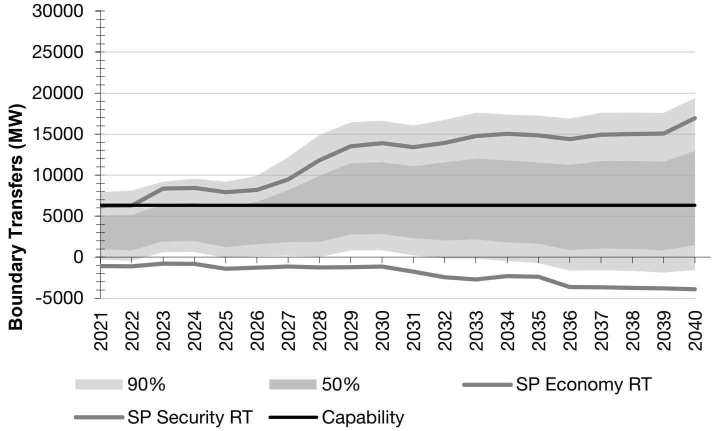
Boundary B7 bisects England south of Teesside. The area between B6 and B7 has been traditionally an exporting area, and constrained by the power flowing through the region from Scotland towards the south with the generation surplus from this area added.

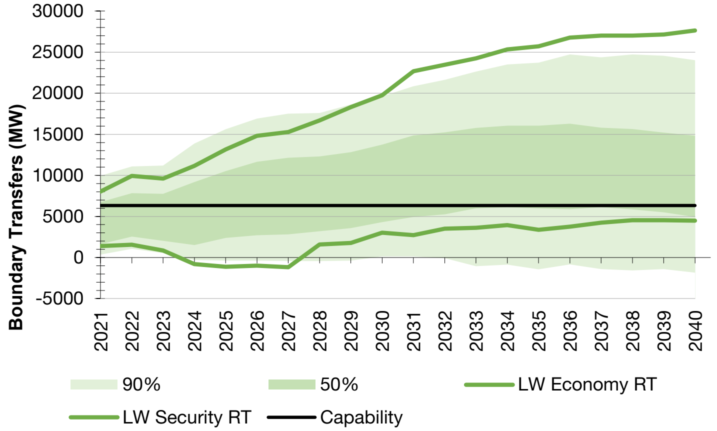


B7 cuts across three 400kV double circuits. The Western HVDC link also crosses the boundary









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

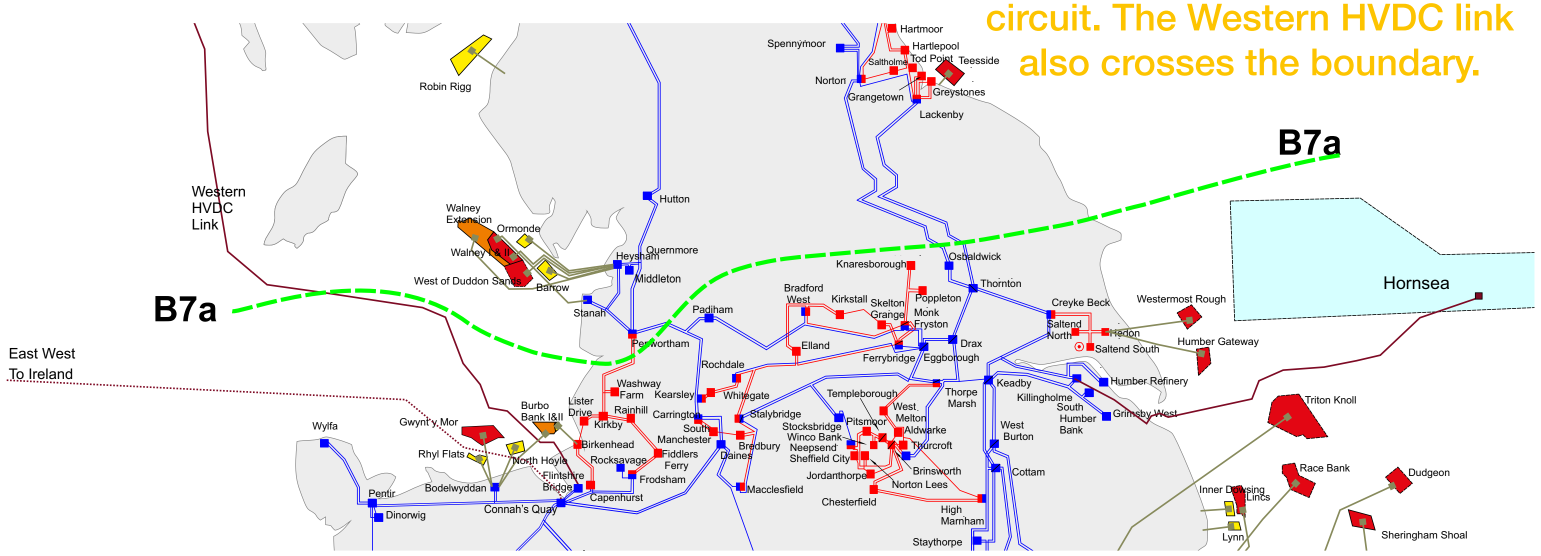
The FES show a lot of intermittent renewable generation in the north, meaning the spread of boundary power flows is very wide. With low generation output in the north it is credible to have power flowing from south to north feeding northern demand. The magnitude of the south to north power flows is low compared to those in the opposite direction so network capability should be sufficient to support those conditions.

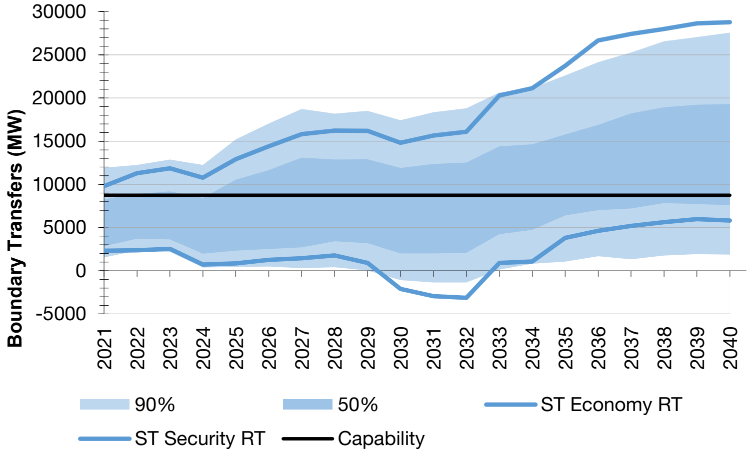
The boundary capacity is 6.3GW limited thermally by the post-fault load rating of transformers at Harker under the Harker–Hutton double-circuit fault

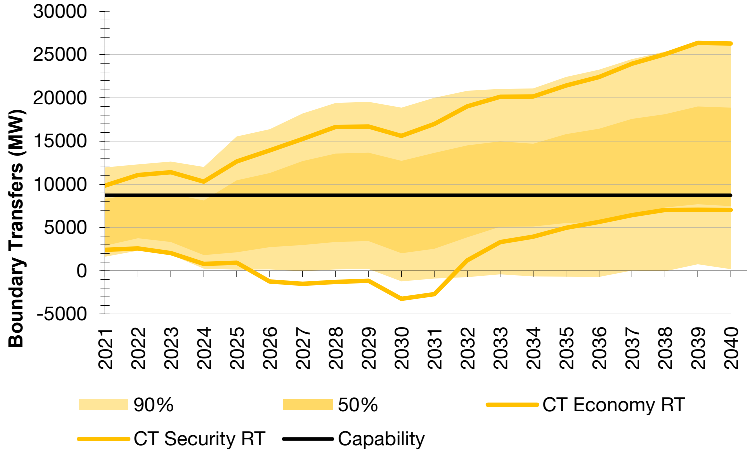
B7a – Upper North of England

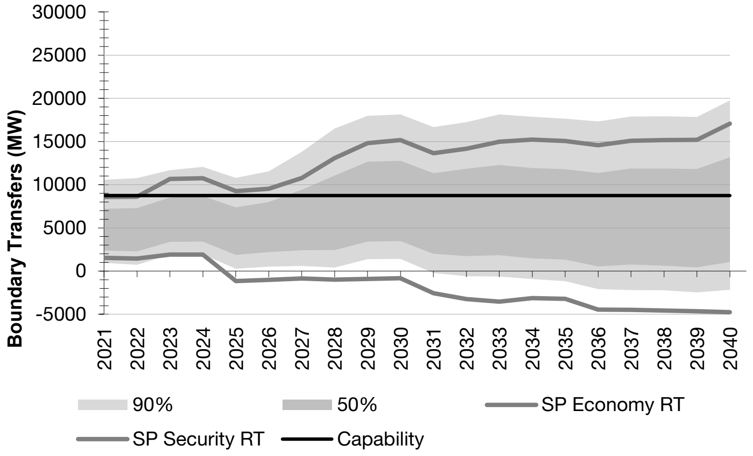
Boundary B7a bisects England south of Teesside and into the Mersey Ring area. It is used to capture network restrictions on the circuits feeding down through Liverpool, Manchester and Leeds.

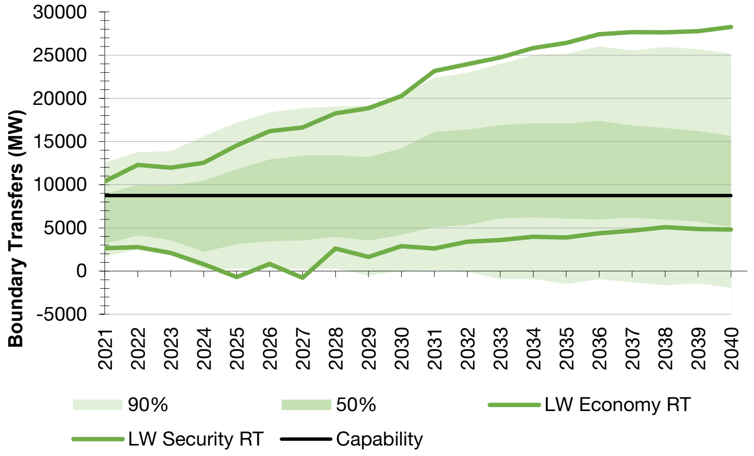
B7a cuts across three 400kV double circuits and one 275kV circuit. The Western HVDC link also crosses the boundary.











For all except the Steady Progression scenario, the SQSS economy required transfer and expected power flows grow to well beyond the present boundary capability in the next ten years. This suggests a need for network development to manage the increasing power flows.

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

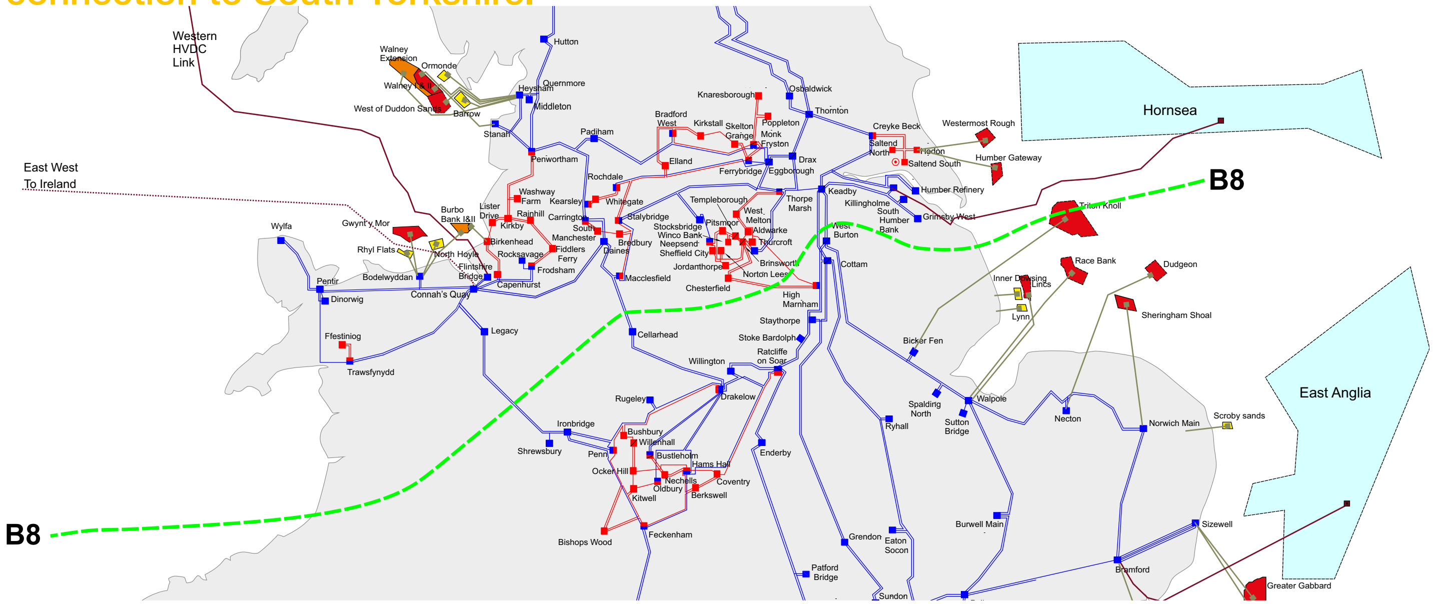
The magnitude of the south to north power flows is low compared to those in the opposite direction so network capability should be sufficient to support those conditions

The boundary capacity has remained 8.7GW limited thermally by the post-fault load rating of the 400kV circuits from Penwortham

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.

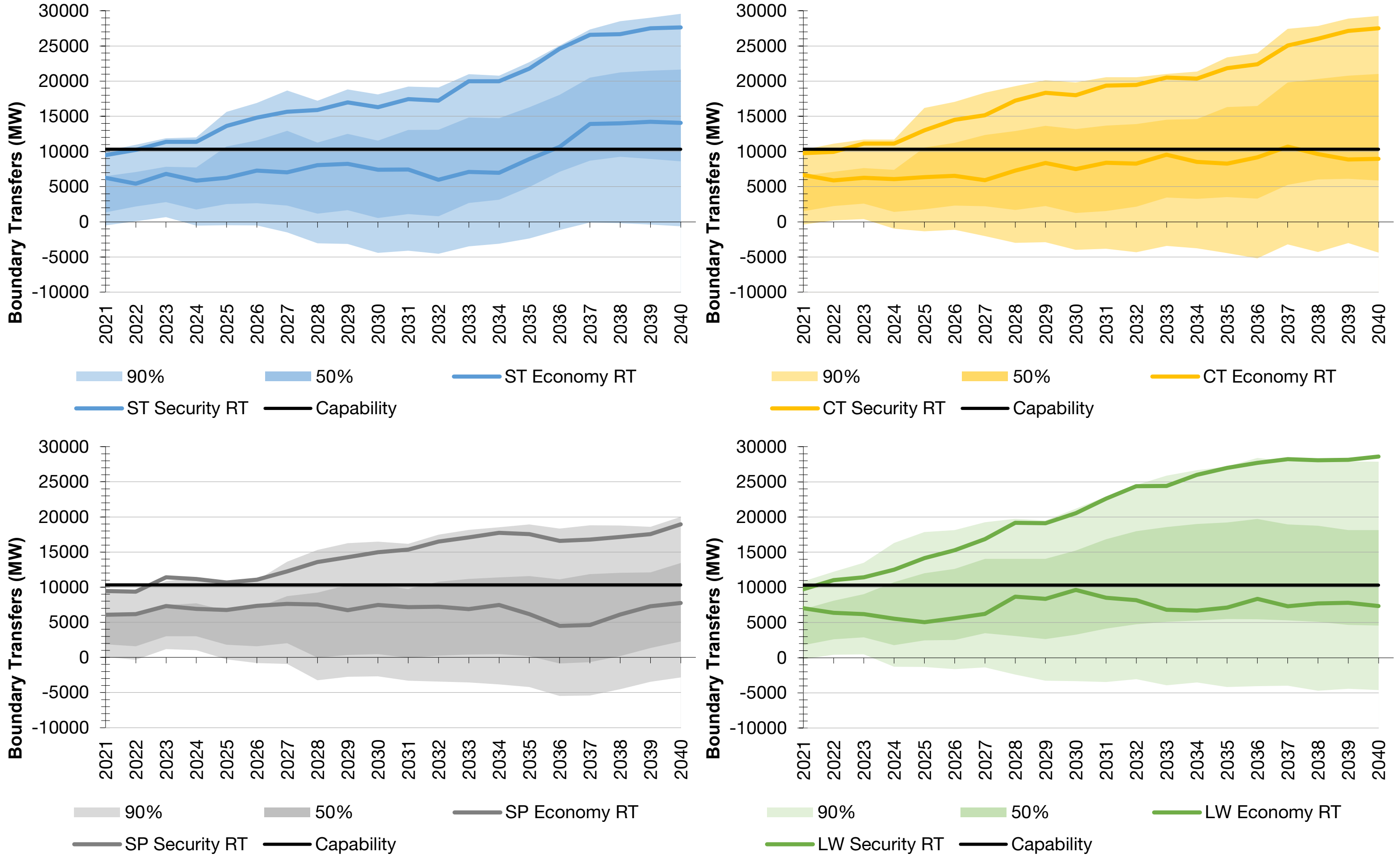
B8 cuts across four 400kV double circuits and a limited 275kV connection to South Yorkshire.



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

The FES shows a lot of intermittent renewable generation in the north - the spread of boundary power flows is very wide.

With low northern generation output, it is credible to have power flowing from south to north feeding northern demand, although this is not significant until beyond ten years in the future. 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

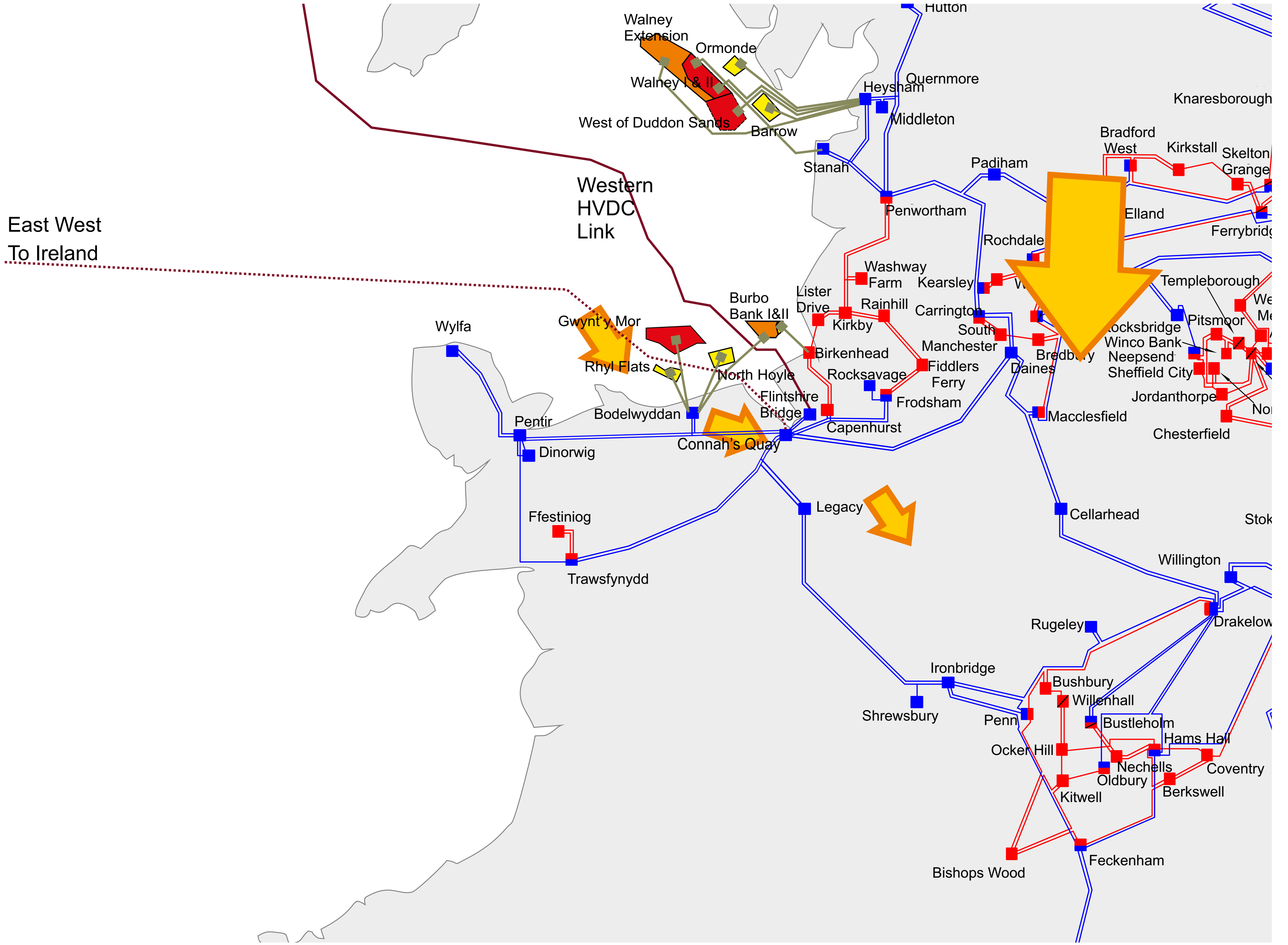


The boundary capacity is 10.3GW limited thermally by the post-fault load rating of the Cellarhead-Drakelow 400kV circuit

Wales and the Midlands

The Western transmission region includes boundaries in Wales and the Midlands. The figure below shows likely power flow directions in the years to come up to 2030.

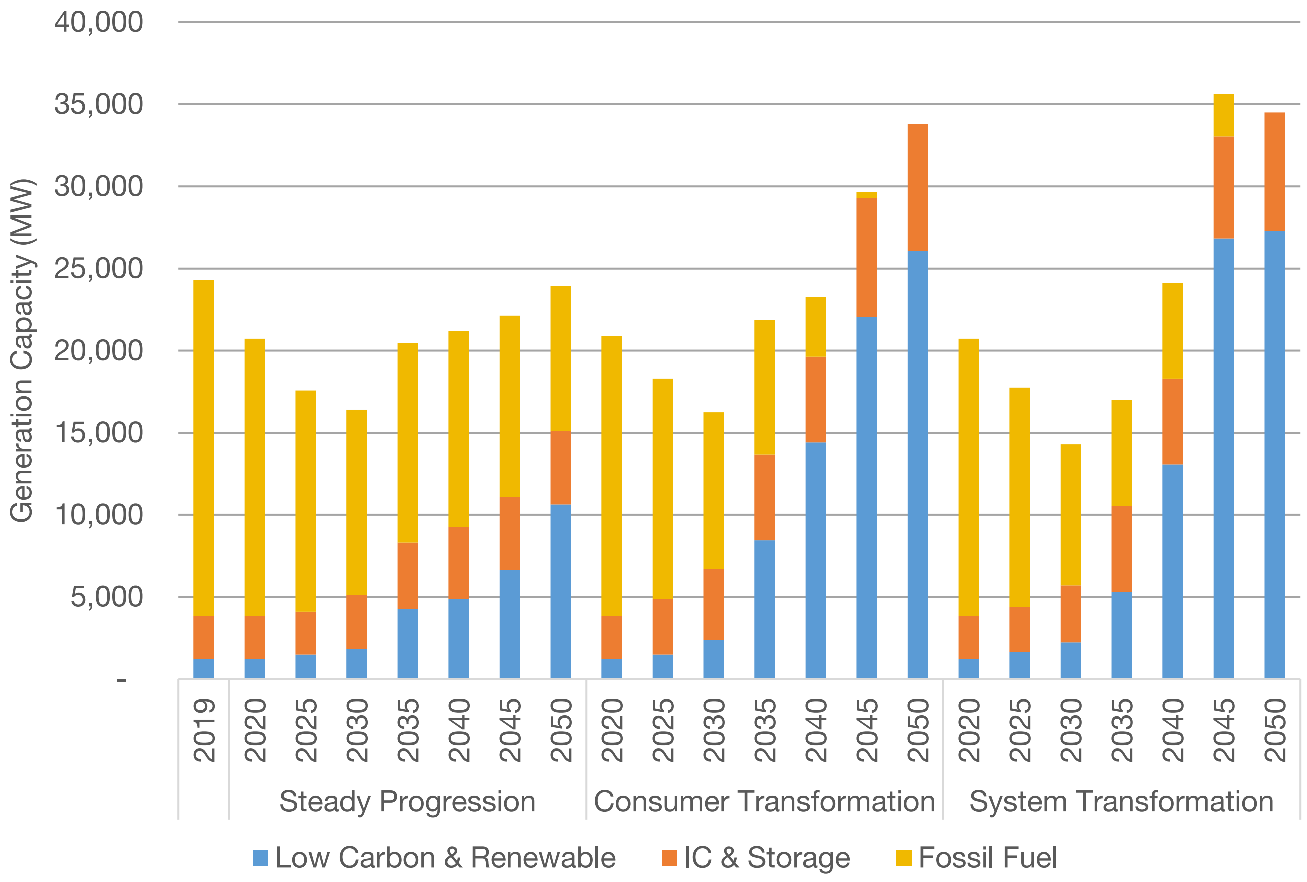
The arrows in the diagram are to illustrate power flow directions and, to an approximate scale, the flow magnitude in winter peak.

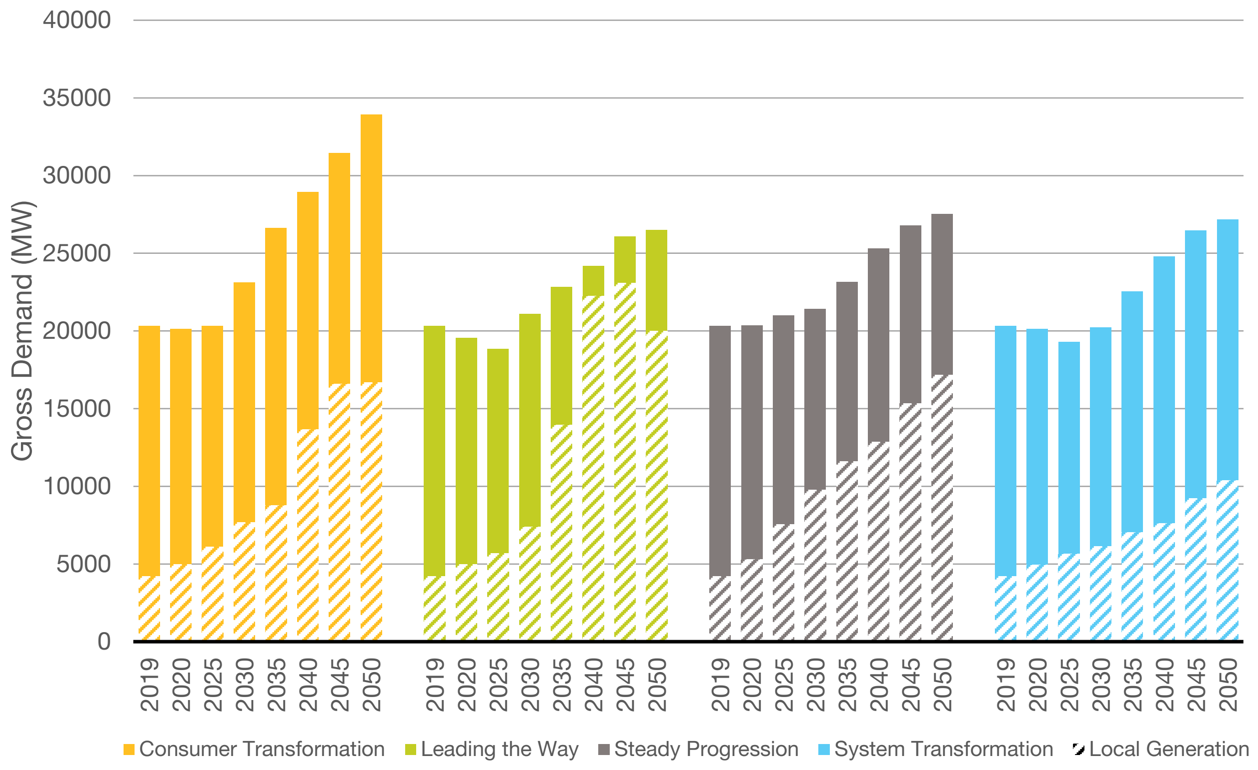


Regional Drivers

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

By 2035, the scenarios suggest a total amount of generation capacity of between 12GW to 24GW. At present, this region has significant levels of fossil fuel (about 20GW). All scenarios show a decline in fossil fuel with slight growth in low-carbon technologies, interconnectors and storage.





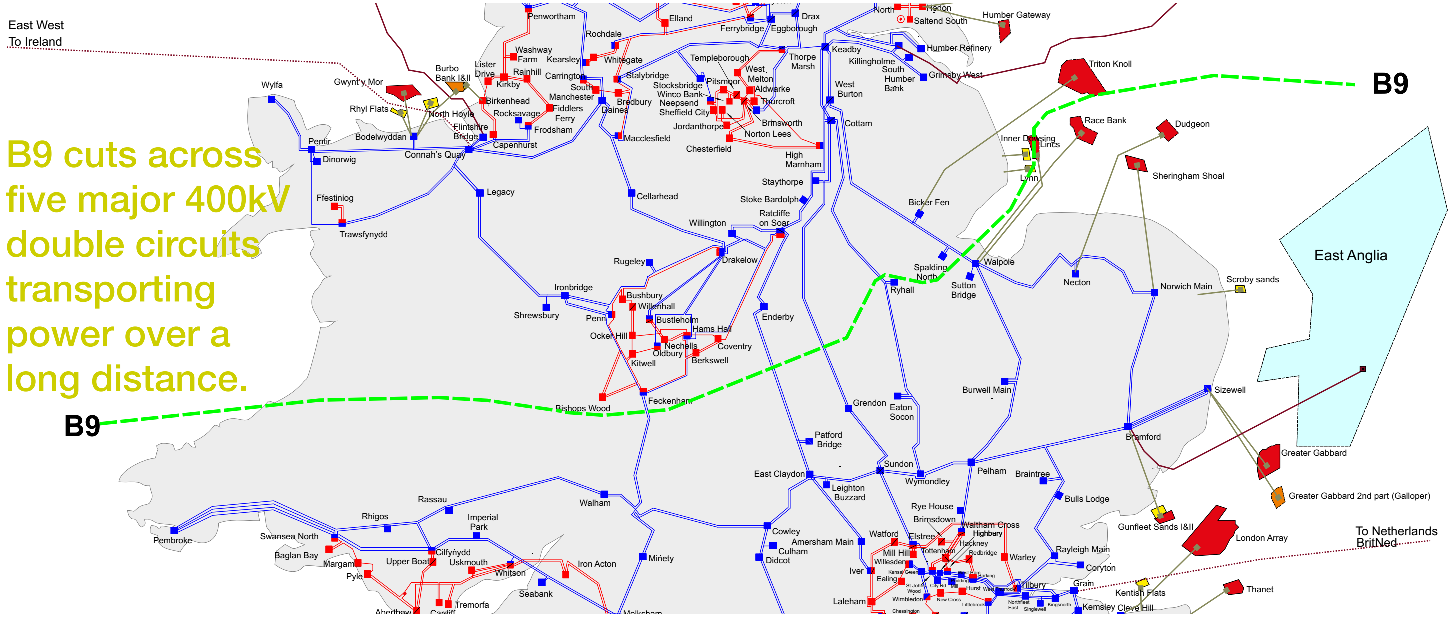
The graph shows that the gross demand as seen from the transmission network in the region will increase across all scenarios. This is driven by the adoption of technologies such as electric vehicles, heat pumps and embedded storage.

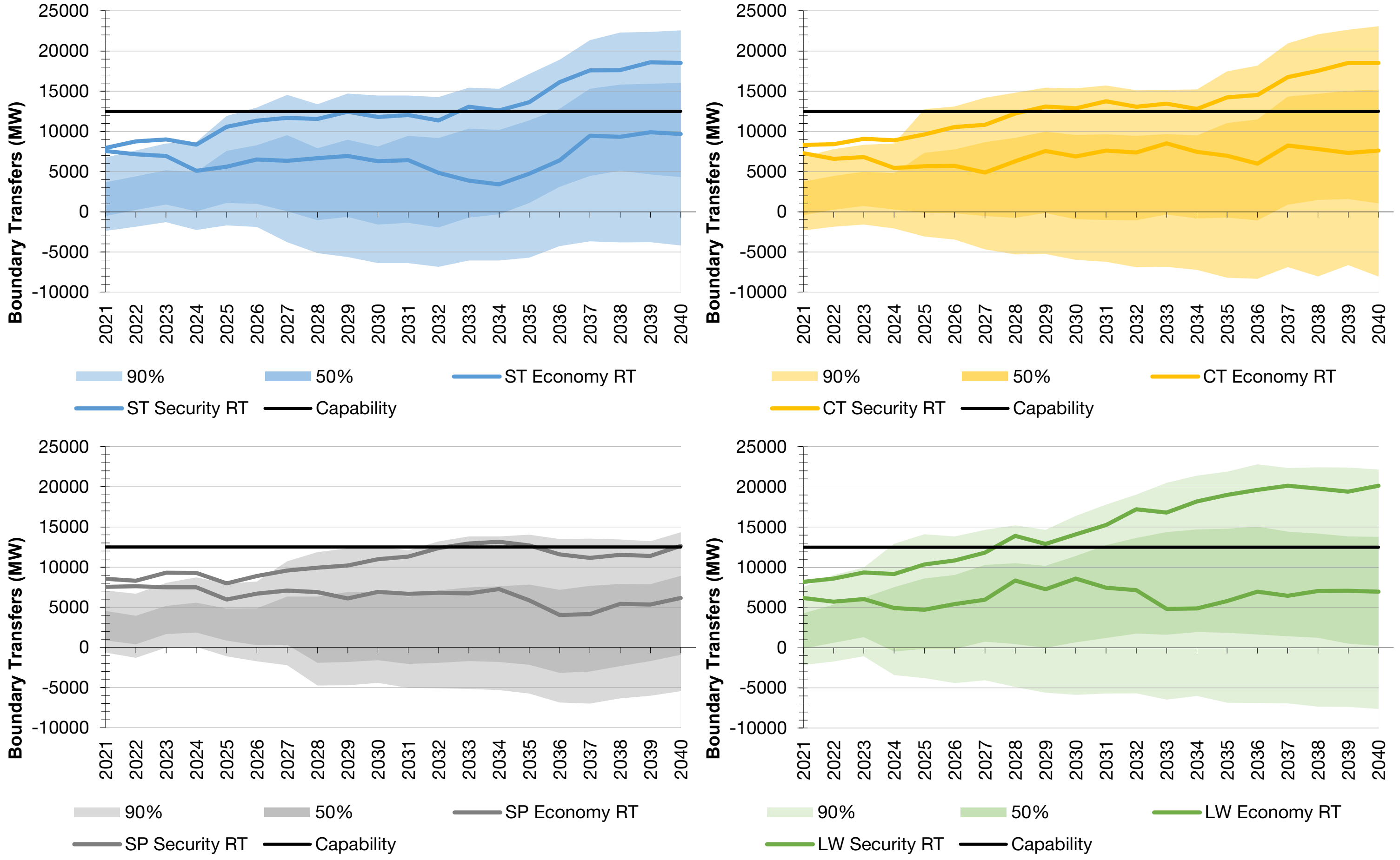
In a high decentralised scenario like System Transformation, local generation capacity connected at the distribution level in this western region could reach more than 49GW by 2040. Of that capacity, a typical embedded generation output on average might be around 20GW. This will vary depending on factors like wind speeds, and how other local generators decide to participate in the market.

Boundary B9 – Midlands to South of England

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

B9 cuts across five major 400kV double circuits transporting power over a long distance.





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

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

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

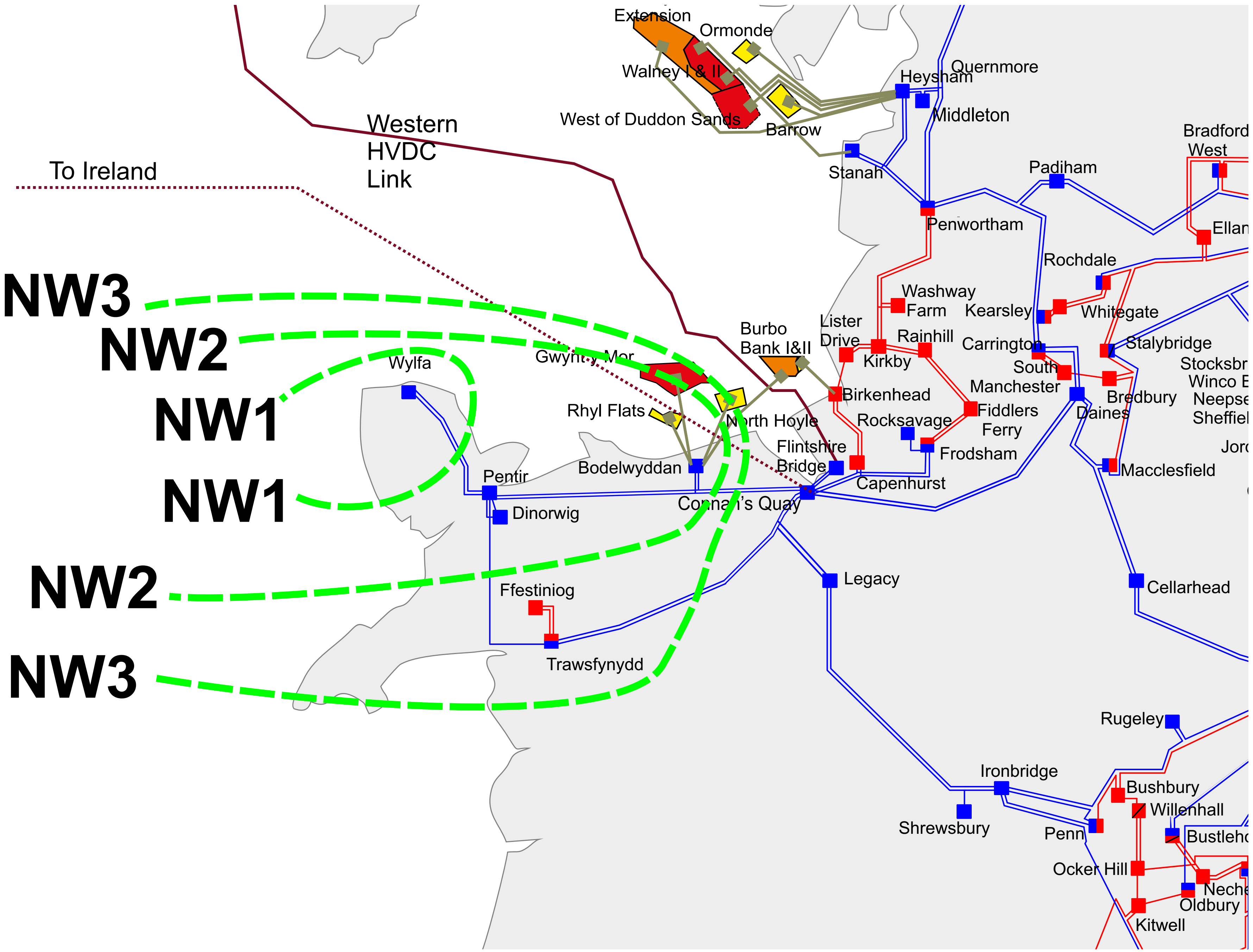
The boundary capacity is 12.5GW limited by a voltage constraint for a fault on the Enderby–Ratcliffe on Soar double-circuit.

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.

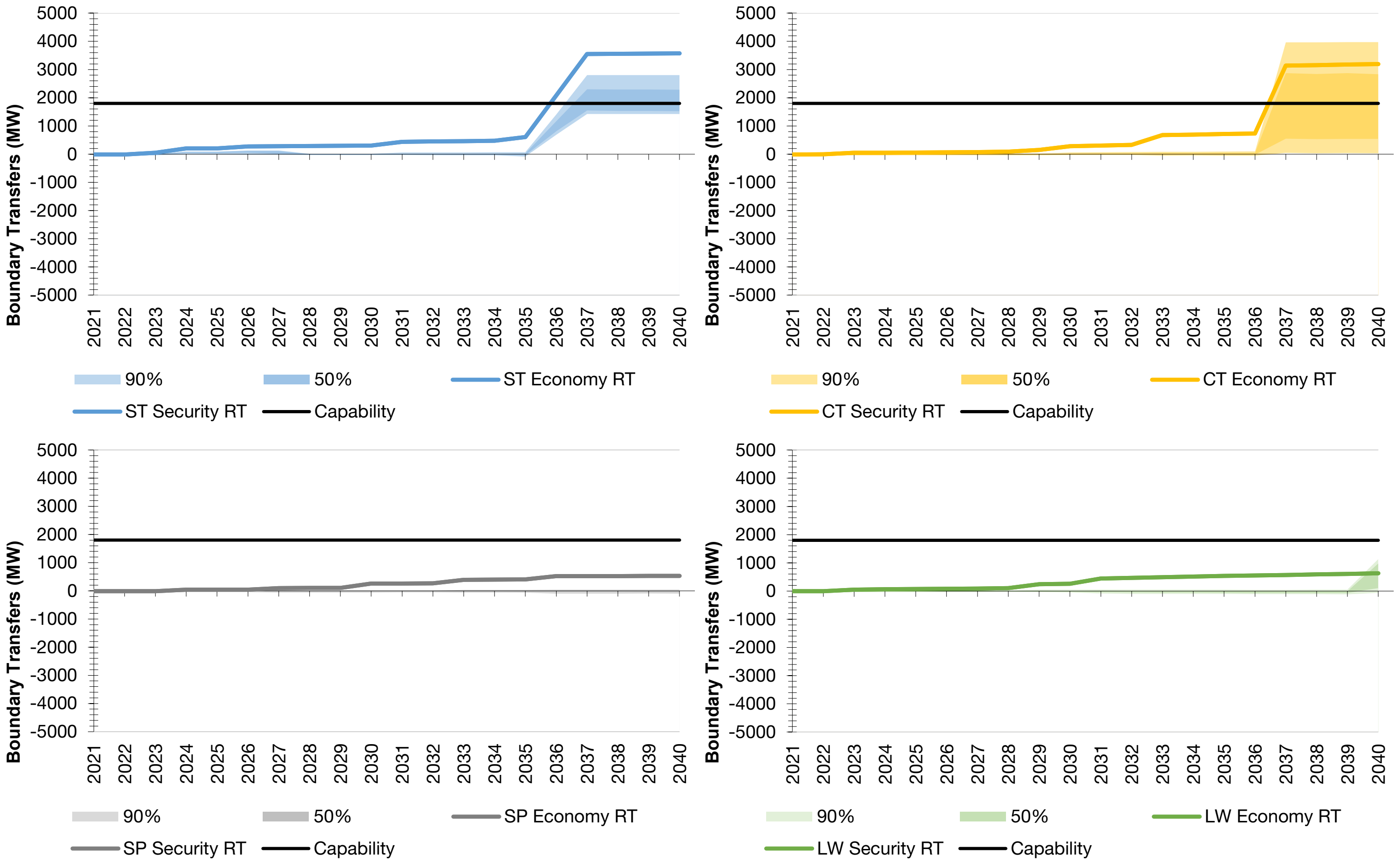
Most of these circuits are of double circuit tower construction. However, Pentir and Trawsfynydd within the Snowdonia National Park are connected by a single 400kV circuit, which is the main limiting factor for capacity in this area. The area is studied by analysing the local boundaries NW (North Wales)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



Boundary NW1 – Anglesey

The generation expected behind NW1 is a combination of offshore wind generation and biomass generation

In the System Transformation and Consumer Transformation scenarios in the FES, the requirements increase to above the boundary capability for NW1. The increase is more than last year suggesting a need for additional boundary capability in the future for two out of the four scenarios.

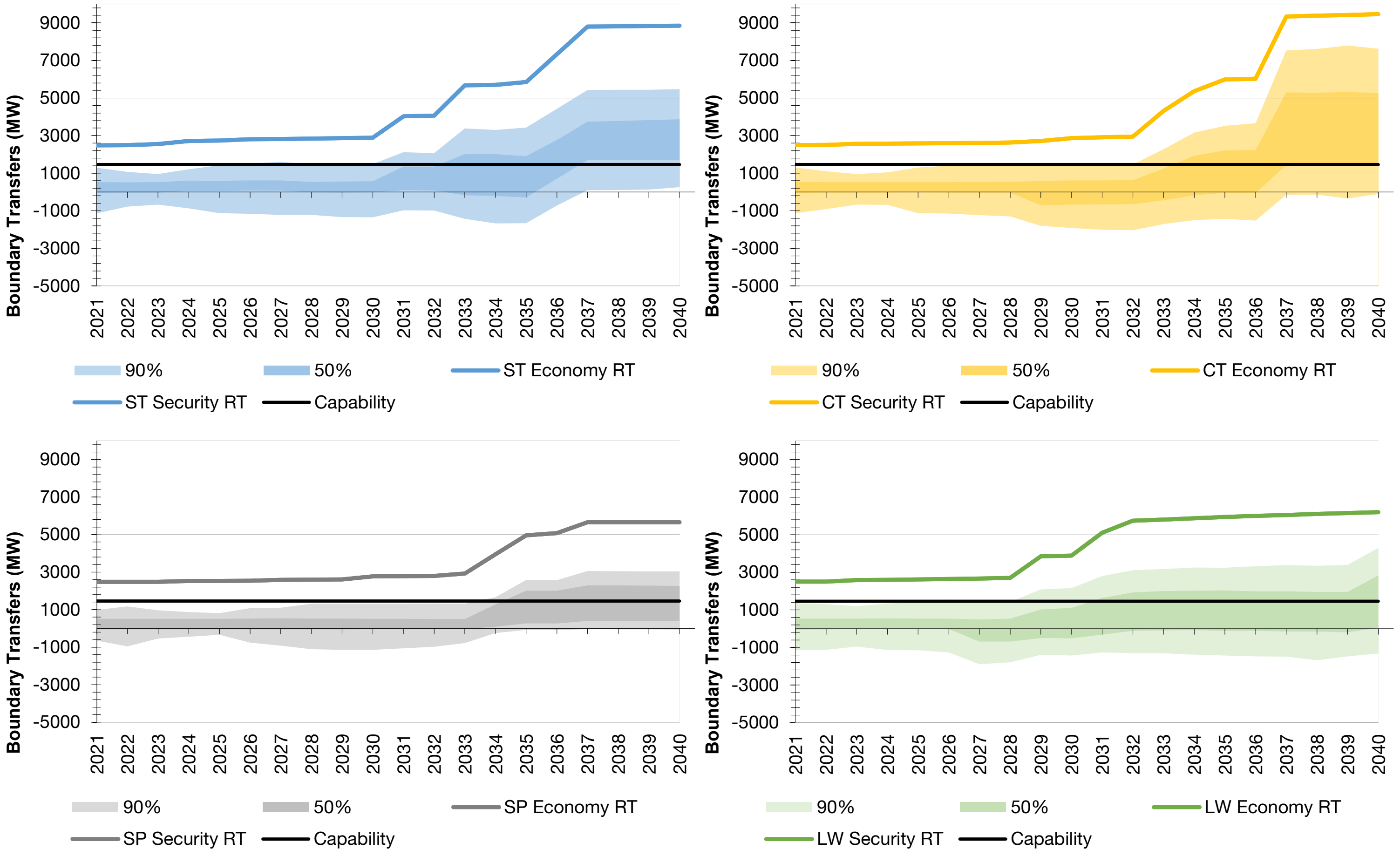


The boundary transfer capability is limited by the **infrequent infeed loss risk criterion** set in the SQSS, which is currently **1,800MW**. If the infrequent infeed loss risk is exceeded, the boundary would need to be reinforced by adding a new transmission route across the boundary.

Boundary NW2 – Anglesey and Caernarvonshire

Across all four FES scenarios, the SQSS economy required transfer grows beyond the present boundary capability. The expected power flows only grow beyond present capability from around 2029.

The scenarios show similar requirements until 2028 where they diverge due to different assumptions of connection time and dispatching of potential offshore wind and biomass generation behind this boundary.

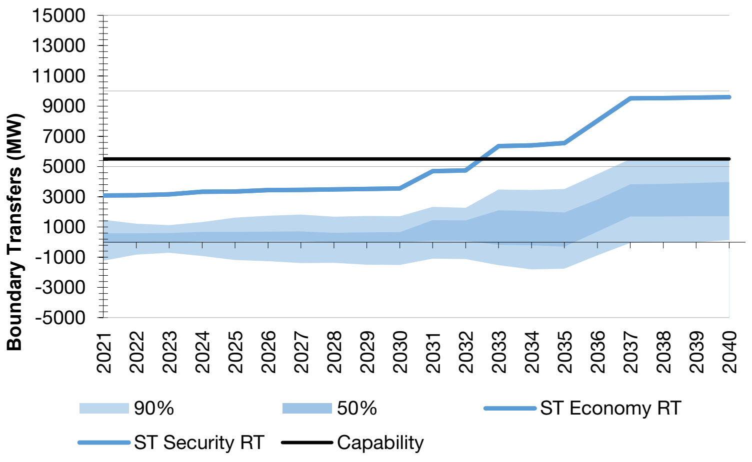


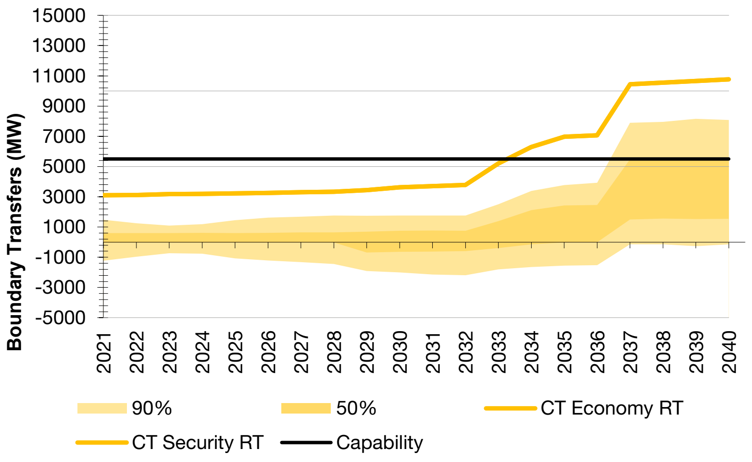
The boundary capability is thermally limited at 1.4GW for a double-circuit fault on the Connah's Quay–Bodelwyddan–Pentir circuits which overloads the Pentir–Trawsfynydd single circuit

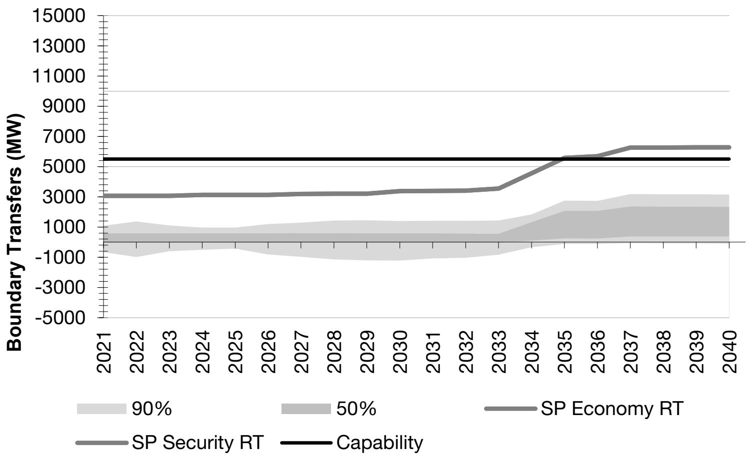
Boundary NW3 – Anglesey and Caernarvonshire and Merionethshire

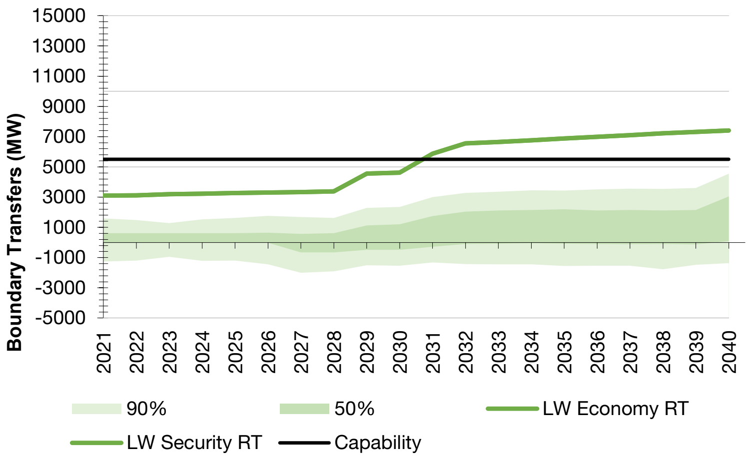
In all four scenarios in the FES, we see the SQSS economy required transfer grow beyond the present boundary capability.

The scenarios show a similar requirement until 2028 where they diverge due to different assumptions of connection time and dispatching of potential offshore wind and biomass generation behind this boundary







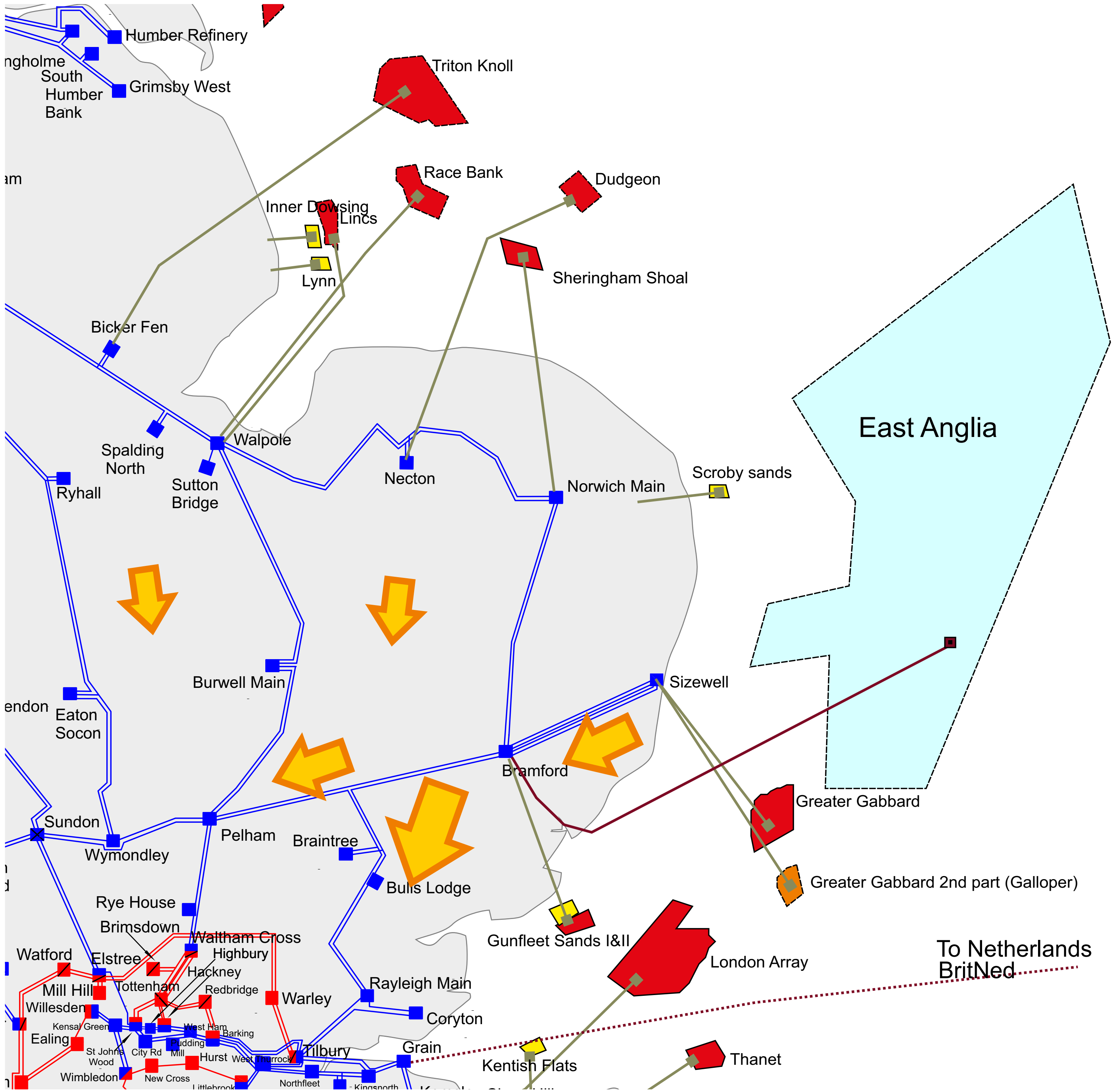


The boundary capability is **thermally** limited at **5.5GW** for a double-circuit fault on the **Trawsfynydd–Treuddyn–Connah's Quay tee circuits** which overloads the Connah's Quay–Bodelwyddan– Pentir tee circuits

East of England

The East of England region includes the counties of Norfolk and Suffolk. The figure below shows likely power flow directions in the years to come up to 2030.

The arrows in the diagram are meant to illustrate power flow directions and an approximate scale to the flow magnitude in winter peak.



Regional Drivers

With the large amount of generation contracted to be connected in the area, predominantly offshore wind, nuclear and interconnector developments, the supply may significantly exceed the local demand which could cause heavy circuit loading, voltage depressions and stability issues.

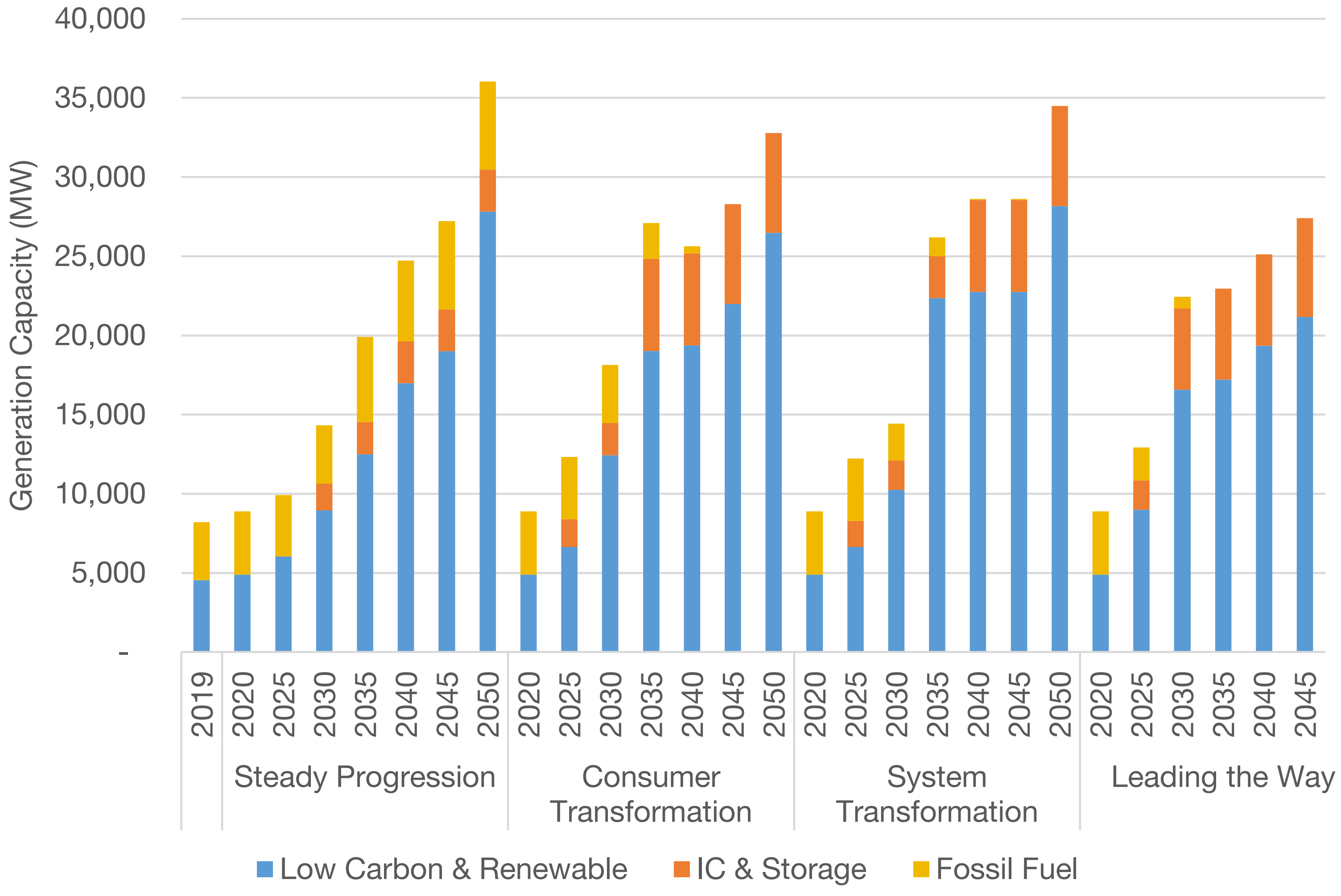
The future energy scenarios highlight that generation between 7 and 25GW could be expected to connect within this region by 2035.

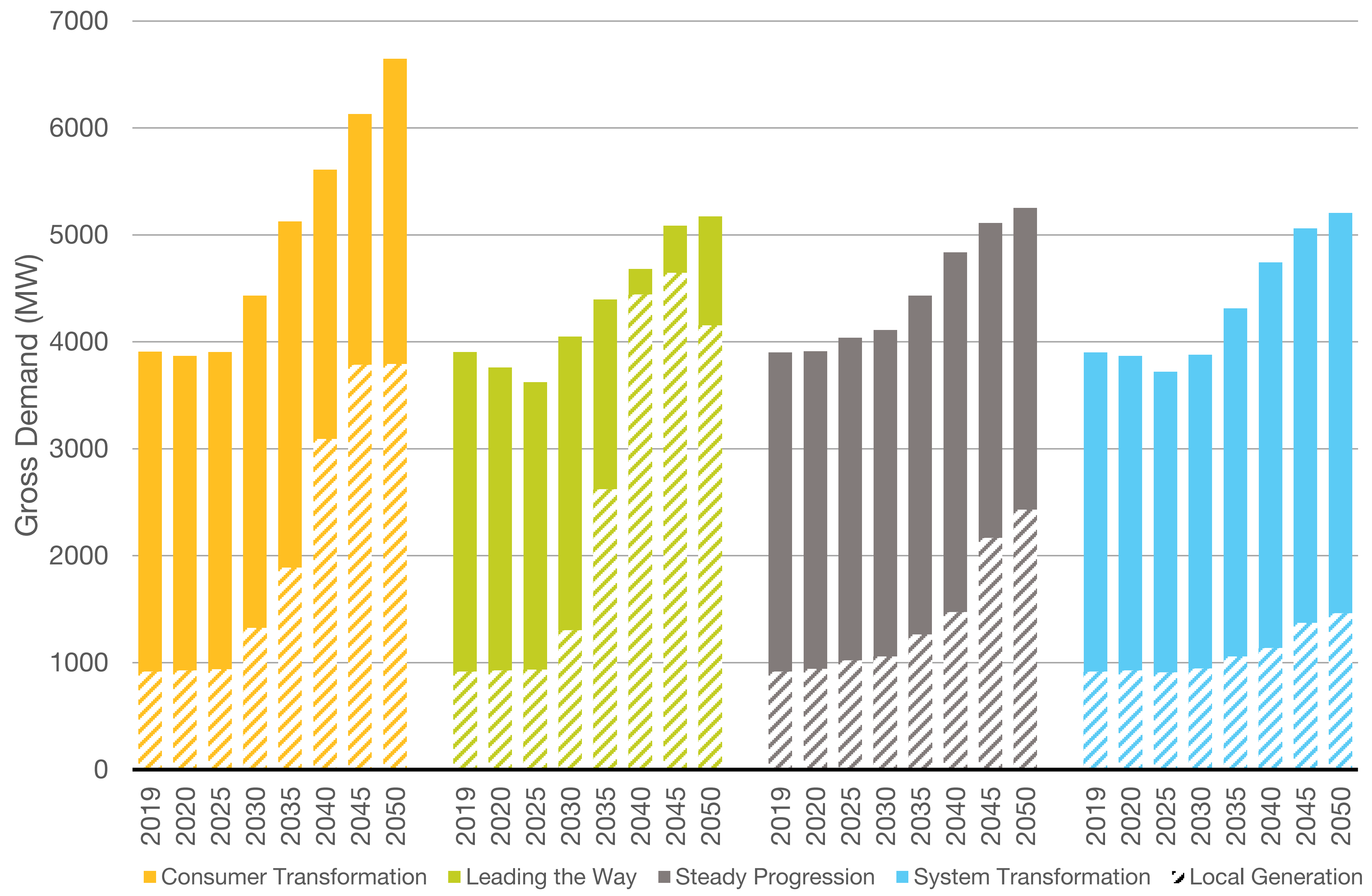
All scenarios show that, in the years to come, large amounts of low-carbon generation, predominantly wind, can be expected to connect. Fossil fuel generation can also be expected to connect within this region as well as an interconnector. The total generation in all the scenarios will exceed the local demand; thus the East of England will be a power exporting region.

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

- The East of England region is connected by several sets of long 400kV double circuits, including Bramford Pelham/Braintree, Walpole–Spalding North/Bicker Fenn and Walpole–Burwell Main.

  During a fault on any one set of these circuits, power exported from this region is forced to reroute. This causes some of the power to flow through a much longer distance to reach the rest of the system, predominantly the Greater London and south east England networks via the East Anglia region.





- Stability becomes an additional concern when some of the large generators connect, further increasing the size of the generation group in the area connected to the network.
  Losing a set of double circuits to a fault will lead to significant exposure to a risk of instability as power transfer increases.

Peak gross demand in the East of England region is expected to be around 5-7GW by 2040.

In a highly decentralised scenario like Leading the Way, local generation capacity connected at the distribution level in this eastern region could reach more than 15GW by 2040. Of that capacity, a typical embedded generation output on average might be around 4.8GW. This will vary depending on factors like wind speeds, and how other local generators decide to participate in the market.

The graph shows snapshots of the peak gross demand for the East of England across the four different scenarios.

The NOA 2020/21 will assess the likelihood and impact of the above mentioned potential scenarios and accordingly recommend preferred reinforcements for the East of England transmission region.

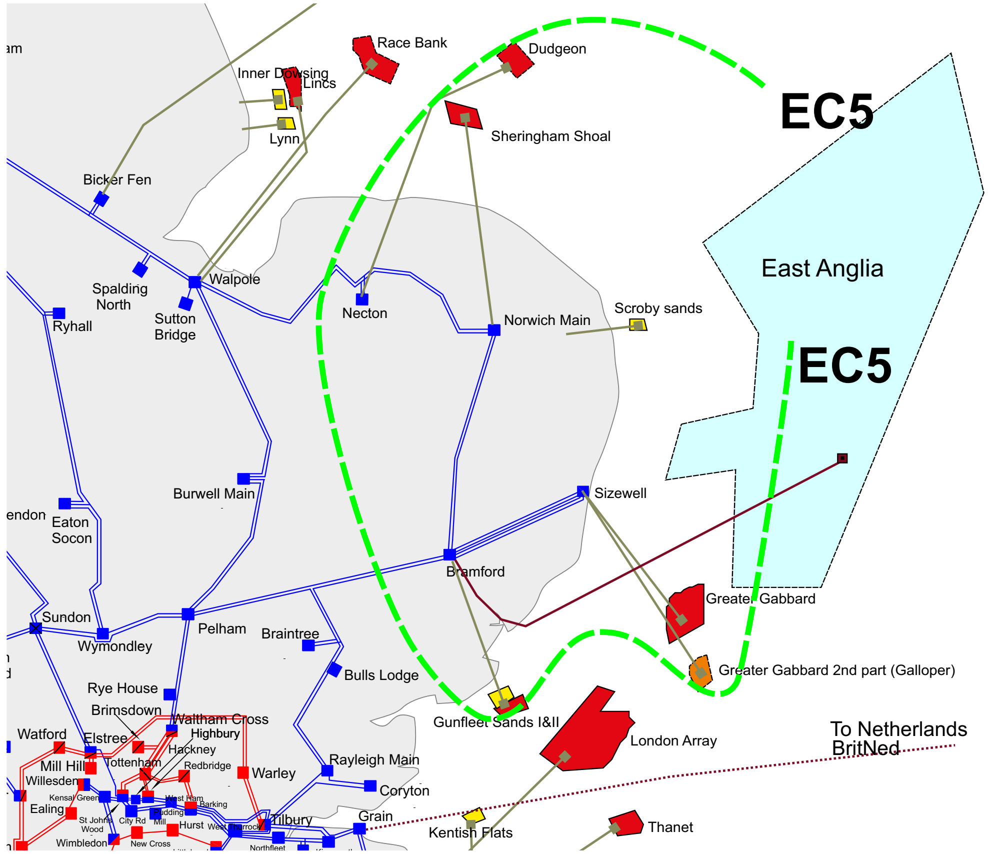
Boundary EC5 – East Anglia

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

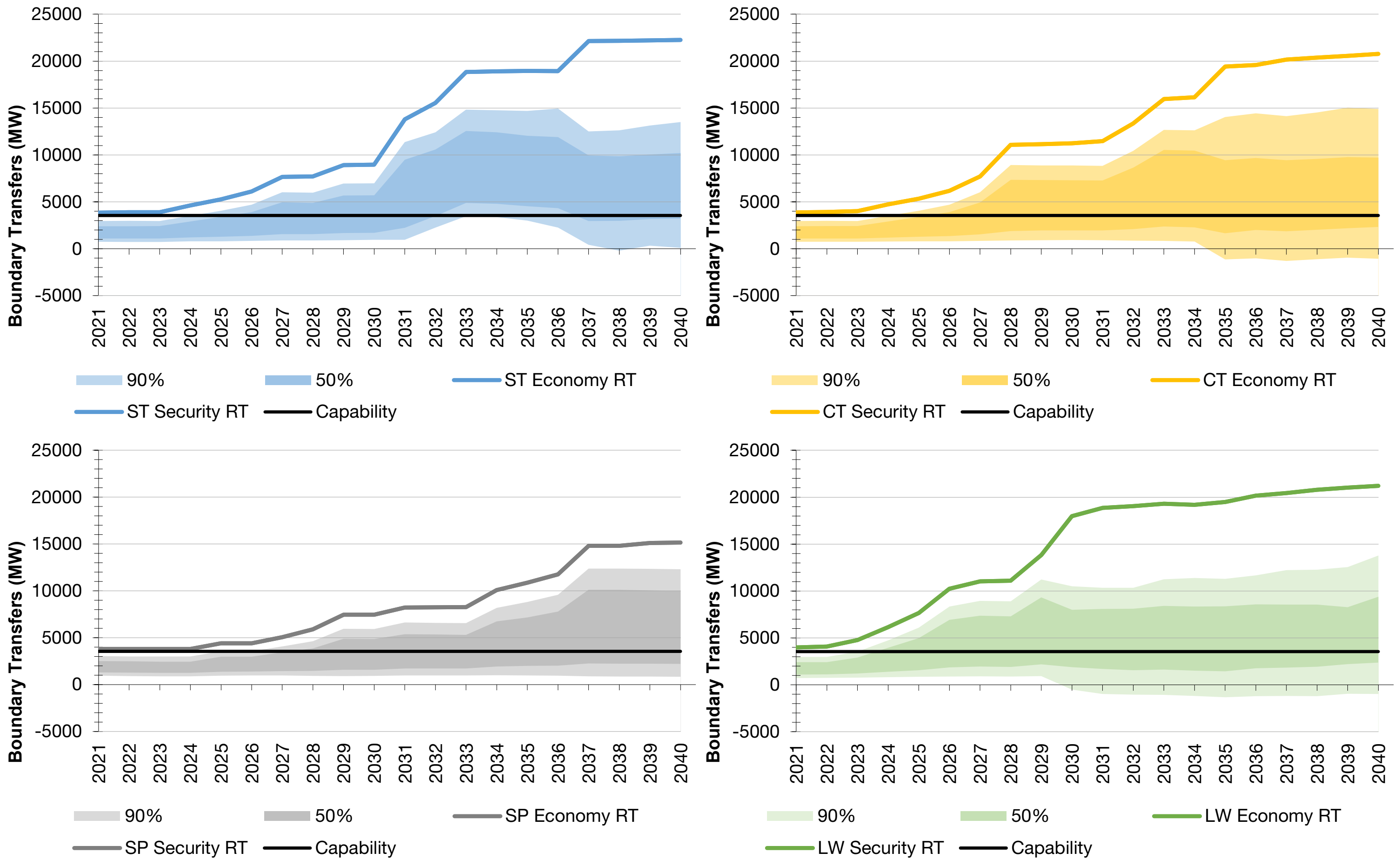
The coastline and waters around East Anglia are attractive for the connection of offshore wind projects, including the large East Anglia Round 3 offshore zone that lies directly to the east.

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

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



In all scenarios, the SQSS economy required transfer and expected power flows grow rapidly from around 2023 to beyond the present boundary capability. This suggests a need for network development to manage the increasing power flows.



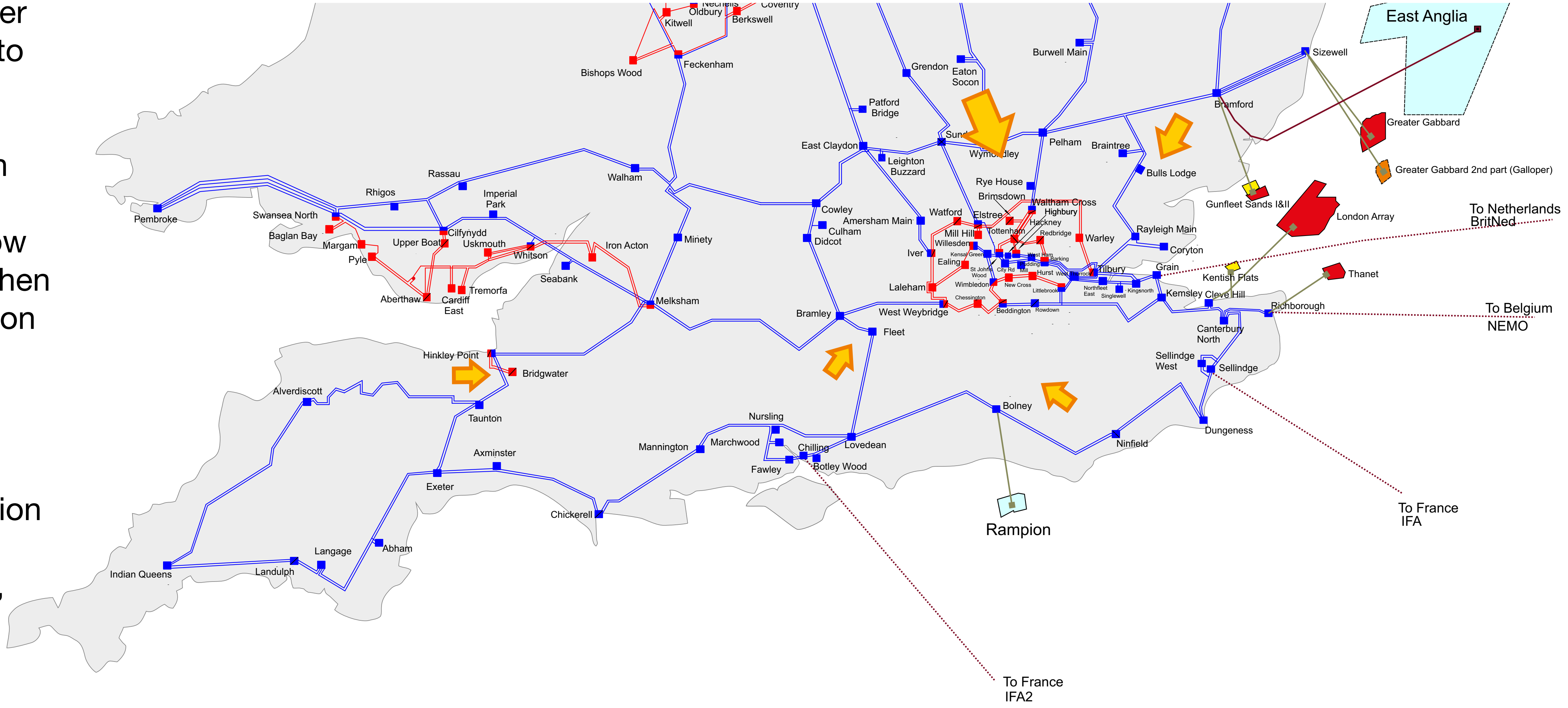
The boundary capability is currently a **voltage compliance** limit at **3.5GW** for a double-circuit fault on the Bramford–Pelham and Bramford–Braintree–Rayleigh Main circuits causing **low voltage at Burwell Main substation**.

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 figure shows likely power flow directions in the years to come up to 2030.
The arrows in the diagram are meant to give illustration to power flows and an approximate scale to the flow magnitude in winter peak when importing energy to the UK on the interconnectors.

The South Wales boundary is defined by SW1 while the South of England transmission region includes boundaries B13, B14, LE1, SC1, SC1.5, SC2 and SC3.



Regional Drivers

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 14GW of interconnectors and energy storage capacity may connect in the south.

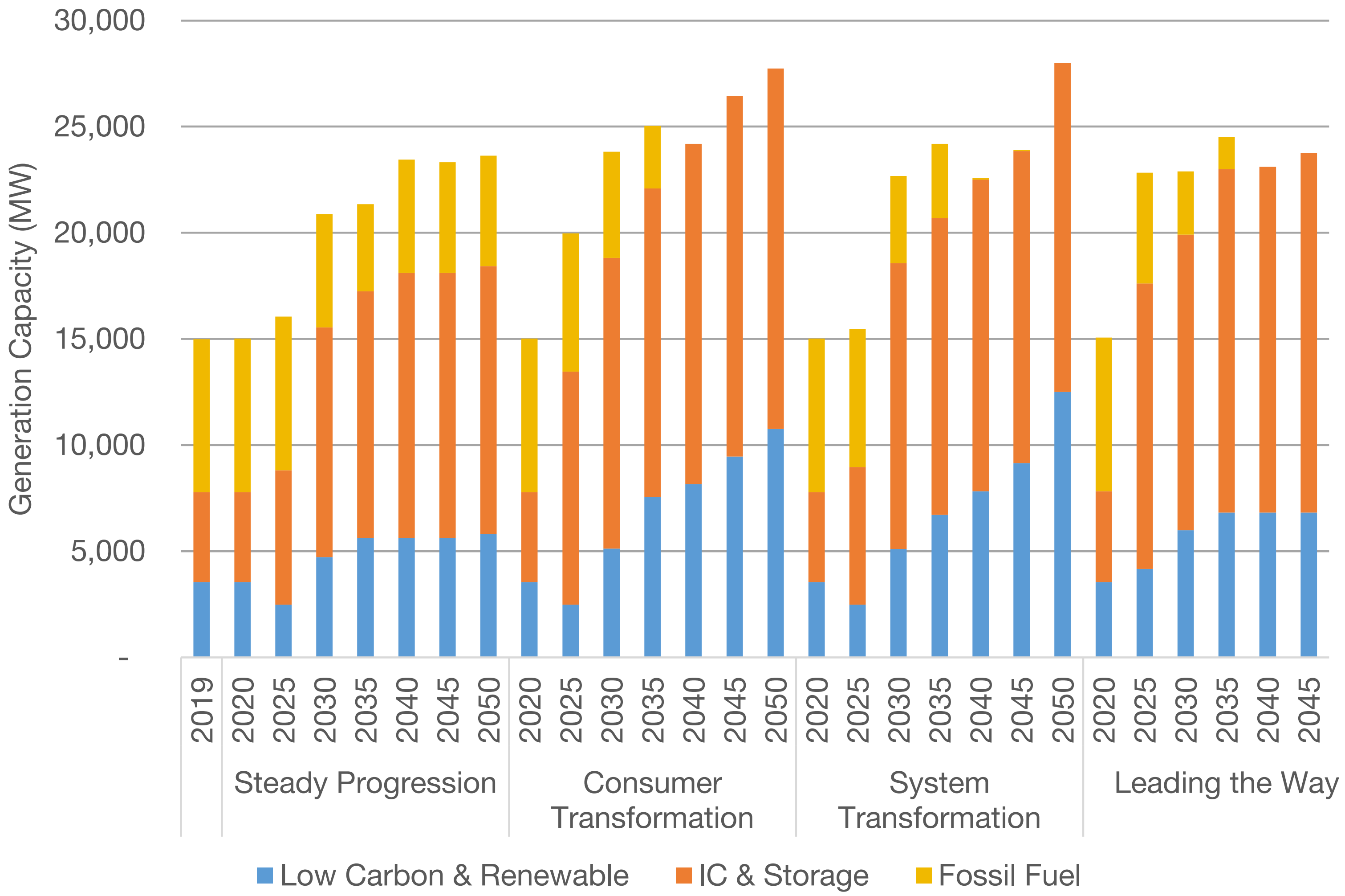
As interconnectors and storage are bi-directional, the south could see their capacity provide up to 14GW power injection or 14GW increased demand. This variation could place a very heavy burden on the transmission network.

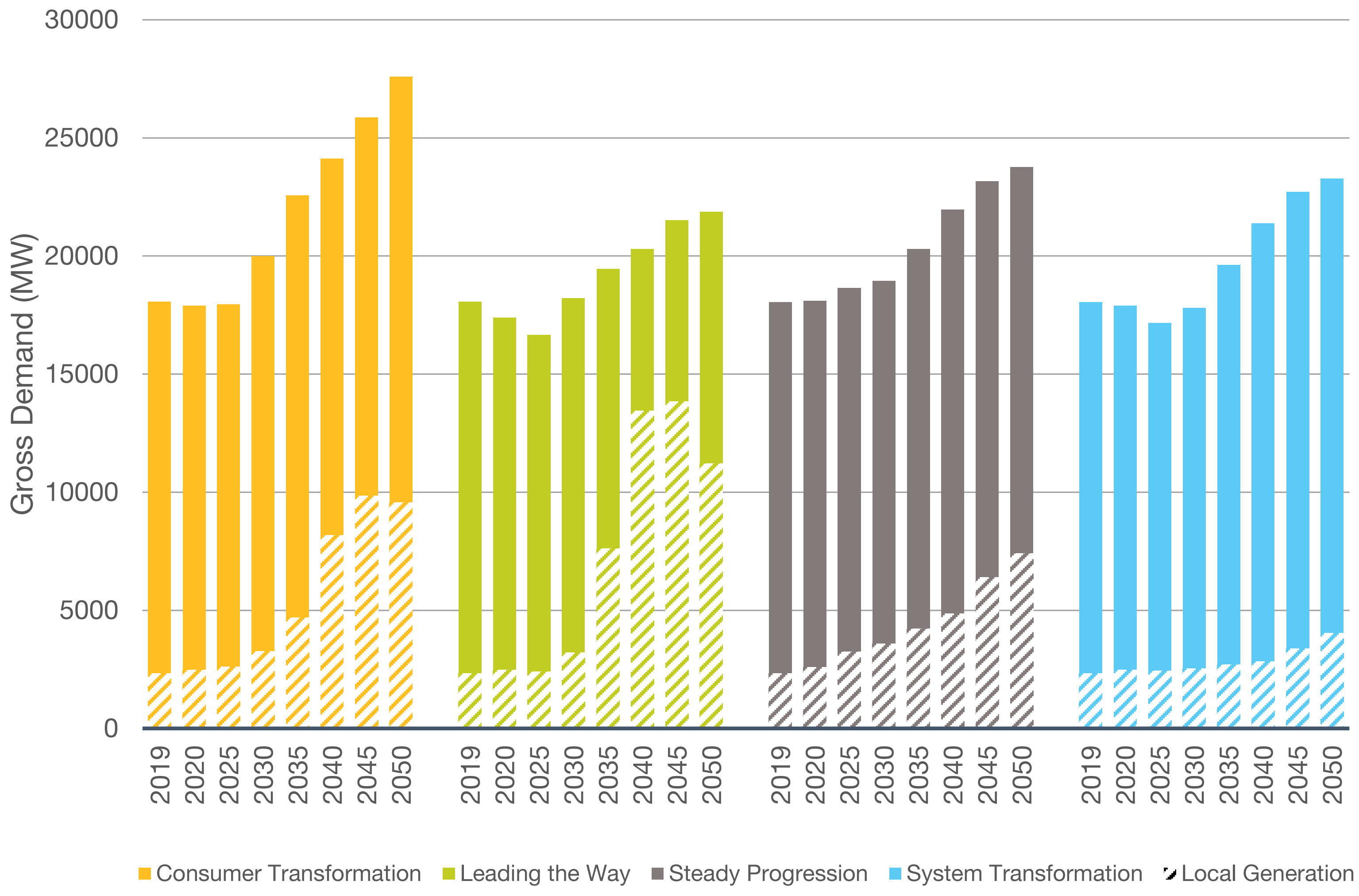
Most of the interconnectors will be connected south of boundary SC1 so the impact can be seen later in the chapter in the SC1, SC1.5 and SC2 requirements.

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

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

The connection of the new nuclear generating units at Hinkley may also require reinforcing the areas surrounding Hinkley. With new interconnector and generation connections, boundaries SC1, SC1.5, SC2, SC3, LE1 and B13 will need to be able to support large power flows in both directions which is different from today when power flow is predominantly in one direction.





South Wales has seen some generation closures recently, freeing some transmission capacity, but the power export capacity out of the area remains tight. If there is growth in generation capacity in the area, the transmission capacity could be limiting

In a highly decentralised scenario like Leading the Way, local generation capacity connected at the distribution level in this region could reach up to 14GW by 2040. Of that capacity, a typical embedded generation output on average might be around 5-10GW.

This will vary depending on factors like wind speeds, and how other local generators decide to participate in the market and capacity available on the distribution networks.

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.

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

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

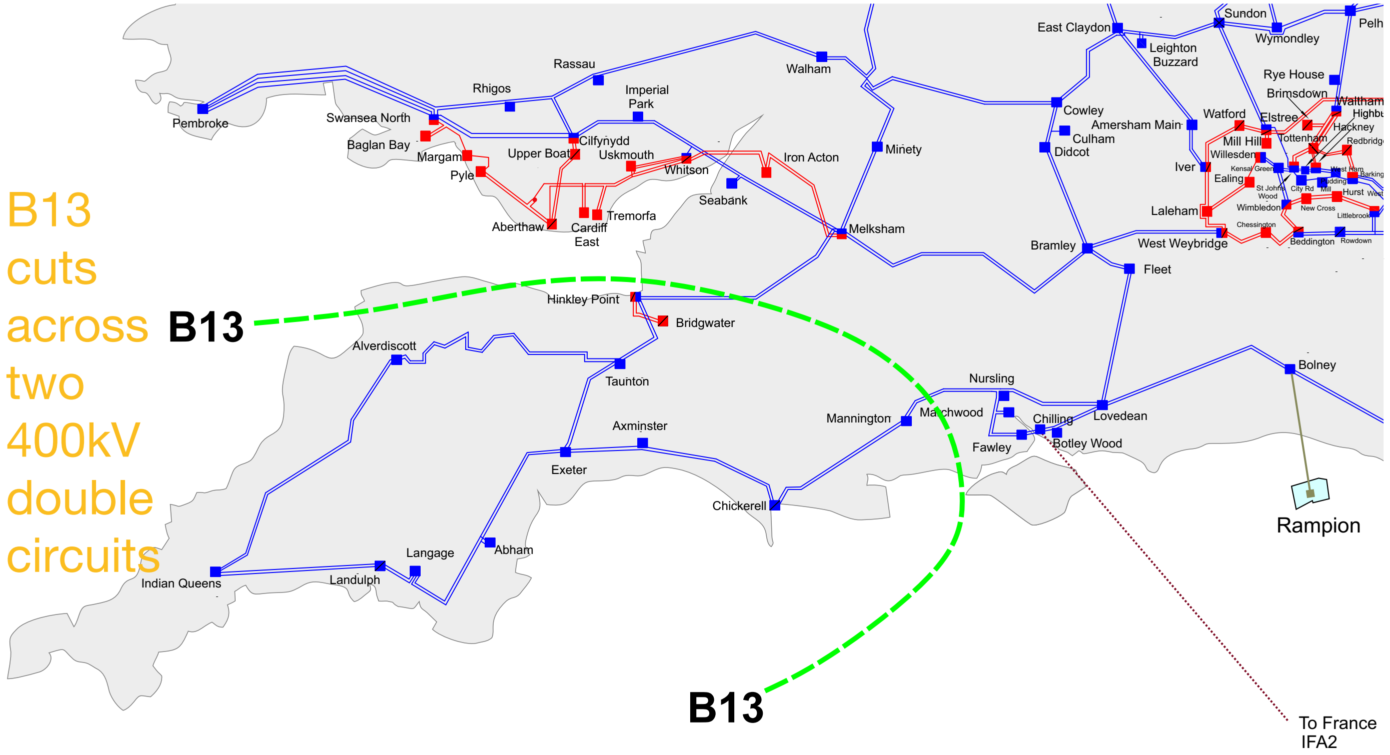
The NOA 2020/21 will assess the likelihood and impact of the above mentioned potential scenarios and accordingly recommend preferred reinforcements for the South of England transmission region

Boundary B13 – South West

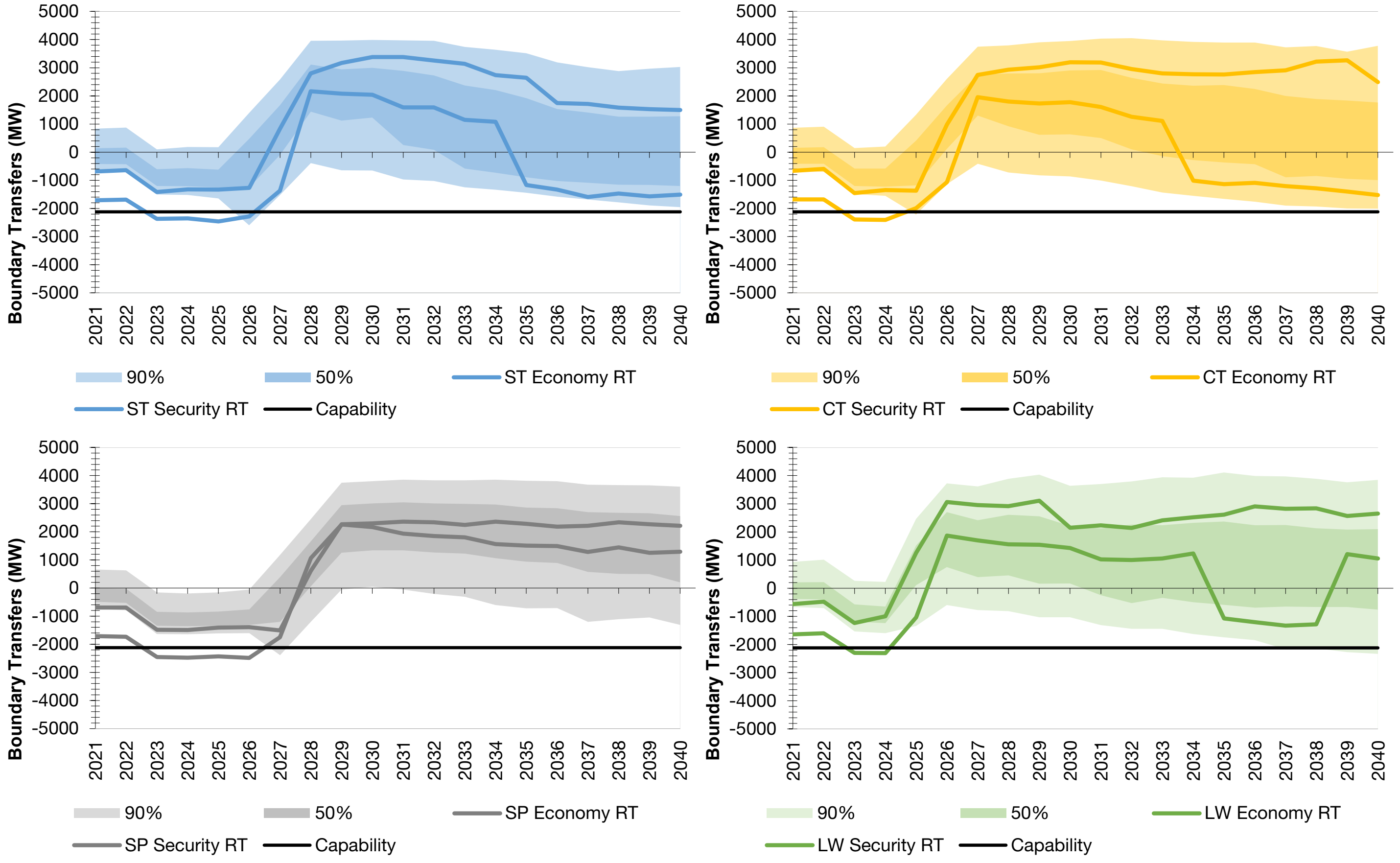
Wider boundary B13 is defined as the southernmost tip of the UK below the Severn Estuary, encompassing Hinkley Point in the south west and stretching as far east as Mannington. The southwest peninsula is a region with a high level of localised generation and demand.

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

B13 cuts across two 400kV double circuits



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.

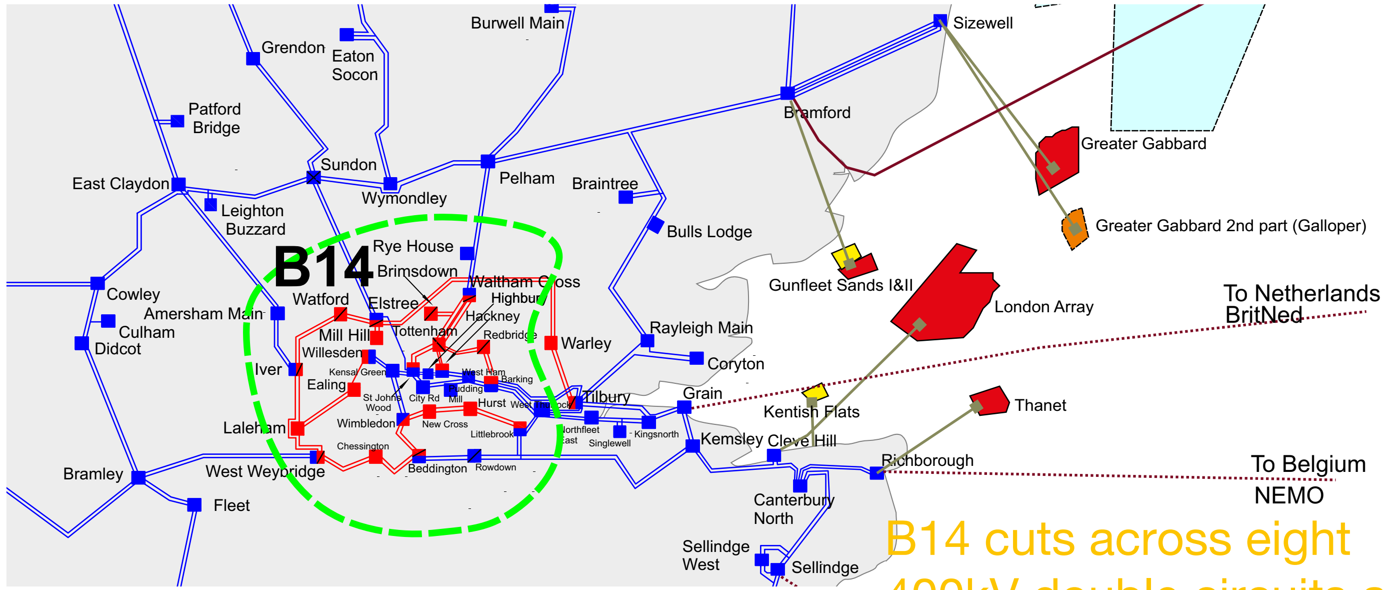


The boundary capability is currently a voltage compliance limit at **2.1GW** for a double-circuit fault on Alverdiscott–Taunton circuits causing low voltage at Indian Queens substation

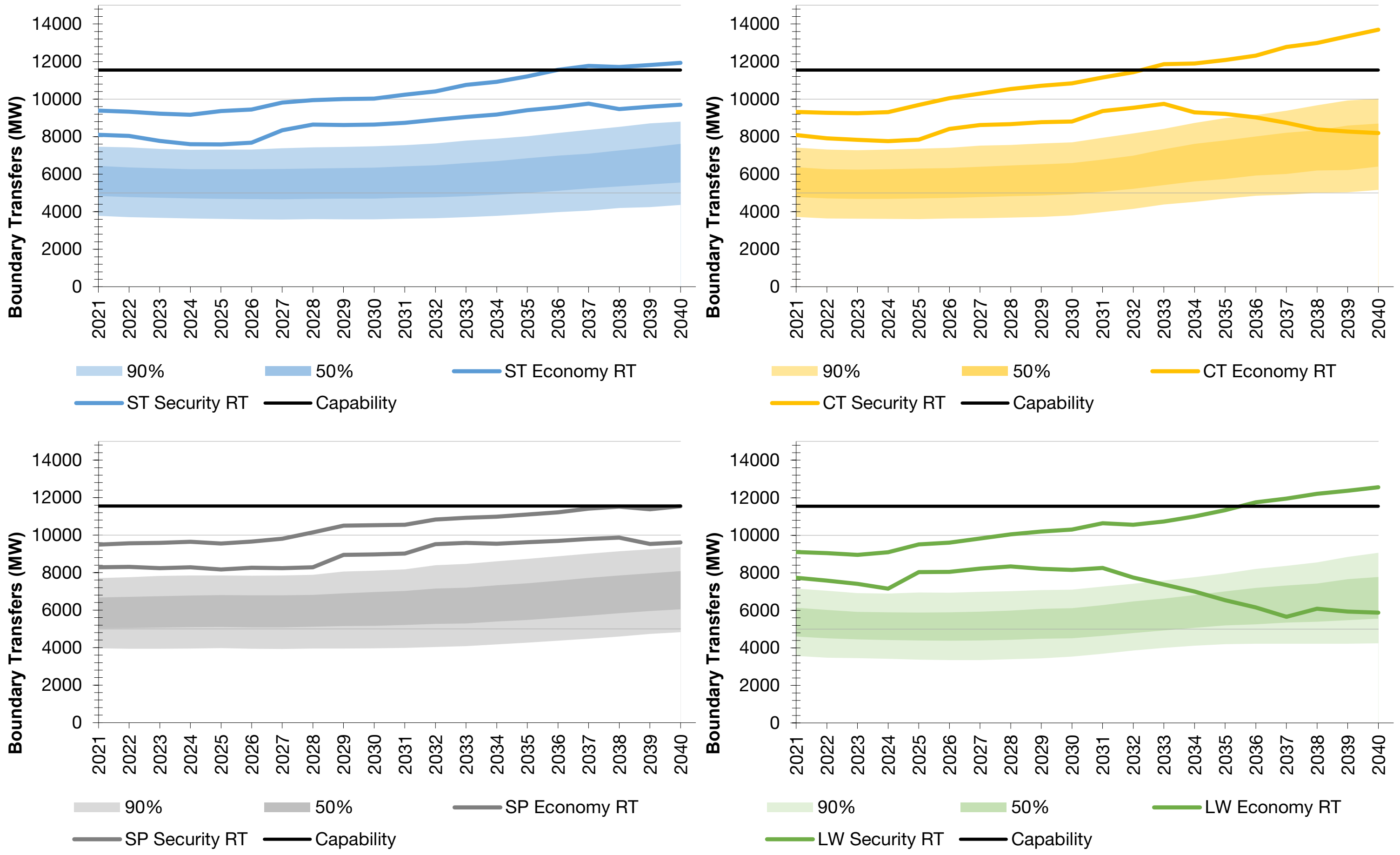
Boundary B14 – London

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.



B14 cuts across eight 400kV double circuits and a 275kV double circuit



As the transfer across this boundary is mostly dictated to 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.

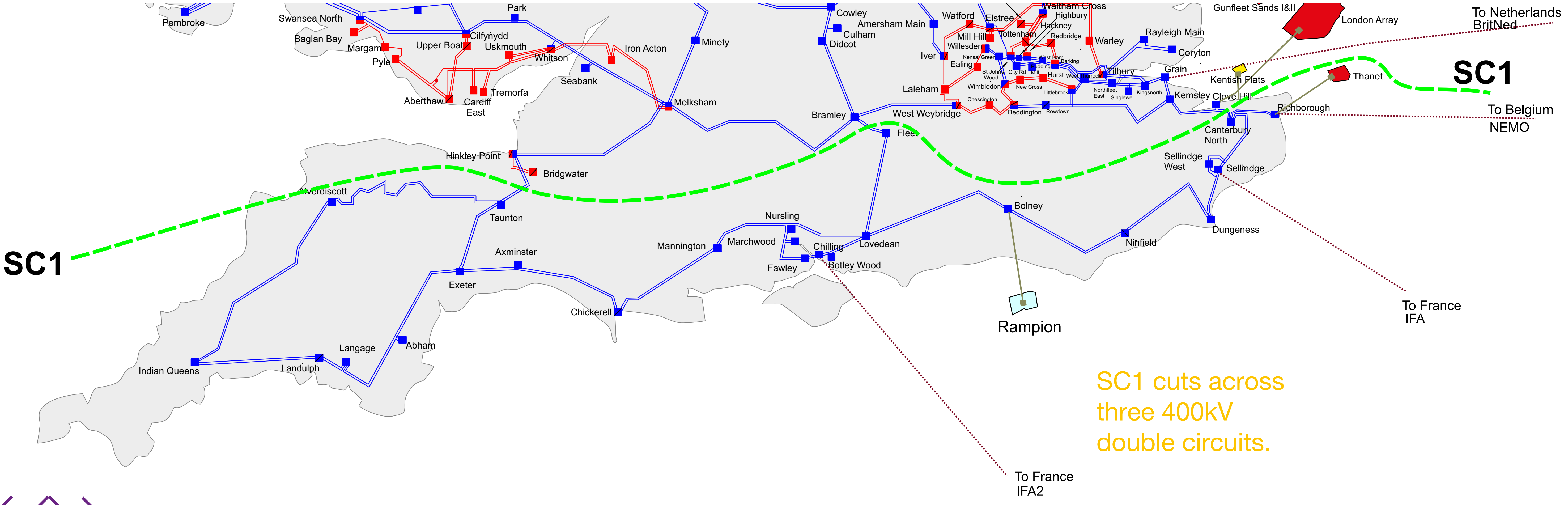
The boundary capability is currently limited by thermal constraints at 11.6GW for a double-circuit fault on the Grain–Kingsnorth and Grain–Tilbury circuits

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



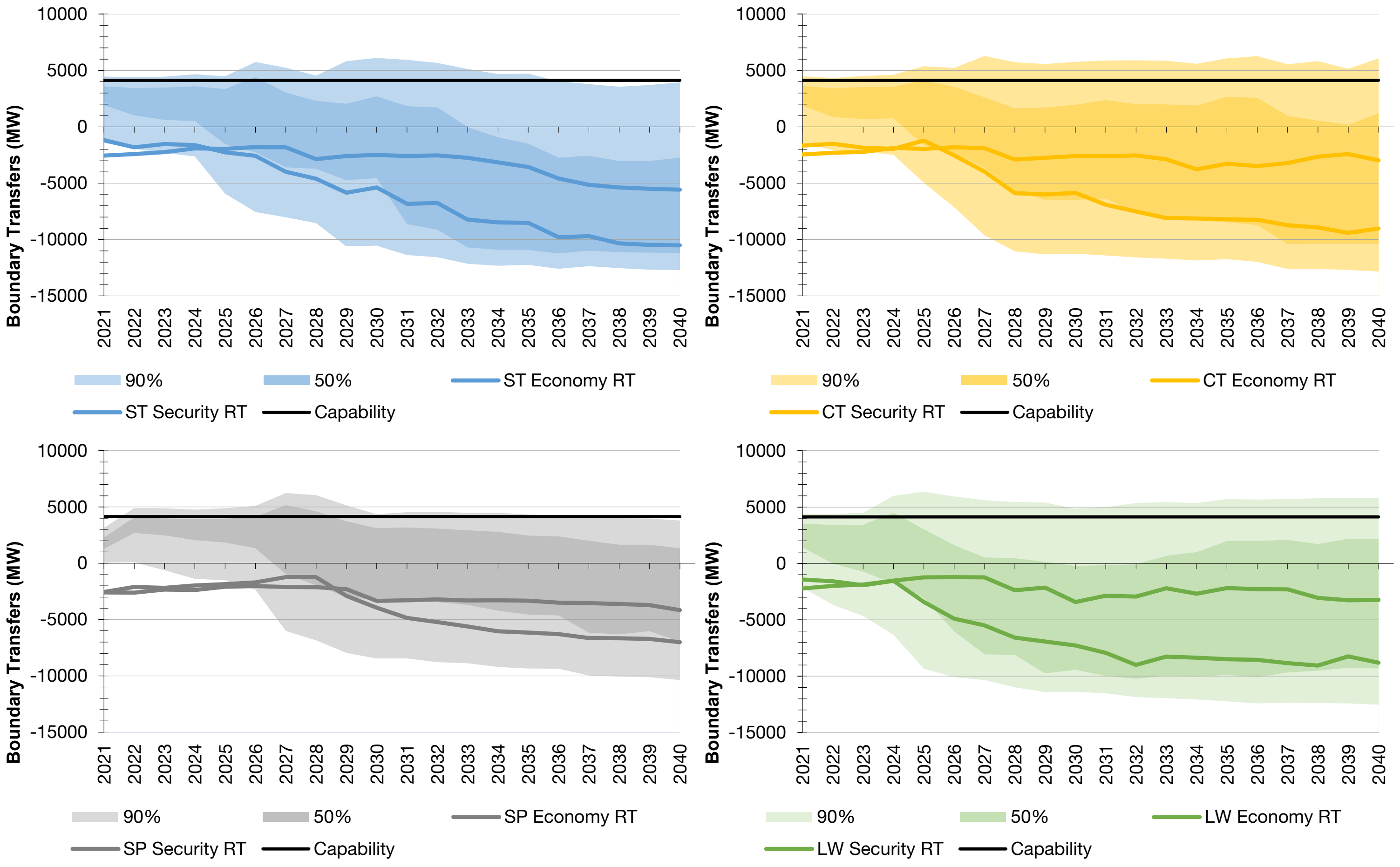
SC1 cuts across three 400kV double circuits.

Boundary SC1 – South Coast (contd.)

The boundary capability is currently limited by voltage compliance at 4.1GW* for a double-circuit fault on the Kemsley–Clevehill and Kemsley–Canterbury circuits for interconnector import sensitivity. When the interconnector is exporting, voltage collapse occurs at 6.0GW of transfer. This happens after a fault on the Bramley–Fleet double-circuit.

*Positive values represent exporting power flows out of the south east area enclosed by the boundary,

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 in around 2023. The volatility of interconnector activity can be seen in the required transfers as the requirements swing from power flow south and north.

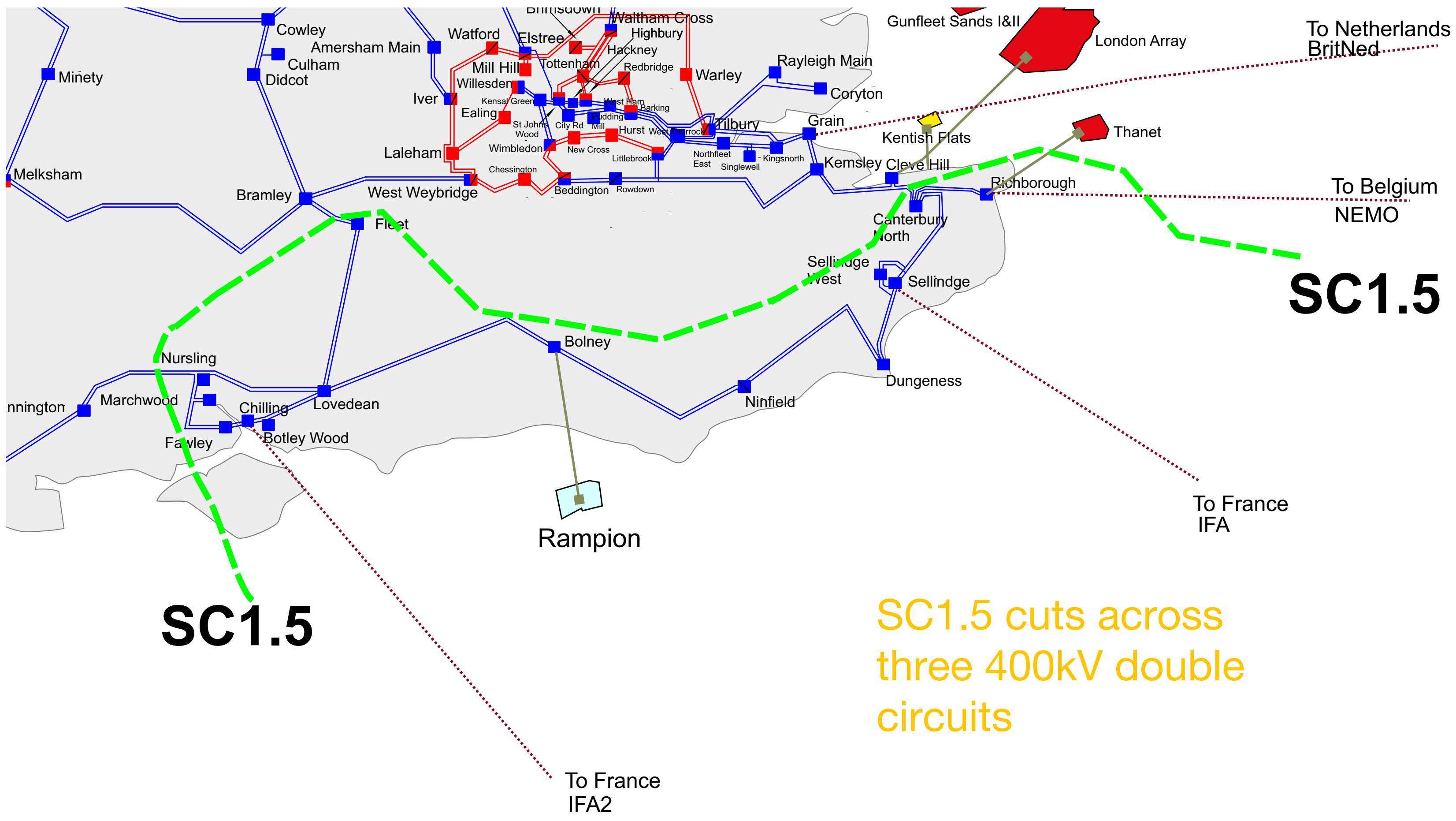
The SQSS calculation of required transfers does not place high loading on the interconnectors so the transfers are not seen to peak at very high values.

Boundary SC1.5 – South Coast

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

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

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



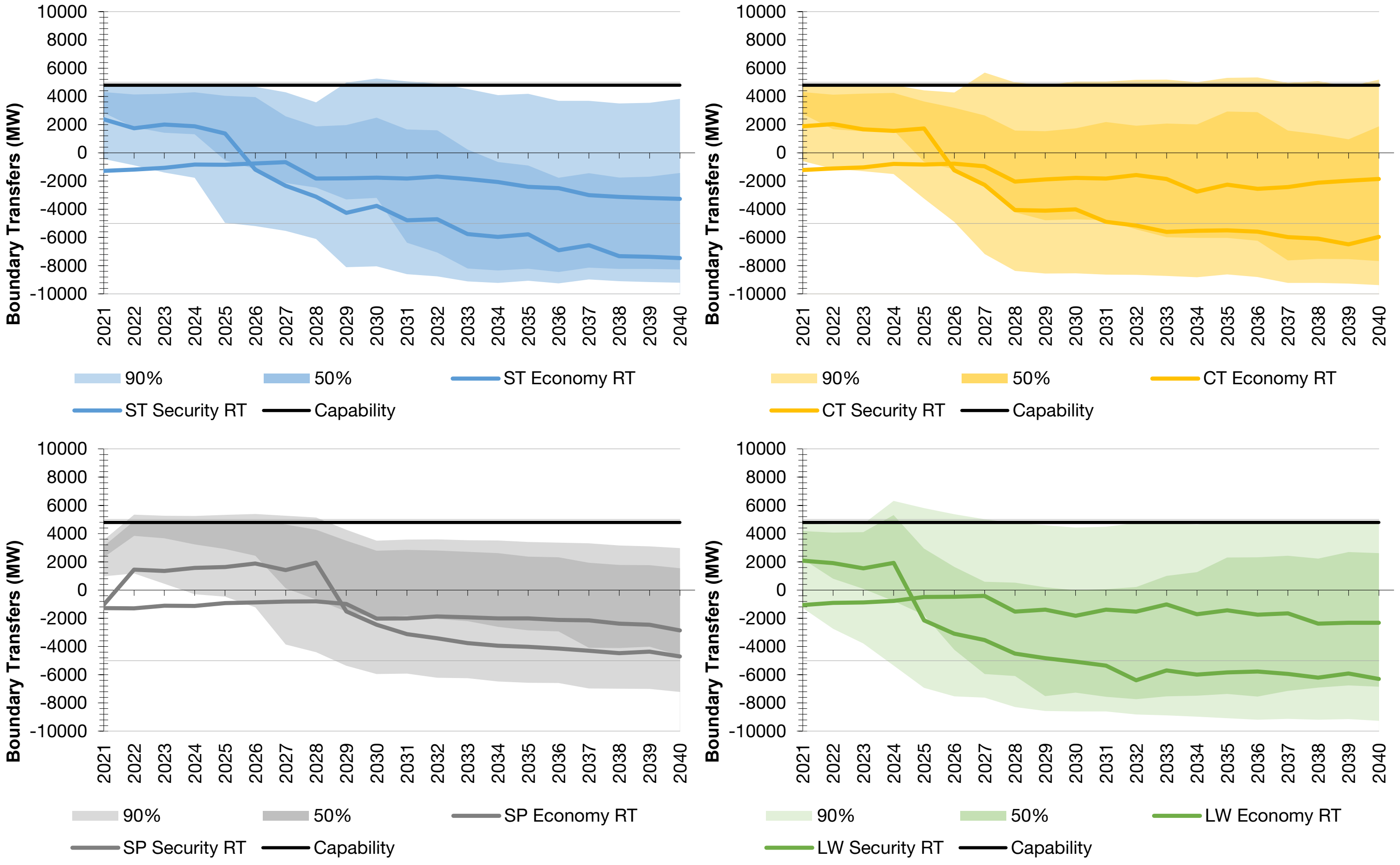
SC1.5 cuts across three 400kV double circuits

Boundary SC1.5 – South Coast (contd.)

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.

*Positive values represent exporting power flows out of the south east area enclosed by the boundary.



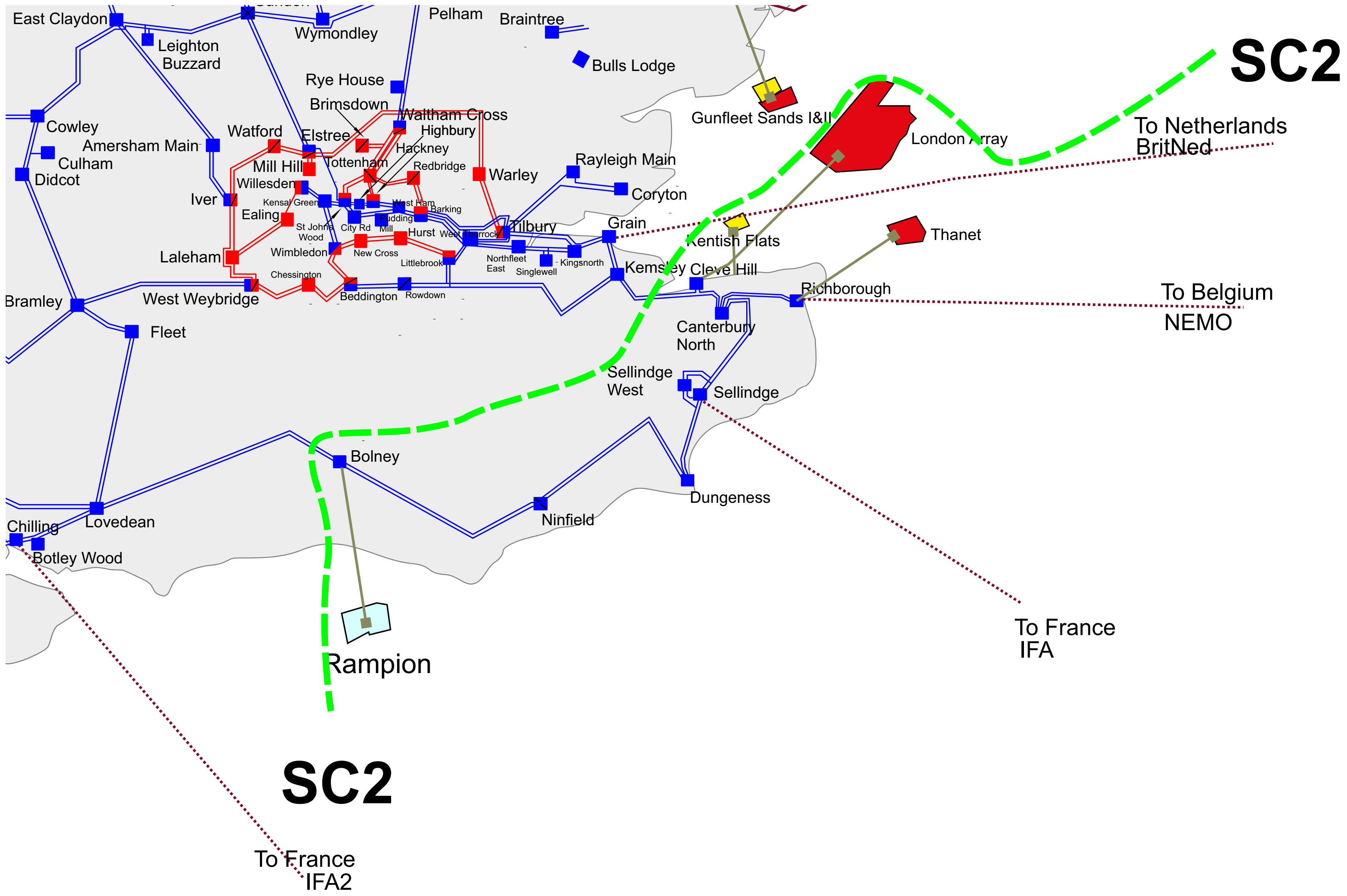
The boundary capability is currently loading limited at 4.8GW*.

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.



Boundary SC2 – South Coast (contd.)

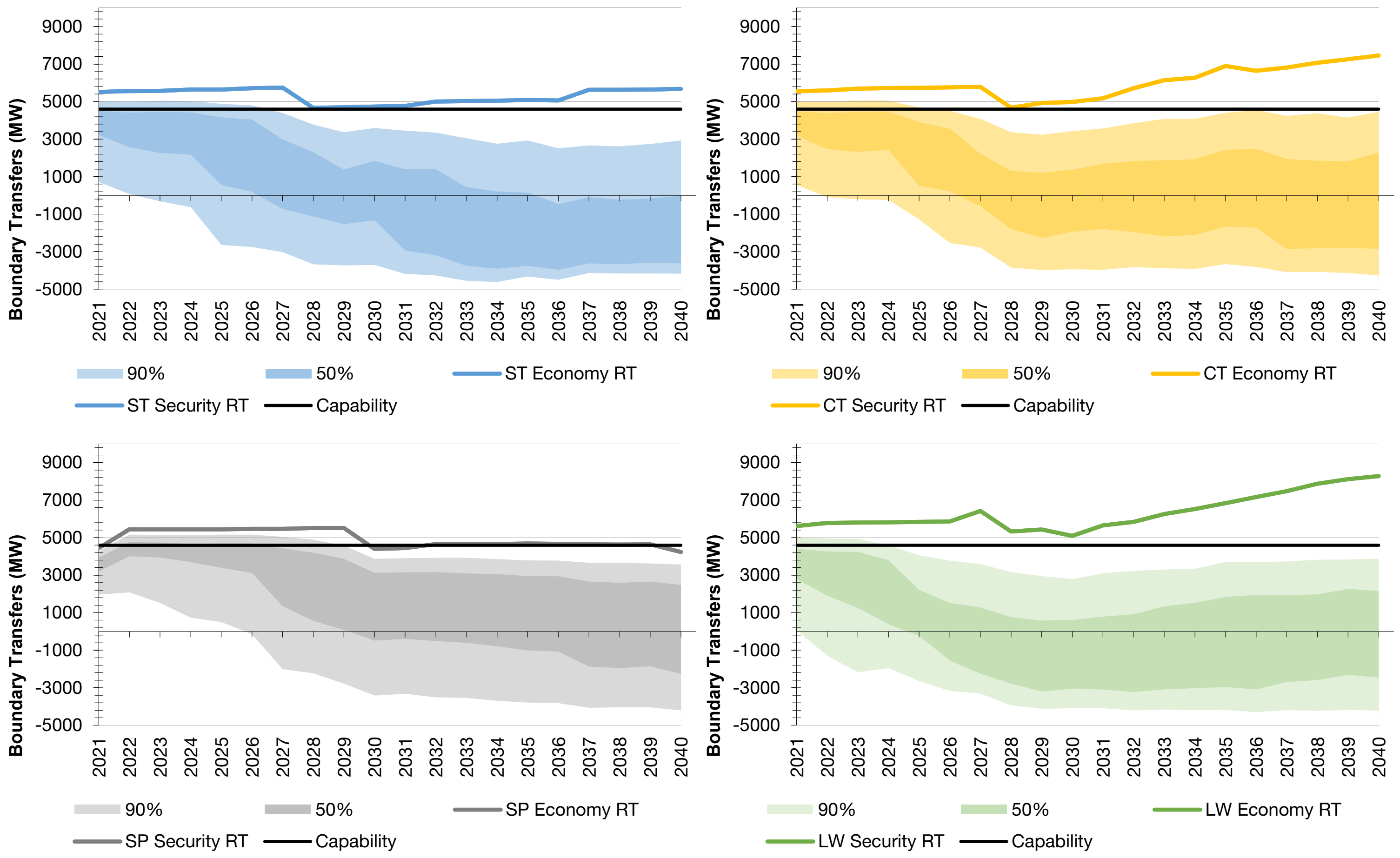
*Positive values represent exporting power flows out of the south east area enclosed by the boundary.

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.

*Positive values represent exporting power flows out of the south east area enclosed by the boundary,

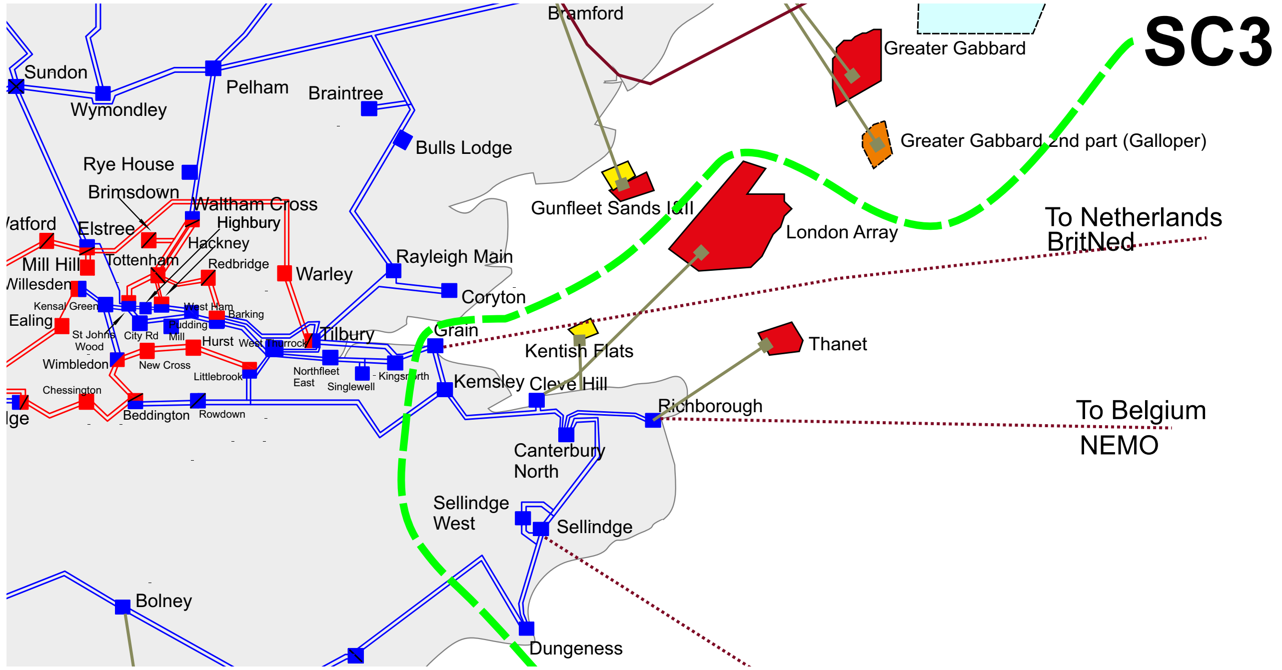


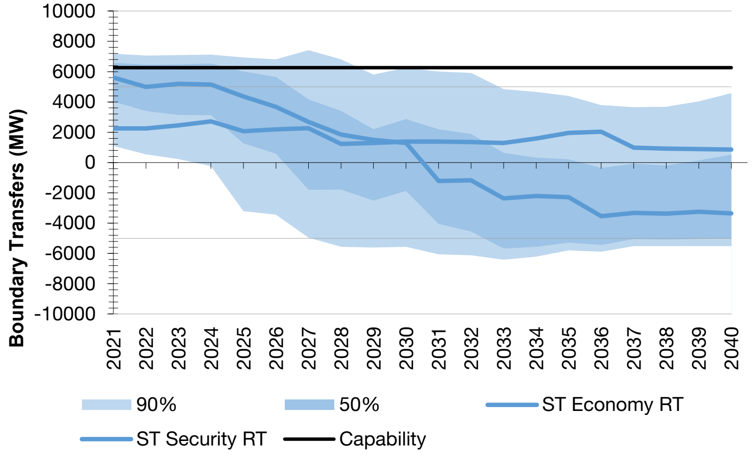
The capability for this boundary is limited by voltage compliance limit at 4.8GW*.

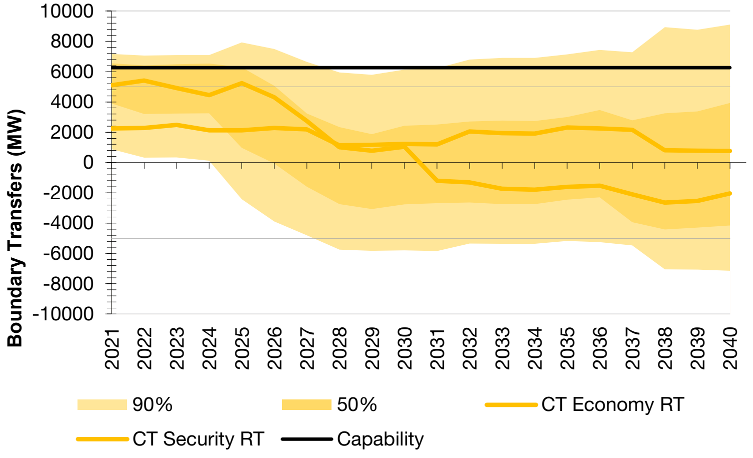
Boundary SC3 – South Coast

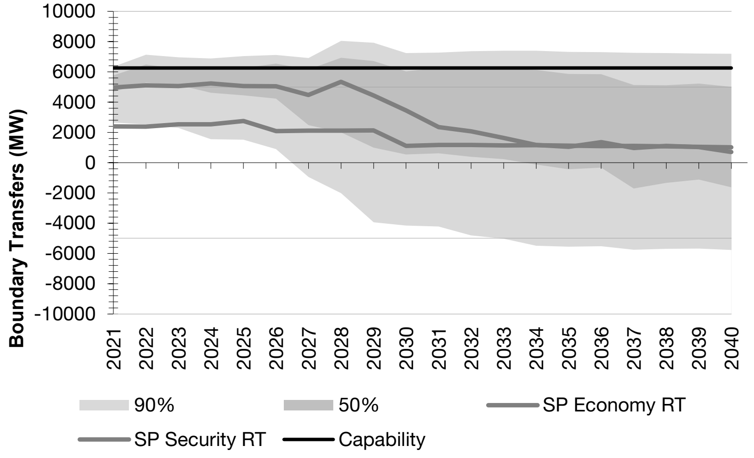
Boundary SC3 is created to capture transmission issues specifically in the south-east part of the network.

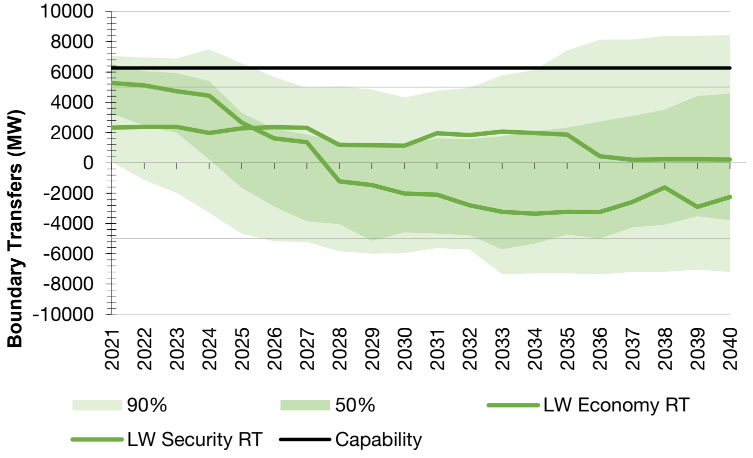
The current and future interconnectors to Europe have a significant impact on the power transfers across SC3. The current interconnectors to France, the Netherlands and Belgium connect at Sellindge, Grain and Richborough respectively.











The current and future interconnectors to Europe have a significant impact on the power transfers across SC3 with their ability to transfer power in both directions.

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 boundary capability is currently limited by thermal loading at 6.2 GW for a double-circuit fault on the Grain–Tilbury–Kingsnorth circuits

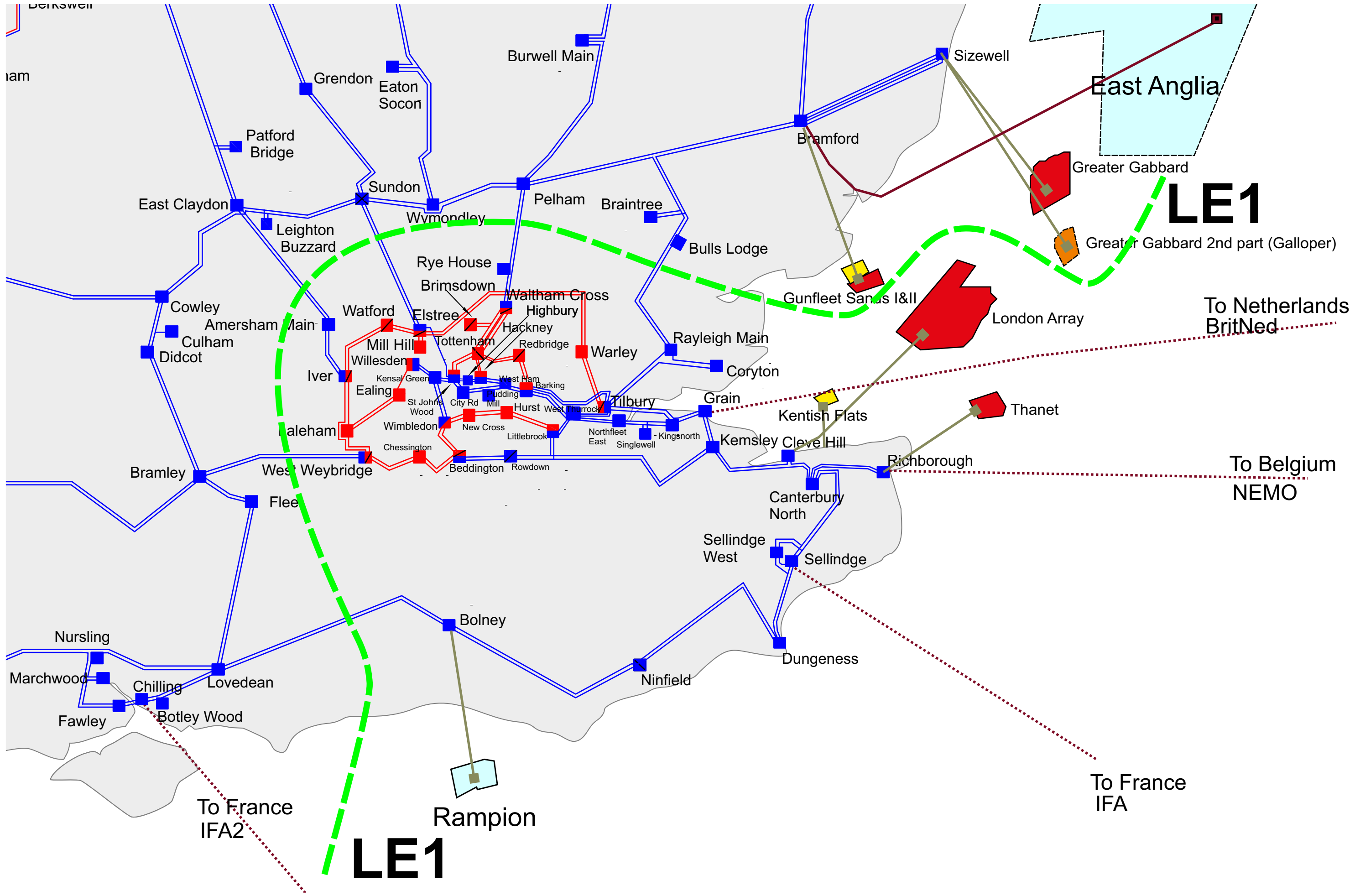
Boundary LE1 – South East

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

LE1 is characterised by two distinct areas. Within London, there is high local demand and little generation. The remainder of the area contains both high demand and high levels of generation.

In particular, there are a number of gas power generators in the Thames estuary area and an interconnector to the Netherlands, while connected to the south east coast are a number of wind farms, interconnectors to France and Belgium, as well as nuclear and gas power stations.

LE1 almost exclusively imports power from the north and west into the south east, and the purpose of the boundary is to monitor flows in this direction. With the existing and proposed interconnectors importing power from the Continent, power flows enter London from all directions, to the extent that flows across LE1 reduce and limited constraints are seen similar to those by B14 on the south coast boundaries.

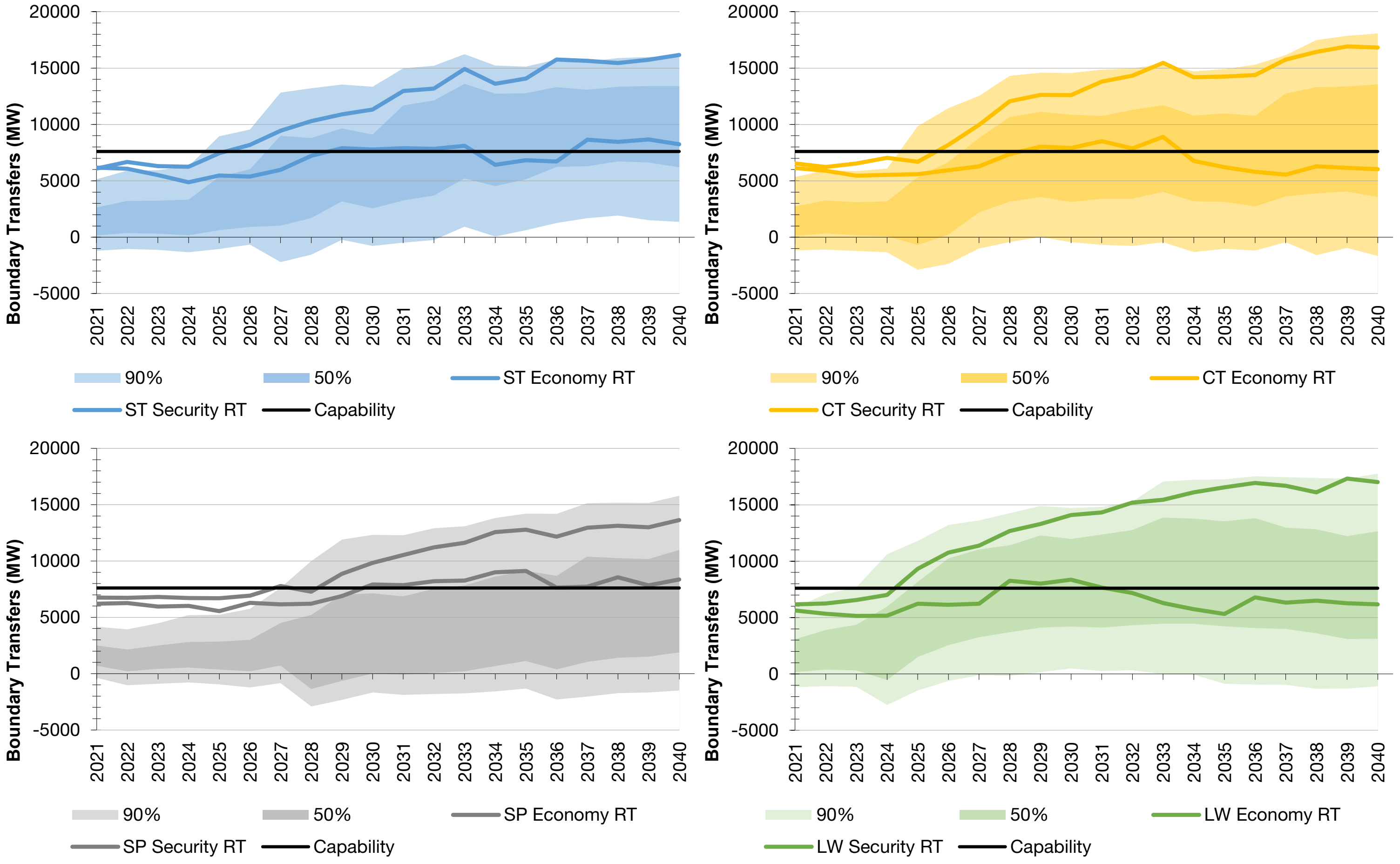


Boundary LE1 – South East (contd.)

However, with increased number of interconnectors, and (in some scenarios) increased likelihood of them exporting power in future years, LE1 can become a high 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



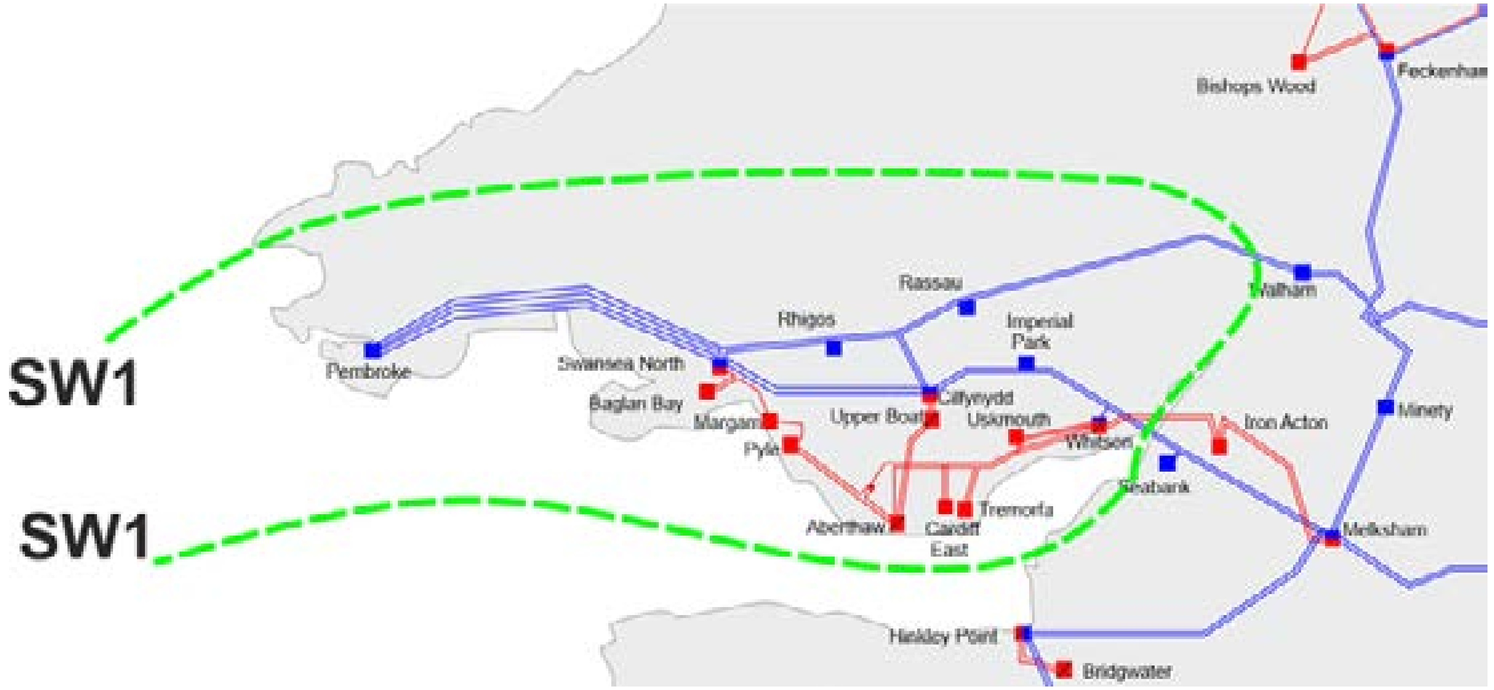
The boundary capability is currently limited by thermal constraints at 7.6GW with overloads of the Rayleigh Main–Tilbury circuit

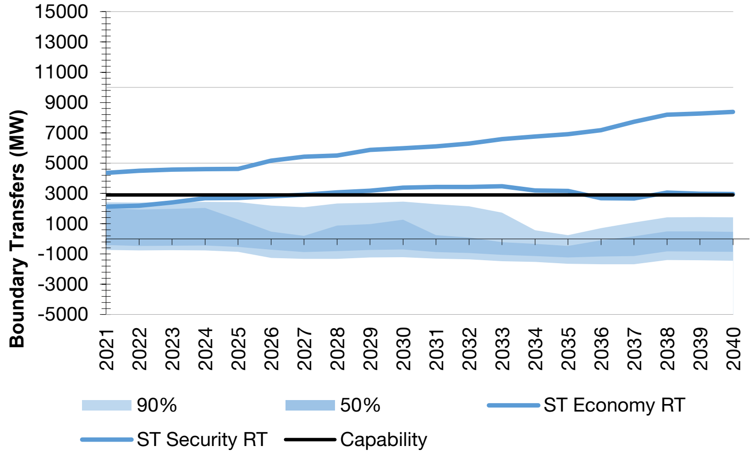
Boundary SW1 – South Wales

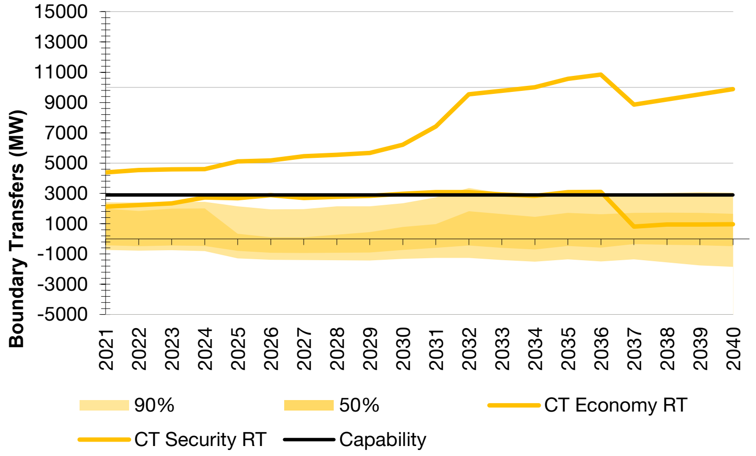
Boundary SW1 encloses South Wales is considered a wider boundary.

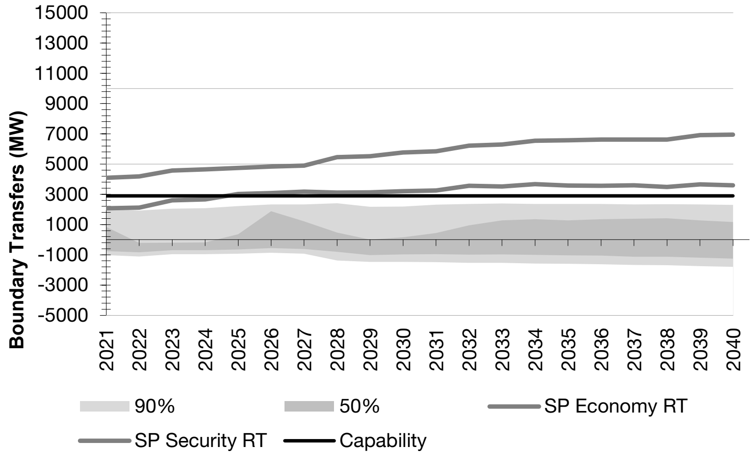
Contained within the boundary is a mixture of generation types including gas combined cycle, coal, wind and solar. Some of the older power stations are expected to close but new generation capacity is expected to connect, including new generators powered by wind, gas, solar and tidal.

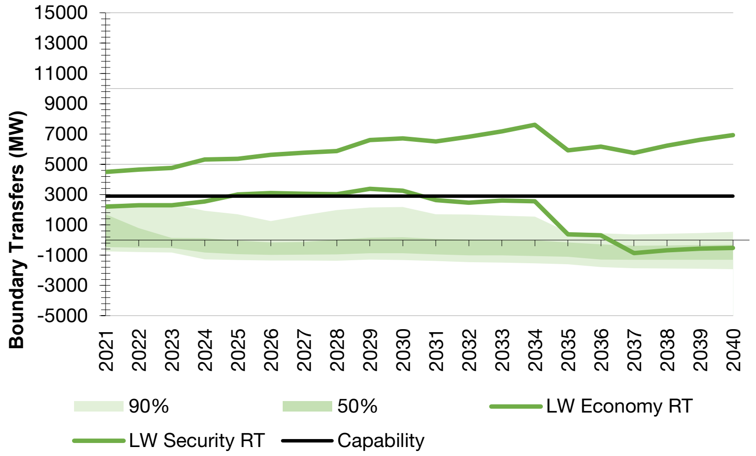
South Wales includes demand consumptions from the major cities, including Swansea and Cardiff, and the surrounding industry.











The SQSS boundary requirements are higher than the boundaries present boundary capability but the majority of the expected power flows stay within the capability. Therefore some constraints can be expected and some additional boundary capability may be beneficial.

The capability of SW1 is 2.9 GW which is restricted by thermal limits caused by the Imperial Park - Melksham circuits

Year round probabilistic analysis

Introduction

The flows on the system over the next 10 years are uncertain. This is caused by a range of generation sources that can be variable and intermittent within the different boundaries presented in chapter 3. When high wind, solar and other embedded sources are at their peak output at the same time, it can lead to severe network constraints and in some cases, this can be very expensive.

Probabilistic analysis looks at year-round conditions. It captures more snapshots, building on what we already do in the previous Chapter 3, by assessing many generation and demand background conditions that the system could face.

This could lead to more informed network investment and operational planning decisions, by considering the potential risk and the cost involved to mitigate it.

In ETYS 2019, we showed how the probabilistic approach can provide more information on the transmission network's requirements and performance. This year, we have extended this and our tool capabilities to now include:

- power flow control devices such as Quadrature-Boosters (QB)
- optimisation techniques, for setting of these devices for both pre-fault (preventative) and post-fault (corrective) conditions
- an improvement to our statistical analytics
- addition of data mining capabilities to help us understand year-round requirements, drivers, and opportunities.

We are also exploring the development pathway for our probabilistic tool and in future publications we will showcase some improvements that we hope to implement.

With probabilistic analysis we can understand the likelihood and the impact of the constraints from the uncertain flows on the transmission system.

We're working with academia to understand how use this analysis this under the many generation and demand scenarios that could happen across a year. We're hoping this allows us to investigate a broader range of options that could improve year-round boundary performance. We'll provide more detail in the case study section of this chapter.

How do we do this?

The analysis looks at year-round conditions and we can identify the most likely conditions that the system must be able to accommodate, as well as some rare extreme conditions.

Although these rare conditions may only occur for a relatively short duration over a year, it is important to understand the additional requirements that such an outcome would impose on the NETS.

1. Prepare snapshots

2. Identify “acceptable” and “unacceptable” operating conditions

3. Determine any additional year-round system needs

4. Assess various options to address requirements

1. Prepare snapshots

We start the analysis by looking at a snapshot of the system and seeing what generation, demand and assets are connected on the system at that time. From this, we can see what is happening on the system, what constraints are active and the drivers behind them.

For example, if we were looking at a snapshot of a summer afternoon, we could see large amounts of embedded solar with minimal demand on the system and identify what constraints are reaching their limit.

Similarly, if we were looking at a snapshot with a large amount of wind generation instead we could see if different issues arise on the system as a result.

In our analysis we look at 10 different snapshots for every hour, which represents approximately **87,600** scenarios across the course of the year

2. Identifying acceptable and unacceptable outcomes

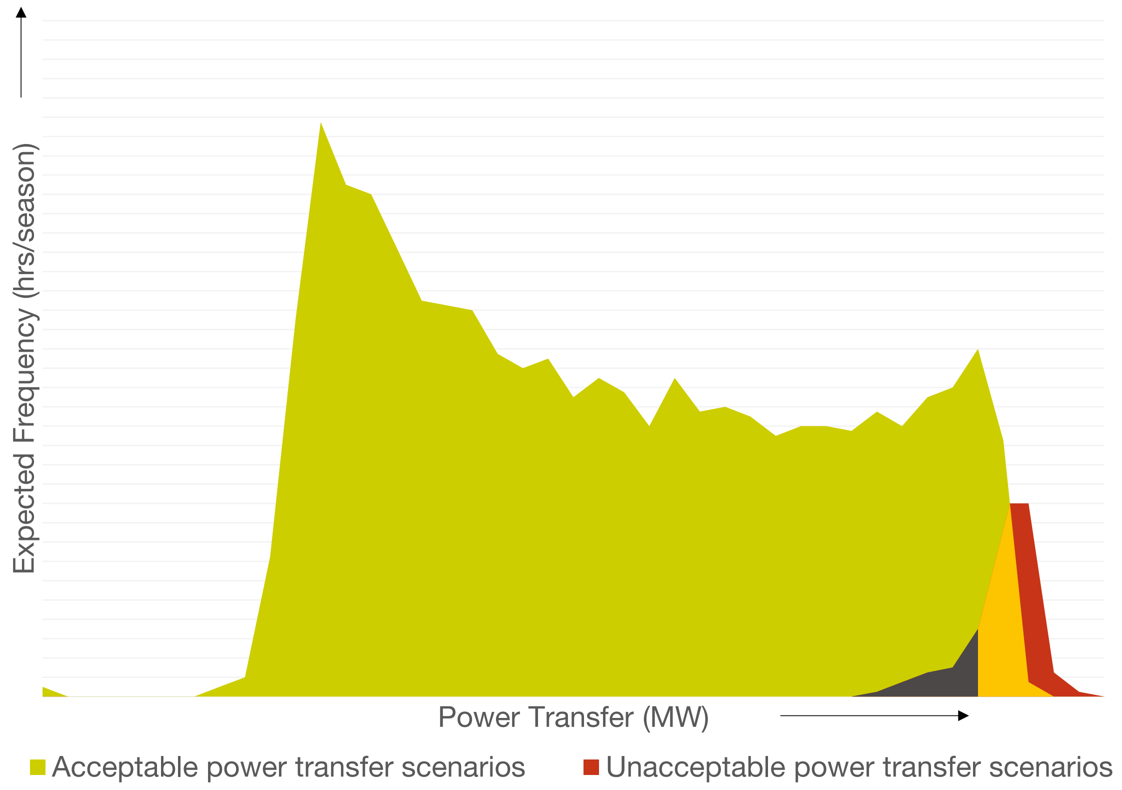
An “acceptable” outcome is where the network does not see any thermal overloads after a credible fault has occurred in a snapshot or a scenario and an “unacceptable” outcome is when the network sees at least one thermal overload after a credible fault condition has been applied to the network.

To identify acceptable and unacceptable outcomes, we assess many power transfer scenarios across a boundary, based on how likely it is to occur and then summarise this in a probability distribution chart on the right.

From the graph, the blue line shows the number of acceptable outcomes that have occurred, and the red line shows the number of unacceptable outcomes for a particular level of power flow.

We can also break the graph into a few regions:

- green - unrestricted – no issues
- black - within boundary capability limits (from Chapter 3) but we see some unacceptable outcomes in certain rare scenarios. The scenarios are rare enough that, there would be a low likelihood having this scenario on the system in a year
- amber – above boundary capability limits (from chapter 3) and relatively higher likelihood for an unacceptable scenario. At this point, the event is manageable but more severe than the black region; constraints in this region may last for moderately low durations with a rare chance of seeing constraints of high magnitudes.
- red – when power transfer is not possible without further investment. This is because attempting to transfer power within this range is likely to result in constraints that last for very long periods as well as of very high magnitude.



So, we can see that at a low power flow, it is more likely that we have more acceptable scenarios where the power flows are low. When we increase the power flow, there is a combination of acceptable and unacceptable scenarios. The unacceptable conditions will need to be managed through action should they occur and there could be an opportunity to propose solutions to manage these conditions economically and efficiently in planning timescales.

The objective is to find ways to make the green shaded area bigger and reduce the amber region (where there are partial restrictions to transfer power).

To turn the amber region green, we might need a range of additional capacity. If the duration of additional capacity is short, it may be possible to consider solutions that last for a short duration such as flexible-generation dispatch actions. We call this non-network solution. We can also consider network build solutions and compare them to non-network solutions to find the one better suited to resolving the issues.

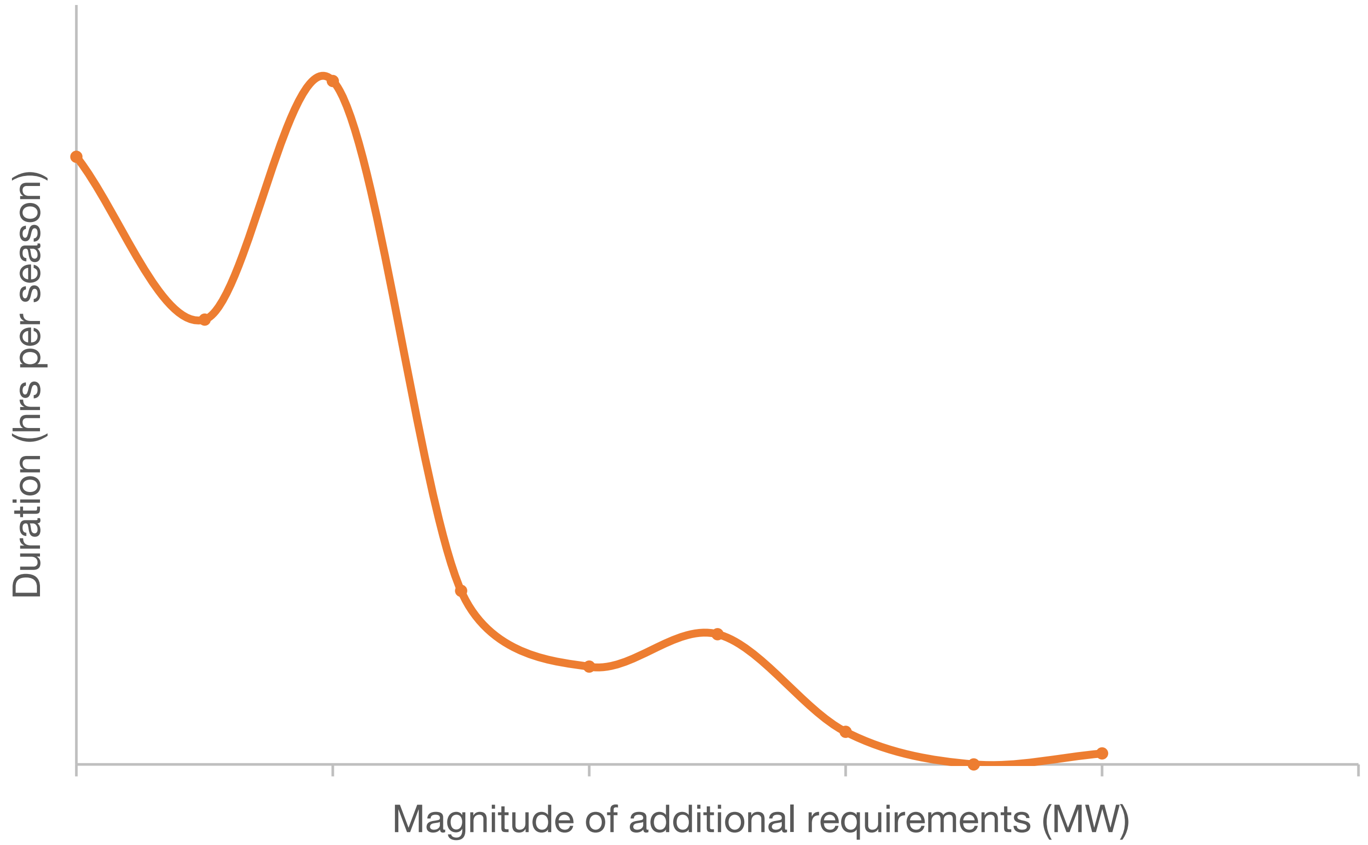
3. Determine any additional year-round system needs

Classifying the shaded regions in the previous step gives us an understanding of a boundary's year-round transfer requirements. To better understand the regions, we introduced a new term - Boundary Congestion Probability (BCP).

The BCP is a ratio between the non-green and green region (from step 2). If the value of the BCP is small, it tells us that, generally, boundary congestions will be experienced for short durations and conversely if the value of the BCP is too high, it tells us that a boundary could be congested for longer durations.

This information means we can choose a BCP value and use it to define specific boundary requirements. Defining requirements this way helps us to see the potential and the need for more solutions beyond the deterministic capability of the boundary.

We could also look at the size of the additional capacity and how long it would be needed to overcome the constraint. We've plotted this on the right to show how additional requirement may vary throughout the year.



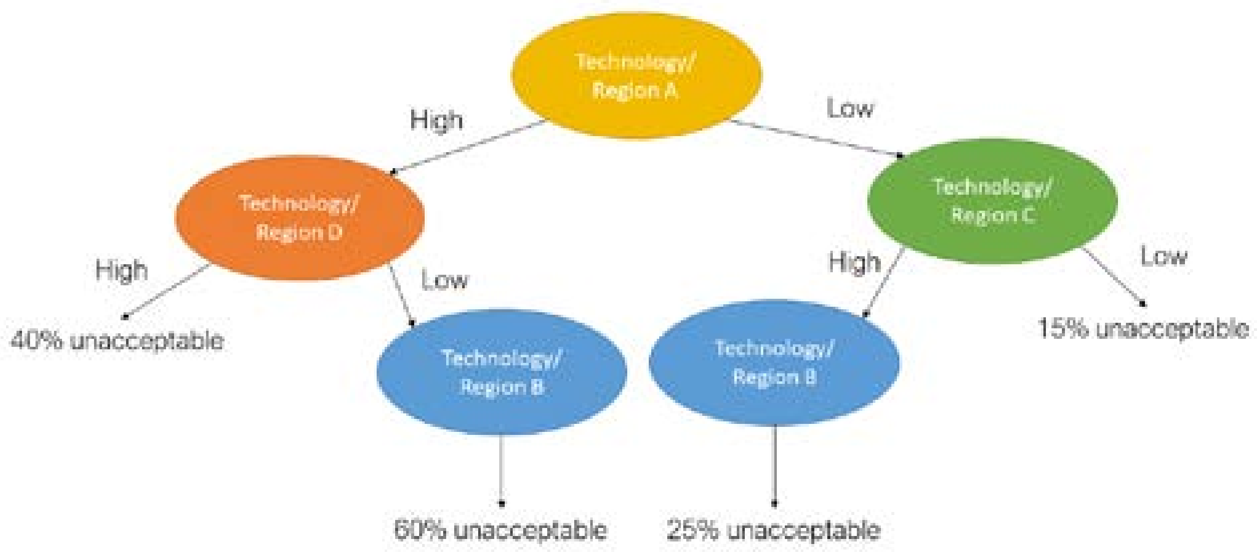
4. Assess various options and address requirements

We've used the "standard classification and regression tree" technique or the CART analysis method to understand the size and the duration of a constraint.

The CART method follows a data mining process to identify key dispatch conditions that may influence the likelihood of an unacceptable outcome within the shaded overlapping region, in the earlier plot.

We classify the key dispatch conditions by either technology type or region and use a binary high/low dispatch output criteria to understand dispatch conditions around the boundary that generate the lowest probability of an unacceptable outcome.

This is illustrated in the diagram on the right where the technologies in region A and C produce the lowest probability of an unacceptable outcome compared to the combination of outcomes from technologies in regions A, D and B that results in a higher probability of an unacceptable outcome.



By analysing the diagram, as an example, we can see that it is more desirable to operate the network with technologies from region A and C than from D and B to lower the probability of achieving an unacceptable outcome.

For example, technology 'A' of a given capacity placed in region 'X' of the boundary can be more useful to alleviating congestion than technology 'B' of a given capacity in region 'Y'. However, effectiveness is one factor amongst many, such as availability and cost. We are developing our analysis and techniques to calculate effectiveness outcomes from various technologies and locations to have a better representation of the magnitude of additional requirements.

Therefore, we can show which regions or dispatch combinations can assist in lowering the outcome of an unacceptable transfer across the boundary and thereby lowering the BCP index—which as earlier stated measures the % of time in a season/year the boundary experiences congestion.

Thermal Probabilistic Case Study – Winter Season

We're seeing diverse generation mixes connected to the GB transmission network. These generation technologies are spread across the network and driven by differing uncertain inputs for which we apply a probabilistic season-round winter analysis.
In this case study, we're primarily concerned with understanding winter season-round operating requirements.

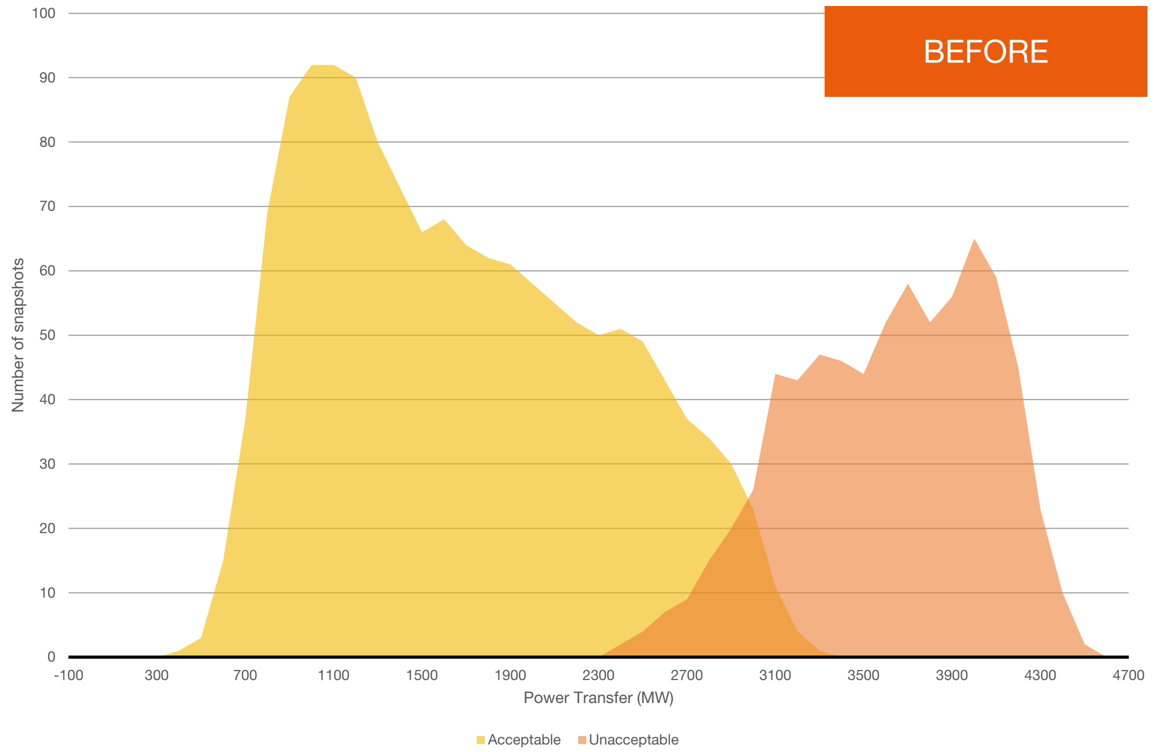
To capture the requirements, we've collected hourly historical data of:

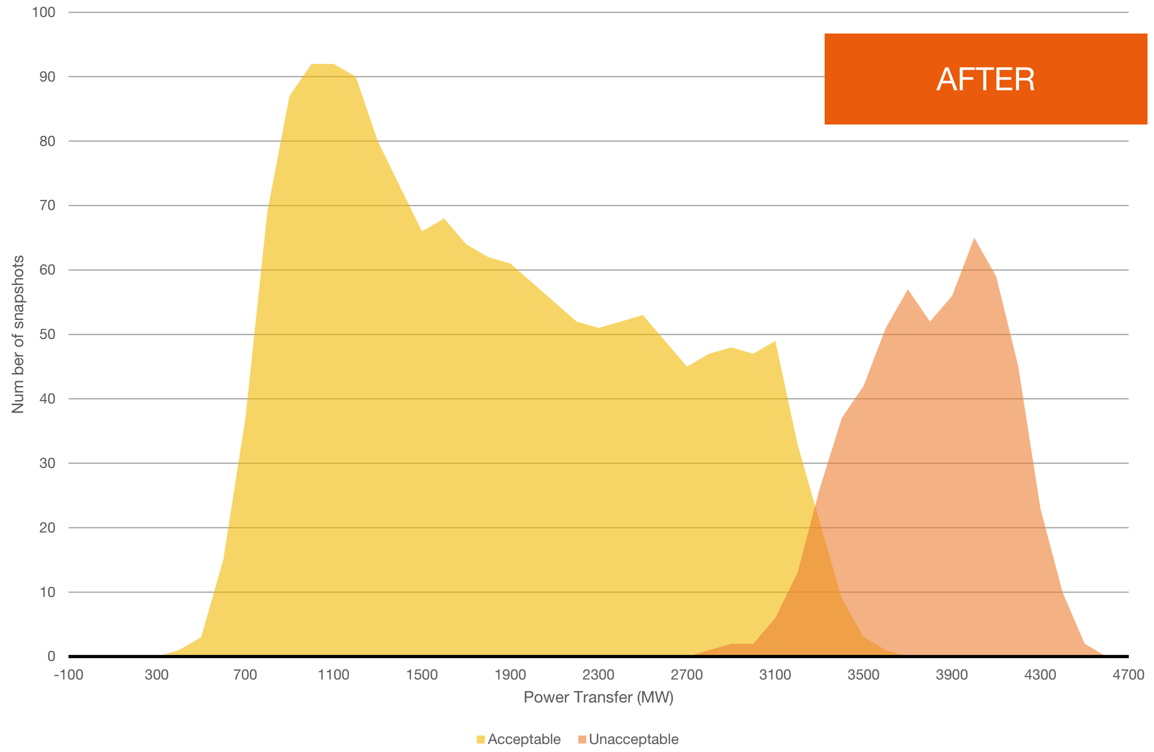
- regional wind
- solar profiles,
- plant availability (both forced and random outage data),
- hydro and pumped storage typical loading patterns. We've applied this data to reflect our winter conditions.
- using our modelling of the European market dispatch we've generated typical interconnector dispatches as well as energy storage charging and discharging cycles.

Like last year, we have validated our probabilistic approach by comparing our generation and demand dispatches against the historical data input. While this is internally verified, we cannot publish these results due to the risk of exposing third party confidential information.

For our winter analysis, we generated around 22 000 scenarios of generation and demand dispatches. From this, considering both intact and contingencies network conditions, we produced around 100 000 network flows, on average, per individual boundary.

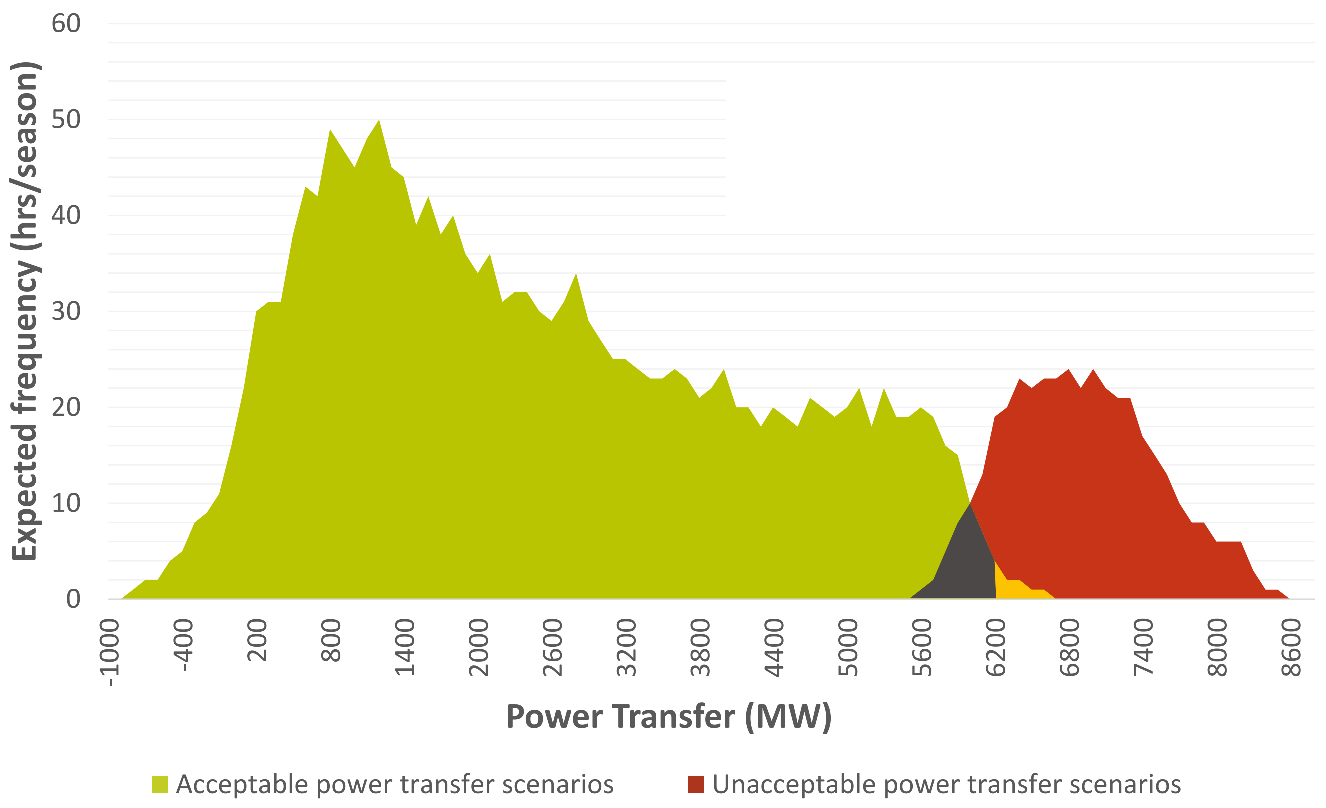
Following last year's publication, we've improved on our network analysis by applying pre- and post-fault actions using power flow control devices (e.g., QB) in addition to 6hr post-fault rating and HVDC flow control. These represent the types of actions already taken in operational timescales to maximise network capability. The graphs on the right show the effect before and after the improvements were made. We see that without applying pre- post-fault actions the network begins to see unacceptable outcomes at around 2400MW. After pre- and post-fault actions are applied we see unacceptable outcomes starting to arise at around 2800 MW.





Example Case: B6

To show you how this might work practically, the following section presents results from using probabilistic analysis on the B6 boundary.

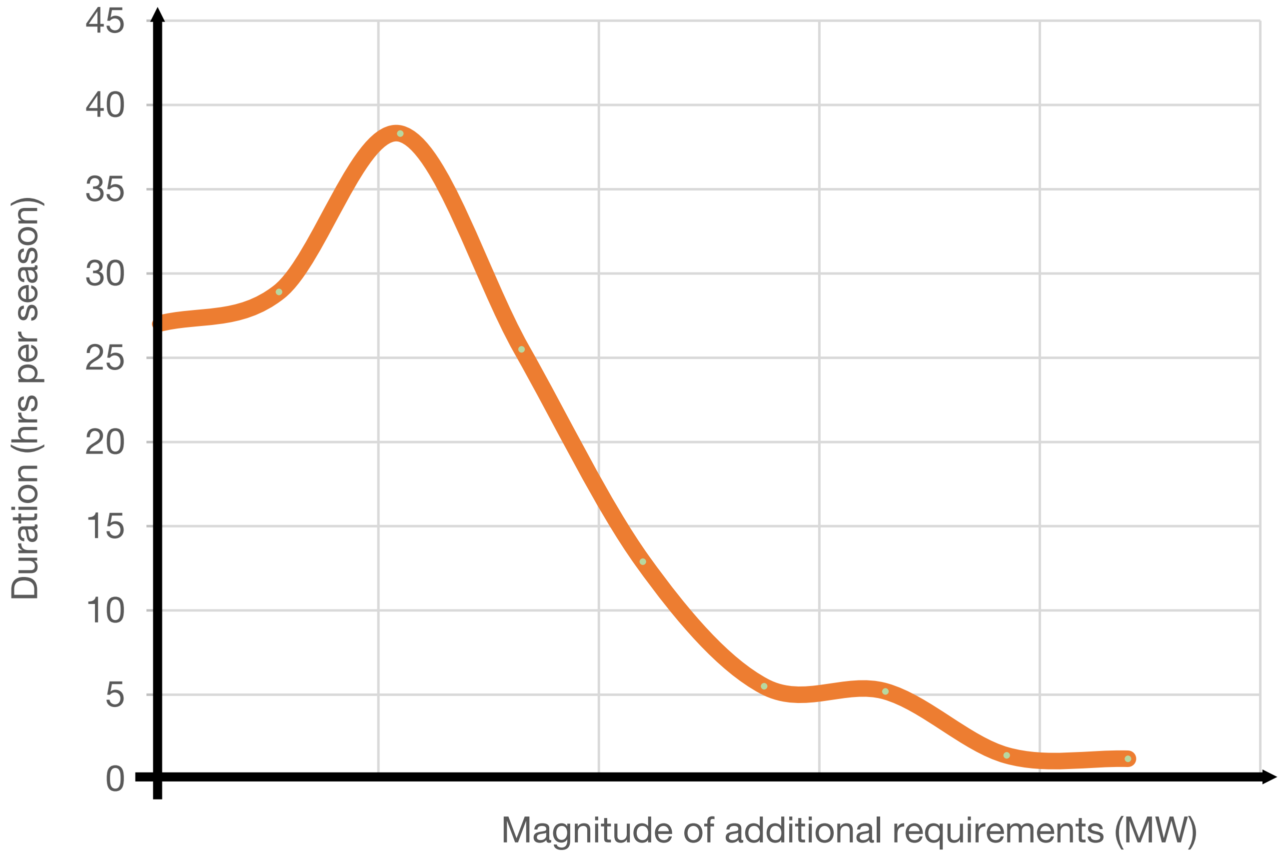


On the graph above, we can see that the black region, the area in which an unacceptable outcome was present below the boundary capability limit, covers the overlap between plots almost entirely. The black region equates to a BCP index of 6.66% or 145.9 hours. To turn this region green, solutions providing additional capacity for that duration need to be considered.

Identifying additional requirements is not limited to just the black region only. We can see from the acceptable plot that there is potential for increasing power transfer beyond the peak capability level, however doing so will increase the BCP index accordingly due to the unacceptable outcomes increasing.

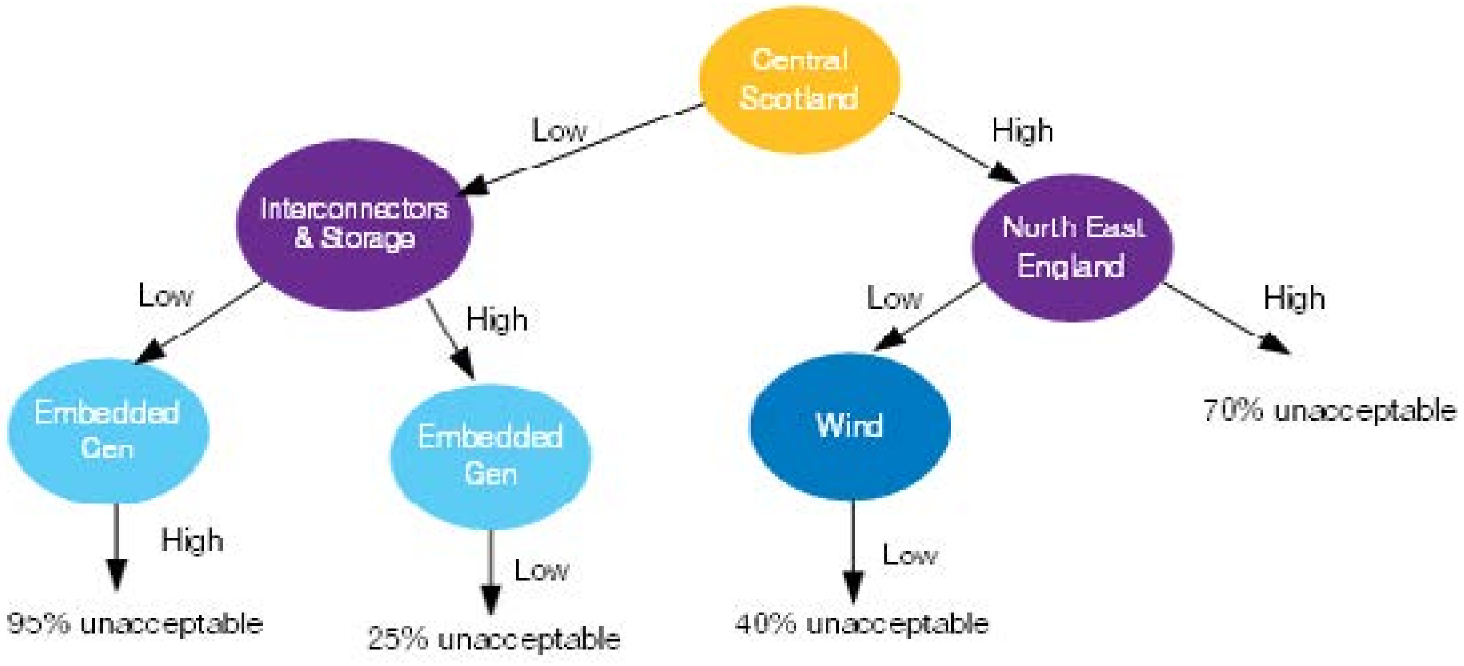
By evaluating BCP values beyond the boundary capability limit we can consider new opportunities for solutions and evaluate whether it may be more appropriate to use a solution that provides short duration capability rather than year-round capability or a combination of the two.

The graph below shows how the BCP index will be distributed between duration and capacity. For boundary B6, we can see that no single magnitude will exceed a duration of 40 hours when transferring power at a time.



Example Case: B6 (continued)

To better understand how certain network conditions influence the probability of an unacceptable outcome, we can look at scenarios on a CART diagram.



When the network sees embedded generation output across the North East of England and Central Scottish regions, there is the lowest probability of an unacceptable power transfer outcome across B6. On the contrary the highest chance of an unacceptable transfer outcome occurs when there is high embedded generation output coupled with low wind from Central Scotland and low interconnector and storage output around the B6 region. This analysis allows us to identify solutions to accommodate additional requirements to securely transfer power across the B6 boundary.

We've done this similarly for boundaries B2 and B4 and their results are summarised in the table on the right

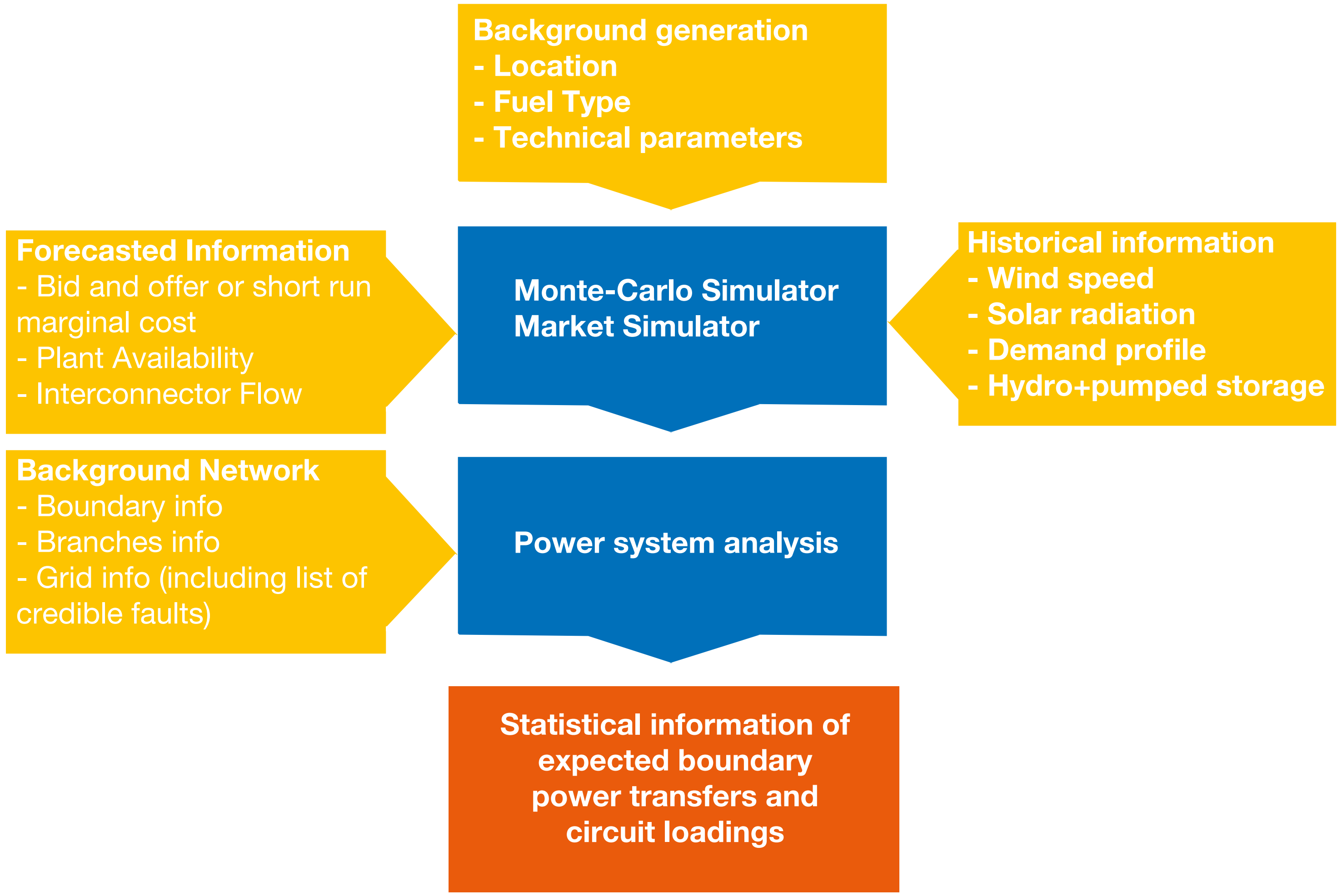
Boundary	BCP Index	CART Summary
B2	0.92% or 20.1 hours over the winter season at chapter 3 capability value	A combination of high wind in the Argyll and Bute region, low wind in the North East of Scotland and relatively high hydro output results in the best network performance. Low wind output across the central highland and Argyll and Bute regions in Scotland results in more constrained boundary performance
B4	2.29% or 50.1 hours over the winter season at chapter 3 capability value	Low output from central Scotland, low hydro output and low wind output in the Argyll and Bute region, results in relatively poor network performance. Low output from Central Scotland but a high hydro output results in relatively better boundary performance.

Probabilistic Thermal Analysis Methodology

Our probabilistic approach uses historical profiles as inputs to a Monte-Carlo method that samples those inputs and uses the technical operational logic of generation and demand to produce realistic outputs of wind farms, solar panels, hydro units, generation units' availability and demand dispatches. We use these dispatches to estimate the likely power flow on individual transmission circuits or a group of circuits. A group of circuits are also known as a boundary as discussed in Chapter 3.

When Monte-Carlo is used to sample likely background generation and demand conditions, it produces hourly snapshots of generation and demand for each sample year. We then use Economic Dispatch (ED) to find out the probable dispatches of energy resources assuming an ideal electricity market. The results, which are hourly generation and demand snapshots, are evaluated by power system analysis based on DC power flow for a set of credible contingencies. Pre- and post-faults actions are applied, when applicable, to relive congestions and increase the transfer capability. The results from the power flow analysis makes us understand the impact on the GB NETS.

Our probabilistic approach can be summarised by two key elements – the Monte Carlo sampling economic dispatch and the DC power flow network assessor element. The overall probabilistic process approach is summarised on the right.

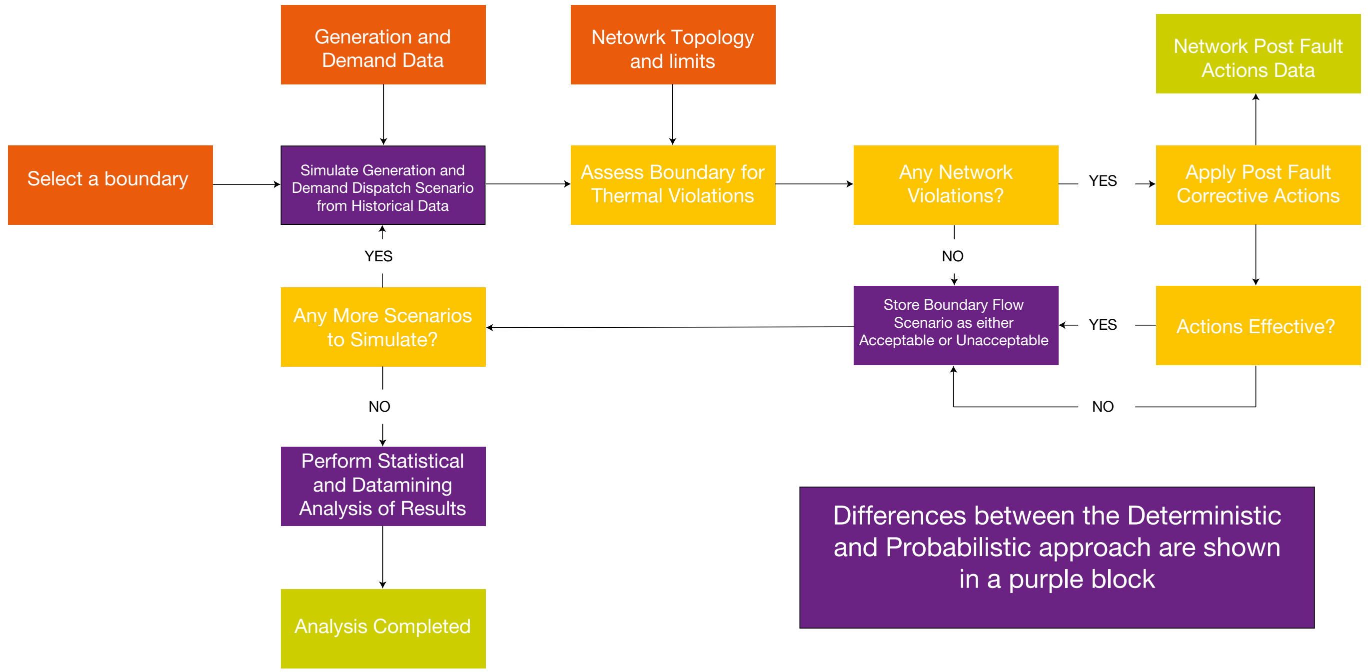


Comparing with our deterministic approach

Developing our probabilistic approach has followed a learning by doing process, which involved reconsidering our deterministic process to identify the steps in the process that we could enhance and incrementally evolve toward a full probabilistic analysis process.

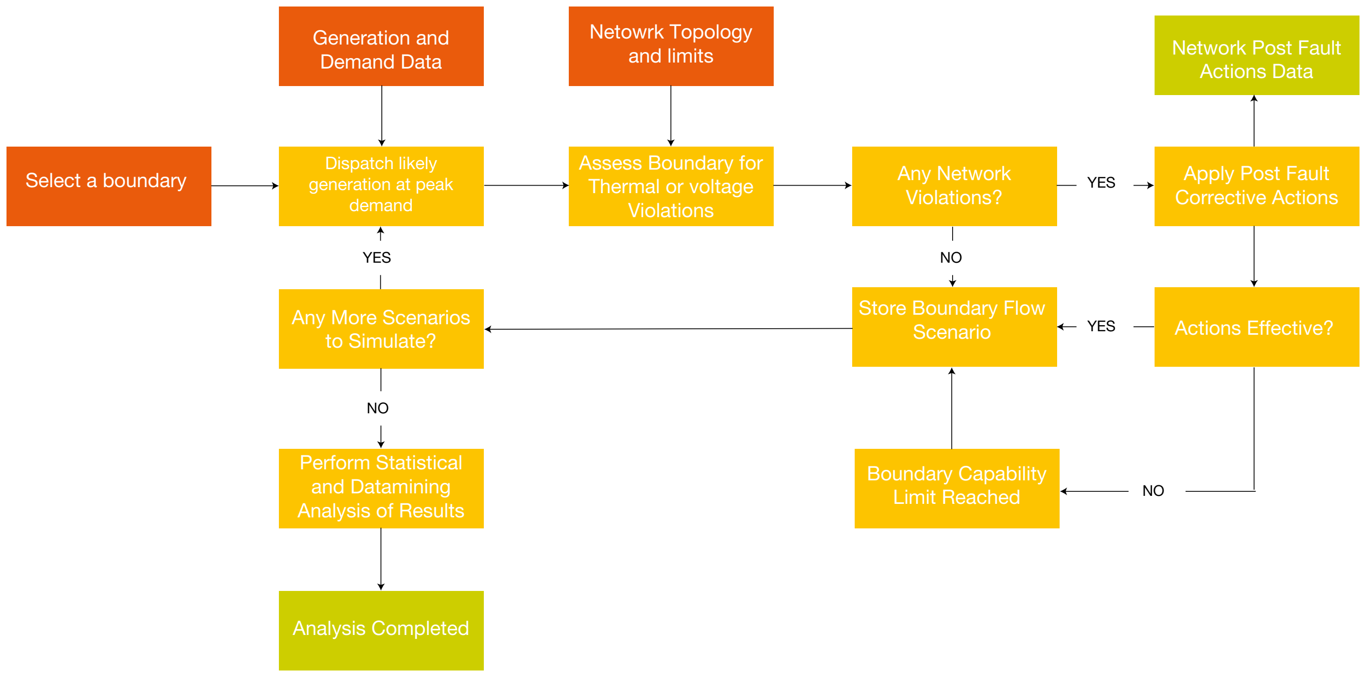
PROBABILISTIC APPROACH

This applies to both the thermal and voltage requirements and capability evaluation process.



DETERMINISTIC APPROACH

This applies only to the thermal requirements evaluation process.



The purple highlights in the probabilistic approach show the steps in our analysis where we have improved on our deterministic process.

In the probabilistic approach, we consider about 10 samples an hour or 87,600 year-round scenarios. This leads to 87600 network flows per studied boundary when it is intact. When contingencies are considered against a boundary, we can generate 87600 network flows multiplied by the number of contingencies considered. We then apply pre- and post-fault actions to relieve congestions and increase the acceptable power transfer across the boundary.

From this we can distinguish a network's state into either an “acceptable” or an “unacceptable” power flow state outcome. We use these outcomes to perform analysis of network thermal requirements, from statistical and data mining approaches.

Our improvements also enable us to use probabilistic generation and demand dispatch results to compare against our single snapshot generation and demand dispatch deterministic method. This helps us see how both the likely and rare worst-case dispatch scenarios compare between the two methods.

Development Pathway

We are continually working to extend our tools' functionalities. Our probabilistic work is one of our pathfinder projects, where we are learning by doing and are shaping our thinking as we apply our new tools to real data.

We are investigating various techniques to integrate probabilistic analysis into the ETYS and the NOA. One of the options is the BCP concept introduced; another one we are working on is a concept called Dynamic Boundary Capability (DBC) which relies on risk-based techniques to calculate multiple boundary capability(ies) per season based on the background condition(s).

Below, we have provided our development pathway. We are working to develop a bespoke joint market and network tool for GB thermal constraint analysis as well as proof of concept for integration of the year-round technical analysis into ETYS and NOA processes.

ETYS 2018	ETYS 2019	ETYS 2020	ETYS 2021
Case study for one boundary Present boundary results in ETYS 2018	Further development of our probabilistic tool and increase its capability to speed up the process All year 1 boundaries studied Data mining on results	Integrate pre and post fault actions (automated and manual)	Proof of concept for bespoke joint network and market tool for thermal constraint analysis Proof of concept for integration of probabilistic network analysis into NOA process

Aside from the probabilistic analysis, we are also working on other innovation projects. You can find out more information in our Network Innovation Allowance summary document which can be found here. Some of the projects are listed below:

Advanced Modelling for Network Planning under Uncertainty (University of Melbourne)

This project was established to independently validate the economic and technical aspects of our NOA methodology, compare our process to those used in other countries and to explore the potential for new analysis tool. The project provided useful recommendations for the tools enhancement which we will publish in a separate report early next year.

Applications of convex optimisation to enhance National Grid's NOA process (University of Strathclyde)

This NIA project focuses on developing new tools and techniques to better assess GB year-round reactive power requirements. A python-based tool is now developed with multiple techniques to do year-round voltage assessment. Further on, we are going to do extensive tests and study using GB data to make the tool fit for purpose.

Probabilistic planning for stability constraints (TNEI)

We are also running another innovation project to explore, develop and test probabilistic approaches for modelling of angular stability. This will enable year-round boundary capability calculation for stability accounting for a number of sources of variability and uncertainty. The project is expected to finalize and publish its findings by end of 2021. You can find more information about the project by visiting https://www.smarternetworks.org/project/nia_ngso0036.

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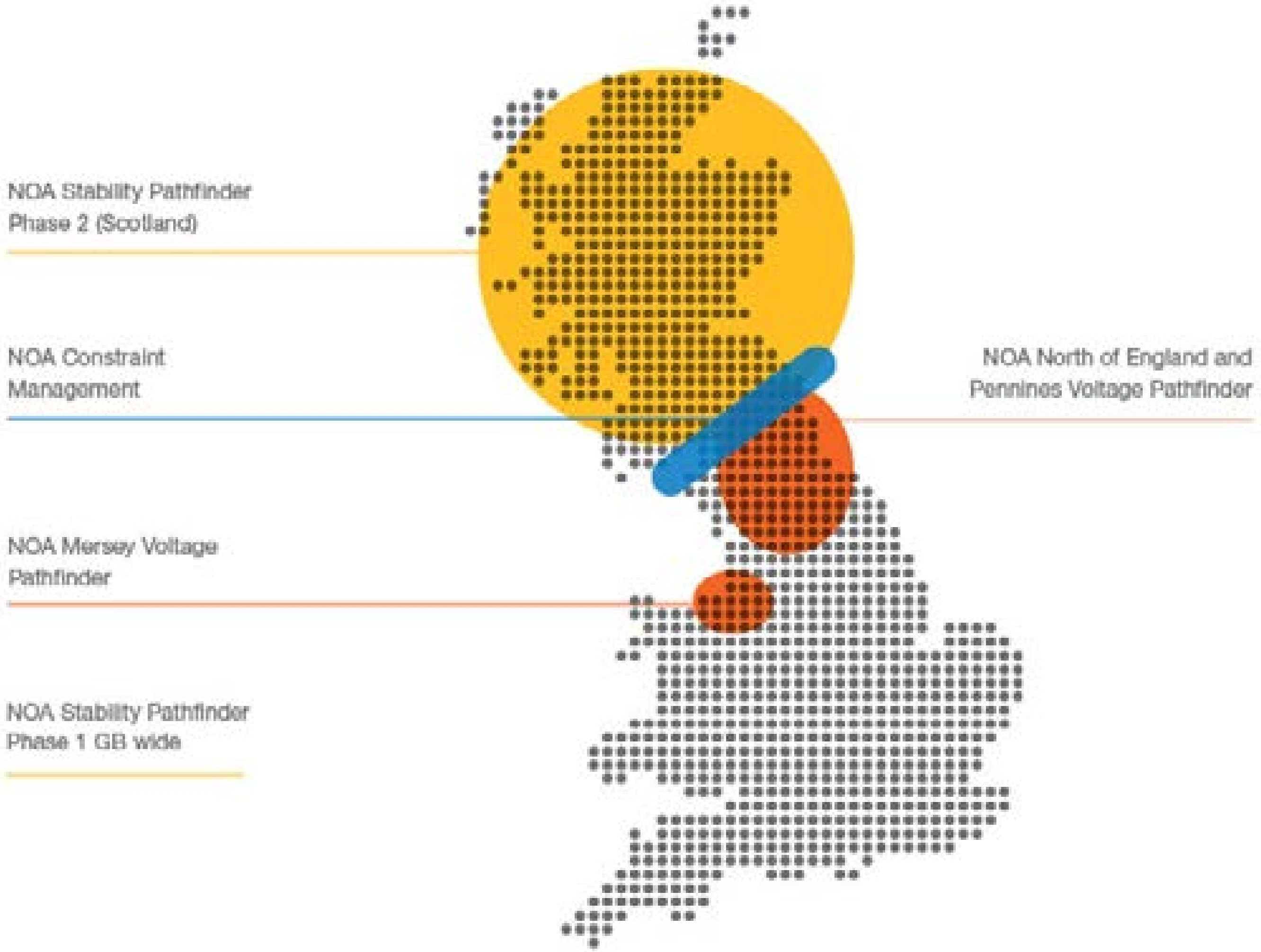
Way forward

The ETYS is learning from the NOA pathfinders

The road to determining the future network capability requirements and opportunities is one that needs to be refined and developed constantly. One of the ways we do this is through the NOA pathfinders. The NOA pathfinders look to investigate specific network requirements and open network development to a wider range of participants than before. NOA pathfinders can be GB-wide or regional.

The future development of the ETYS and NOA processes will be shaped by the NOA pathfinder projects which aim to resolve additional challenges related to thermal, high voltage and stability constraints.



We have been learning from our pathfinders and are investigating expanding the range of system needs beyond bulk power transfer and facilitating competition in our planning process. There are currently three pathfinders:

Voltage Pathfinder	Stability Pathfinder	Constraint Management Pathfinder
Aims to find a solution to resolve regional high voltage issues.	Aims to address our immediate needs of national inertia and deliver local short circuit level needs in Scotland	Aims to resolve network constraint issues and lower balancing costs

Regional high voltage pathfinder projects

Managing high voltages on the transmission system continues to be a growing challenge for the ESO. Over the last decade, the reliance on using balancing services for reactive power control has increased, thereby increasing the costs to manage high voltage.

We are taking steps in planning timescales to better manage the situation. We are addressing these challenges in the short term through short term contracts and in the long term by undertaking our voltage pathfinder projects as a means to establish a new process within the NOA. We summarise below the progress we have made in the last 12 months

Mersey (short-term and long-term)

In January 2020, we published the results of the short-term tender for a 1-year reactive power service from April 2020. A combination of Inovyn, Rocksavage and the agreed operational action(s) were selected as the most economic solutions to meet the requirements for the tender period. These solutions have been in place since April 2020.

In May 2020, we published the results of the Long-term tender for a 9-year reactive power service contract in the Mersey region. A combination of Peak Gen 200 MVAr Reactor and Zenobe, a 38 MVAr of reactive capability from battery storage were selected as the most economic solutions to meet the requirements over the tender period.

In September 2020, an Expression of Interest (EOI) was launched for another short-term reactive Power service to meet a static need in the Mersey region for 1 year from April 2021. We are now finalising the procurement approach and will announce it shortly.

North of England and Pennine

We prioritised the North of England and Pennine region following our voltage screening process and have been working towards a tender for this region. We're using the lessons learnt from the Mersey pathfinders to shape and improve our process for the tender.

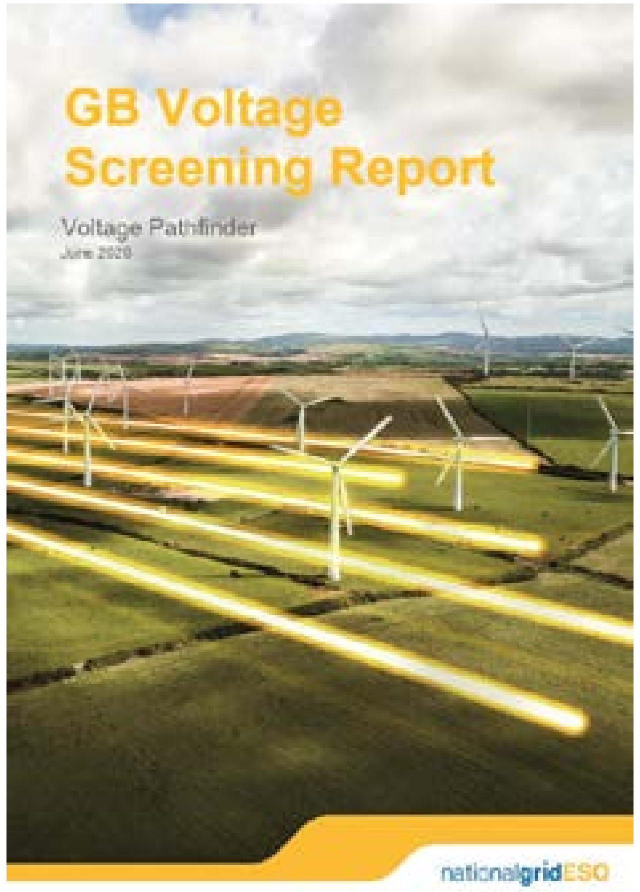
Voltage Screening Report

In June 2020 we published our first voltage screening report that presented the methodology and approach we take to identify regions with high voltage issues. We developed this report as part of our commitment in our Network Development Roadmap to provide you with more information on our voltage screening process. We already progressed the Mersey region to address high voltage issues and as part of the screening process, we identified 5 other regions which could face high voltage issues in the future; these included

- North of England and the Pennines,
- West Midlands,
- London,
- South West Peninsula and
- North Wales.

We prioritised the Pennine region as the next High voltage pathfinder and we will continue to assess issues elsewhere on the network and consider what the next priority region will be. Due to the changing nature of the system, this might be a region we have already identified or a new region.

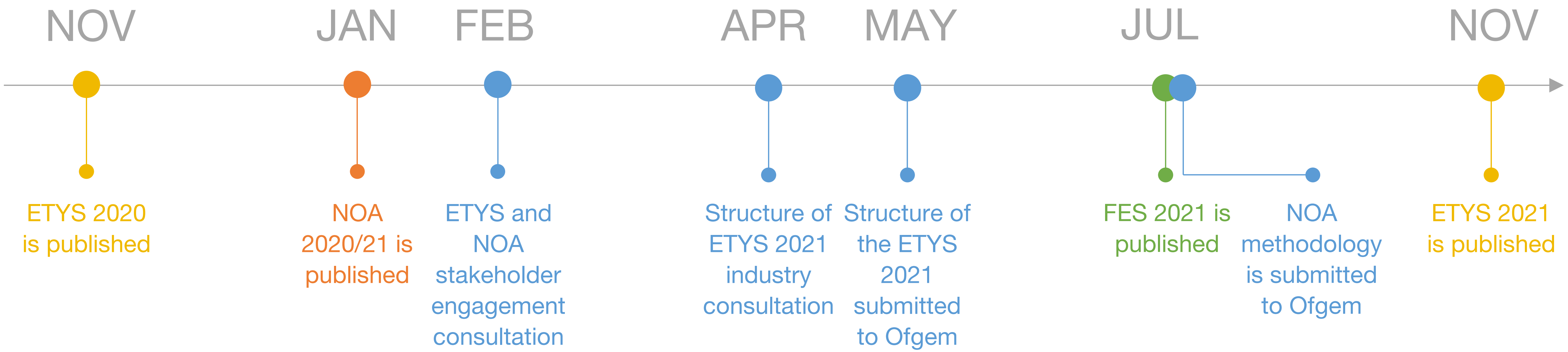
You can download this report from here.



Stakeholder engagement

The ETYS and NOA documents are continually evolving to meet our ambitions set out in the ESO Forward Plan. As the documents expand to a wider audience, we hope you will help shape them to become even more valuable for you and others to use.

We would like to hear your views on how we should shape both ETYS and NOA documents to make them more valuable. Our draft timetable for ETYS and NOA 2020 and 2021 stakeholder activities is shown below.



We welcome your views on this year's ETYS, what works well and what we need to improve. Our stakeholder activities are a great way for us to:

- learn more about the views and opinions of all our stakeholders;
- provide constructive feedback and debate;
- create open, two-way communication about assumptions, analyses and findings; and
- let stakeholders know how we have used their feedback.

There are many ways you can let us have your feedback, including:

- taking part in our written ETYS consultation (planned for April 2021);
- consultation events as part of our customer seminars;
- industry engagement events e.g. operational forums, ENA meetings, etc;
- emails direct to etys@nationalgrideso.com; and
- stakeholder meetings.

Further information

Appendices overview

Appendix A – system schematics and geographic drawings

Appendix A includes a set of system schematics and geographic drawings of the current NETS, with the approximate locations of existing power stations and reactive compensation plants shown. The schematics also show the NETS boundaries and ETYS zones we have used in our analysis

You can view the system schematics and geographic drawings at: ETYS 2020 Appendix A

Appendix B – System technical data

To allow modelling of the transmission network, basic network parameters such as connectivity and impedances are provided in Appendix B. The expected changes in the network based on the previous year's development decisions are also provided.

You can view the system technical data at: ETYS 2020 Appendix B

Appendix C – Power flow diagrams

To demonstrate the impact of future changes on the transmission network, a set of winter peak power flow diagrams are presented in Appendix C. These show snapshots of present and future power flows along major circuit routes for the Two Degrees scenario. The expected changes in the network are based on the previous year's development decisions.

You can view the diagrams at: ETYS 2020 Appendix C

Appendix D – Fault levels

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

You can find out more at: ETYS 2020 Appendix D - Narrative
You can view the fault level data at peak demand: ETYS 2020 Appendix D - Peak
You can view the fault level data at minimum demand: ETYS 2020 Appendix D - Minimum

Appendix E – FES charts and workbook

This appendix contains data and charts relating to national and/or regional National Electricity Transmission System (NETS) information about:

- energy storage and interconnectors
- summer minimum demand
- embedded generation.

You can find the transmission level data at: ETYS 2020 Appendix E

Appendix H – Further information on inputs and methodologies

This appendix explains how the FES generation, demand and interconnector data is applied to the network simulation models. Please note that Appendices F and G which contain week 24 generation and demand data are no longer published within ETYS and have moved to the Transmission Network Use of System (TNUoS) page under tools and calculations.

You can find out more at: ETYS 2020 Appendix H

Appendix I – Transmission Losses

Appendix I provides information on the drivers that may impact the total volume of future transmission losses on the NETS.

You can find out more at: ETYS 2020 Appendix I

Meet the ETYS team

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Network Development

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

- The management and implementation of the Network Options Assessment (NOA) process in order to assess the need to progress wider transmission system reinforcements.
- Producing recommendations on preferred options for NETS investment under the ITPR arrangements and publishing results annually in the NOA report.

You can contact us to discuss:

Network requirements and the Electricity Ten Year Statement

James Whiteford
GB System Capability Manager
James.Whiteford@nationalgrideso.com

Cost-benefit analysis and the Network Options Assessment

Jason Hicks
Technical and Economic Assessment Manager
Jason.Hicks@nationalgrideso.com

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.

Contact details to discuss the network data used in ETYS:

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Cheng Chen
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Supporting parties

Strategic network planning and producing the ETYS requires support and information from many people. Parties who provide support and information that makes our work possible include:

- the GB electricity Transmission Owners
- the SO Energy Insights team who provide 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 email us to join our mailing list to receive ETYS email updates.

Glossary (1/5)

Acronym	Word	Description
	Ancillary services	Services procured by a system operator to balance demand and supply and to ensure the security and quality of electricity supply across the transmission system. These services include reserve, frequency control and voltage control. In GB these are known as balancing services and each service has different parameters that a provider must meet.
ACS	Average cold spell	Average cold spell is defined as a particular combination of weather elements which gives rise to a level of winter peak demand which has a 50% chance of being exceeded as a result of weather variation alone. There are different definitions of ACS peak demand for different purposes.
	Boundary allowance	An allowance in MW to be added in whole or in part to transfers arising out of the NETS SQSS economy planned transfer condition to take some account of year-round variations in levels of generation and demand. This allowance is calculated by an empirical method described in Appendix F of the Security And Quality of Supply Standards (SQSS).
	Boundary transfer capacity	The maximum pre-fault power that the transmission system can carry from the region on one side of a boundary to the region on the other side of the boundary while ensuring acceptable transmission system operating conditions will exist following one of a range of different faults.
CBA	Cost-benefit analysis	A method of assessing the benefits of a given project in comparison to the costs. This tool can help to provide a comparative base for all projects to be considered.
CCS	Carbon capture and storage	Carbon capture and storage is a process by which the CO2 produced in the combustion of fossil fuels is captured, transported to a storage location and isolated from the atmosphere. Carbon capture and storage can be applied to large emission sources like power plants used for electricity generation and industrial processes. The CO2 is then compressed and transported for long-term storage in geological formations or for use in industrial processes.

Acronym	Word	Description
	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 SHE 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.

Glossary (2/5)

Acronym	Word	Description
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.
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.

Acronym	Word	Description
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.
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.

Glossary (3/5)

Acronym	Word	Description
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.
	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.

Acronym	Word	Description
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.

Glossary (4/5)

Acronym	Word	Description
	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.
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.

Acronym	Word	Description
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.
	SHE 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.

Glossary (5/5)

Acronym	Word	Description
	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.

Acronym	Word	Description
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
	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 power on a regional or national level, using fixed infrastructure.

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