November 2021

Electricity Ten Year Statement

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Contents

Welcome

Foreword

Electricity is a modern-day necessity, and our role as the Electricity System Operator (ESO) is to make sure every home and business across Great Britain has access to a safe, reliable, and affordable supply at the flick of a switch. We bring energy to life because without it, society and the economy wouldn't function.

Welcome to our Electricity Ten Year Statement (*ETYS*) 2021. The *ETYS* is the ESO's view of future transmission requirements and the capability of Great Britain's National Electricity Transmission System (NETS) over the next 10 years.

Thank you for your continued feedback on the *ETYS* process. It is vital that we present our data in a way that is useful to the industry, acting as a catalyst for debate. We appreciate continued feedback and encourage you share your views on how we can further improve the *ETYS*. To find out more or to contact us, please visit our website: https://www.nationalgrideso.com/research-publications/etys

Julian Leslie
Head of Networks,
Electricity System Operator
Julian.Leslie@nationalgrideso.com

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 Future Energy Scenarios (*FES*) identify credible pathways for the future of energy up to 2050; so they are at the heart of the *ETYS* process in determining the future transmission network needs. The *ETYS* is a key input into our Network Options Assessment (*NOA*) process that makes recommendations for future investments and solutions.

Our ambition is to be able to operate a zero-carbon electricity system by 2025; a big milestone on the UK's journey to net-zero by 2050. The *ETYS*, along with our other ESO publications, is key in helping us to achieve these goals, through encouraging innovation and informing the development of the electricity network - so that together we can deliver a secure, sustainable, and affordable energy future.

As operation of the National Electricity Transmission System (NETS) becomes increasingly complex, we need to find new ways to identify its weak points so they can be addressed by the network planning process. This involves the use of innovative analysis techniques, such as our work on year-round probabilistic analysis, and developing the *NOA* pathfinders to better address both voltage and stability issues, as well as bulk power transfer. This will lead to more informed network investment and operational planning decisions.

In line with our commitments in the RIIO-2 Business Plan, we are working to enhance our approach to identifying system needs. We have created a new team dedicated to developing innovative methods to improve how we analyse changing network conditions. Work is already under way to develop specific tools for probabilistic modelling, voltage optimisation, and stability assessment. We are also reviewing network planning processes more broadly, to ensure we can identify the future needs of the onshore and offshore networks. This work will inform our approach to developing scenarios, assessing network capability and operability needs and identifying solutions to deliver Great Britain's net-zero ambition.

To facilitate the growing volumes of offshore generation, we are developing a Holistic Network Design through the Pathway to 2030 workstream, part of the Department for Business, Energy and Industrial Strategy (BEIS) Offshore Transmission Network Review. This is likely to develop into a new, enduring approach with much greater integration between the onshore and offshore network planning.

Key Messages

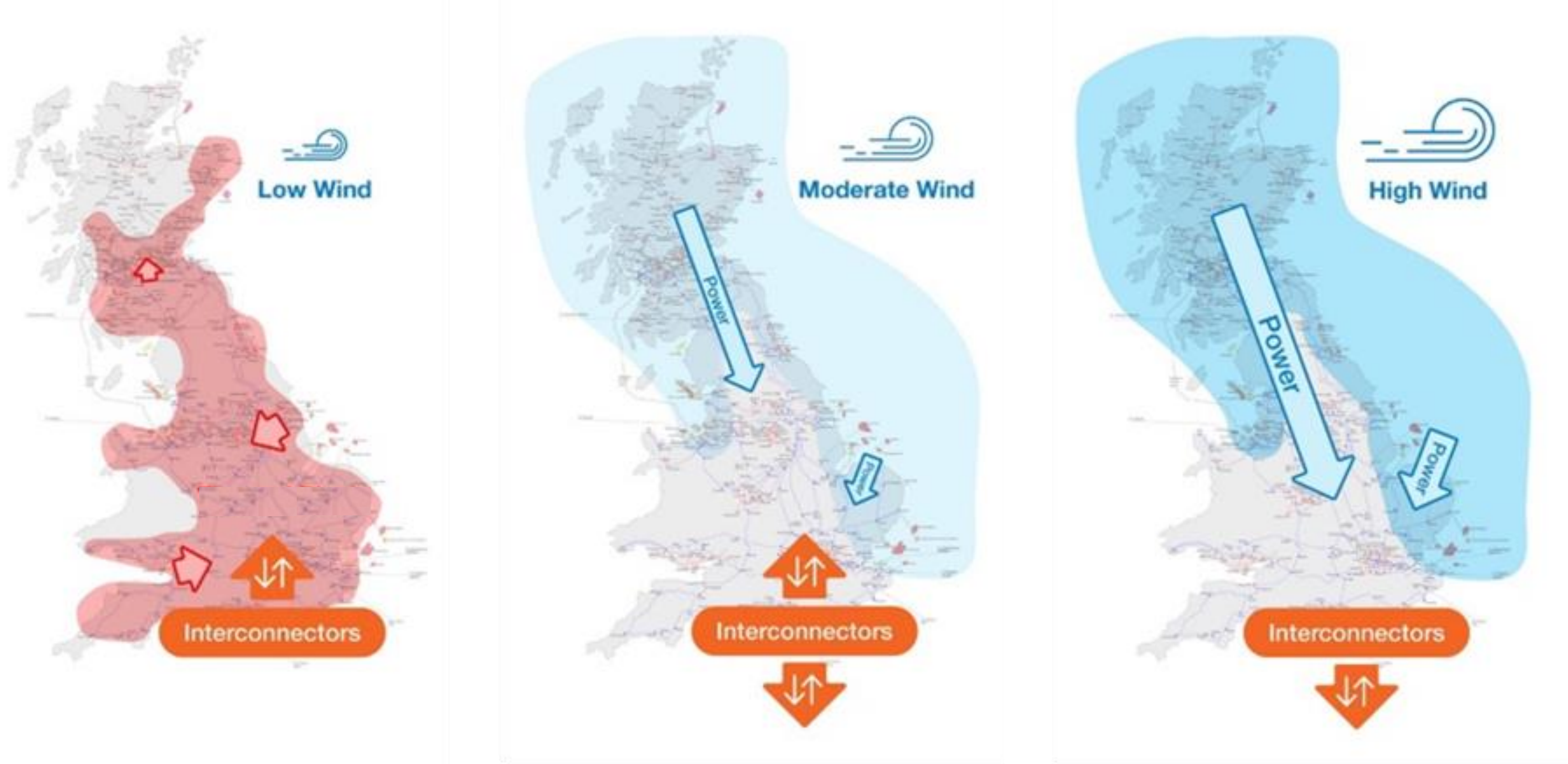
Key Message 1

Growth in north-south power flows continues with high variability

The past year has seen increased ambition for offshore wind, with the Government's Ten Point Plan re-affirming the commitment to reach 40 GW of installed capacity by 2030.

Electricity demand is predominantly located in the south, leading to high north-south power flows. These flows are highly variable due to the intermittent nature of wind generation and interconnection. The system will need to be prepared to manage large swings in power flows.

The north-south flows contribute significantly to system constraints across the entire GB transmission system.



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Key Message 2

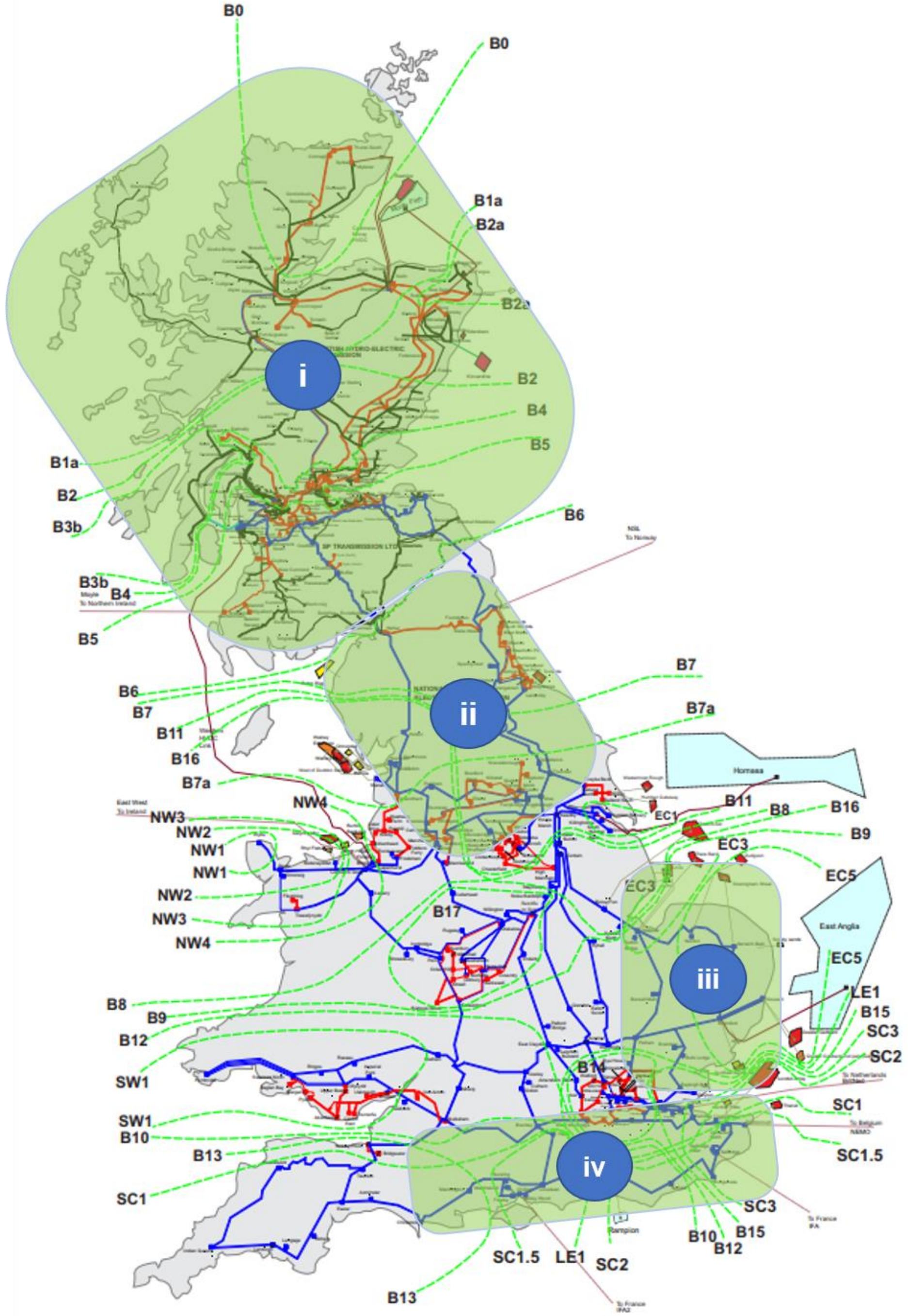
In the next decade the GB Electricity Transmission System will face growing needs in a number of regions

I. A tripling of wind generation connected across the Scottish networks by 2030, driving higher north-to-south power transfers.

II. A doubling at least of transfer requirements from northern Scotland to the Midlands over the next 10 years. New reinforcements will be required to facilitate these power flows through the North of England.

III. Up to a 12GW increase in transmission-connected low-carbon and renewable generation in East Anglia from 2020 to 2030 is expected. Future offshore wind connecting along the east coast and new interconnectors in the region are expected to increase the transfer requirements including during low-wind periods.

IV. New interconnectors with Europe will place increased requirements on the transmission network, interconnector capacity is anticipated to exceed transmission connected generation in the South of England.



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Key Message 3

Click on the boundary names to go to the boundary flows

Timely delivery of network reinforcements in the NOA will significantly help reduce network constraints

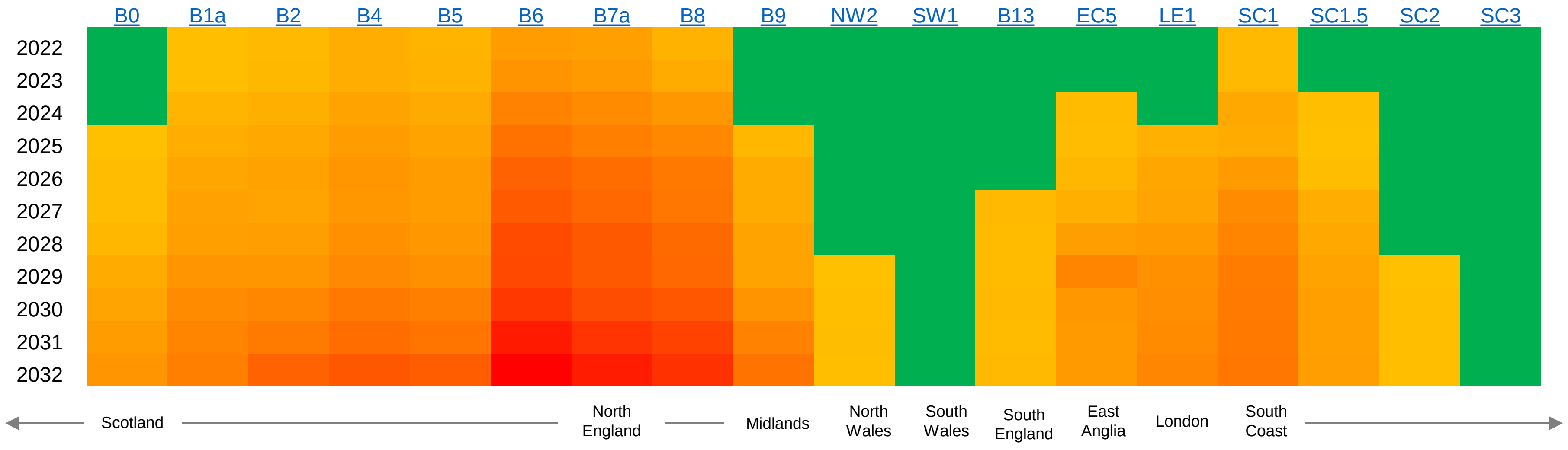
The *ETYS* describes the network capability by looking at the maximum secured power transfer between two regions or the power transfer across a boundary.

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

The heatmap (top-right) shows that if no reinforcements are made (i.e., if over the next 10 years the network remains the same as it is today), the boundaries defined in the ETYS would be significantly constrained due to high flows from the increased generation capacity.

Due to the growth in government ambition reflected in FES 2021, our boundary flow requirements are higher than last year. To reduce network constraints, the NOA 2020/21 recommended a number of options and their effect can be seen on the heatmap on the bottom right. NOA 2021/22 will be looking to recommend options to address these growing system needs. Also, the ESO is progressing it's five-point plan to further tackle network constraints.

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



Excess flows beyond boundary capability **with NOA 2020/21 recommended options applied***

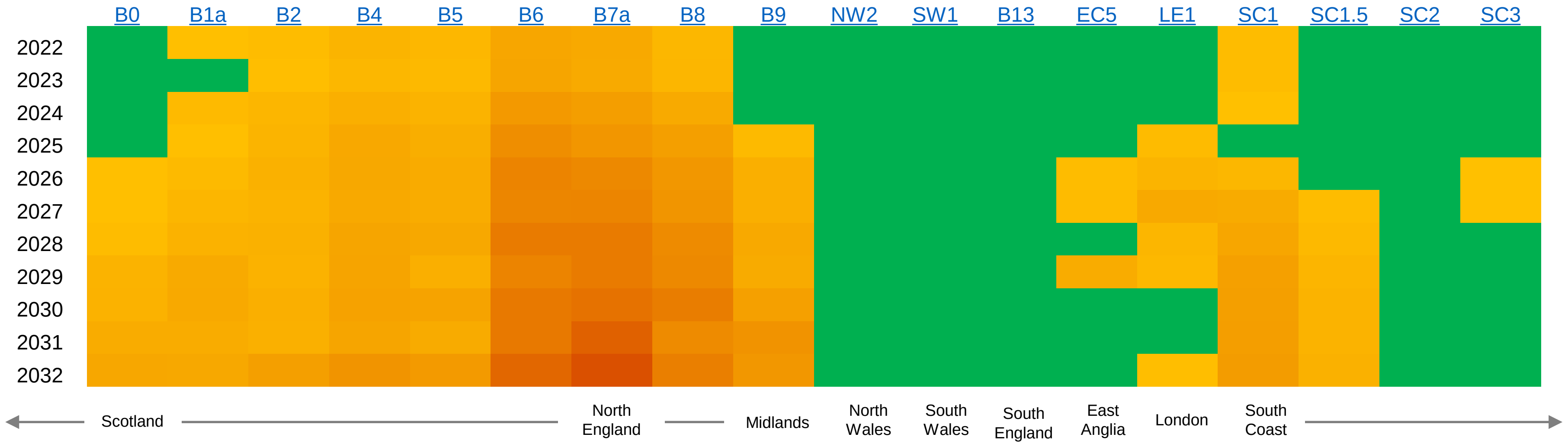


*Chart uses the 2020/21 NOA recommendations against *Leading the Way* scenario in 2021/22 FES flows

Chapter 2

ETYS and the Network Planning Process

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Introduction

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

The ETYS is important in helping us to understand what investment and development is needed to help us achieve our zero-carbon ambition. ETYS 2021's key messages explain some of the most pressing issues we see on the NETS as we drive towards net-zero.

As we emerge from the initial impacts of COVID-19, the past year has reminded us all how much our decisions matter in response to global issues – and we've also seen how far we can adapt to major changes.

About the *ETYS*

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

Once we have assessed the network requirements, we invite stakeholders to propose solutions to these requirements. These proposals are assessed through our Network Options Assessment (*NOA*) process, where the most economic and efficient solution is given a recommendation to proceed, and others put on hold or stop.

What's new in *ETYS* 2021

Last year, we published a web version of the *ETYS* for the first time. This was well received, and we have continued to make improvements so that our web version of *ETYS* 2021 is clearer and easier to use for our readers.

We have removed the section on 'Year-round probabilistic analysis' included last year as we will present our probabilistic tool developments in a separate publication, due in Q1 2022.

In response to the feedback received from our stakeholders this year, the ETYS boundary charts have an indicative boundary transfer capability based on the 2020/21 NOA optimal path. We hope this allows the reader to see the capability of the system and opportunities over the future years as well. Certain boundaries do not have NOA reinforcement uplifts as they are not studied in the NOA.

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The work behind the *ETYS*

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

Using *FES* to Determine Demand and Generation

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

Apply Dispatch and SQSS Planning Criteria

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

Determine Boundary Capabilities

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

Determine Network Requirements

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

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How the *ETYS* fits in with the *FES* and the *NOA*

The ESO produces a suite of publications on the future of energy for Great Britain, which inform the whole energy debate by addressing specific network planning issues. The *FES*, *ETYS* and *NOA* provide an evolving and consistent voice in the development of GB's electricity network.

We use the *FES* to assess network requirements for power transfers across the GB NETS. The network requirements are then published in the *ETYS*.

Once we know what the network requirements are, we invite stakeholders to propose solutions to meet these requirements. These proposals are then assessed through our *NOA* process, where the most economic and efficient solution is given a recommendation to proceed, and others told to hold or stop.

In *NOA* 2020/21, covering the next 10 years, we recommend investing **£183 million** this year to develop **41 asset-based projects** worth **£13.9 billion** and **four ESO-led commercial solutions** that could provide an **additional £2.1bn in consumer benefit**.

FES July 2021

A range of plausible and credible pathways for the future of energy from today out to 2050

ETYS November 2021

The future transmission requirements on the electricity system

NOA January 2022

The recommended options to meet reinforcement requirements on the electricity system

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National Electricity Transmission System (NETS)

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

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

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

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

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

The offshore transmission systems are also separately owned.

There are 22 licenced offshore transmission owners (OFTOs) appointed through Ofgem’s competitive tendering process.

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

1 Scottish & Southern Electricity Networks

2 SP ENERGY NETWORKS

3 nationalgrid

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

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

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

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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.

This is done using the ‘system boundary concept’, which calculates boundary capabilities and the future requirements for bulk power transfer. The transmission network is designed to provide enough capacity to send power from areas of generation to areas of demand.

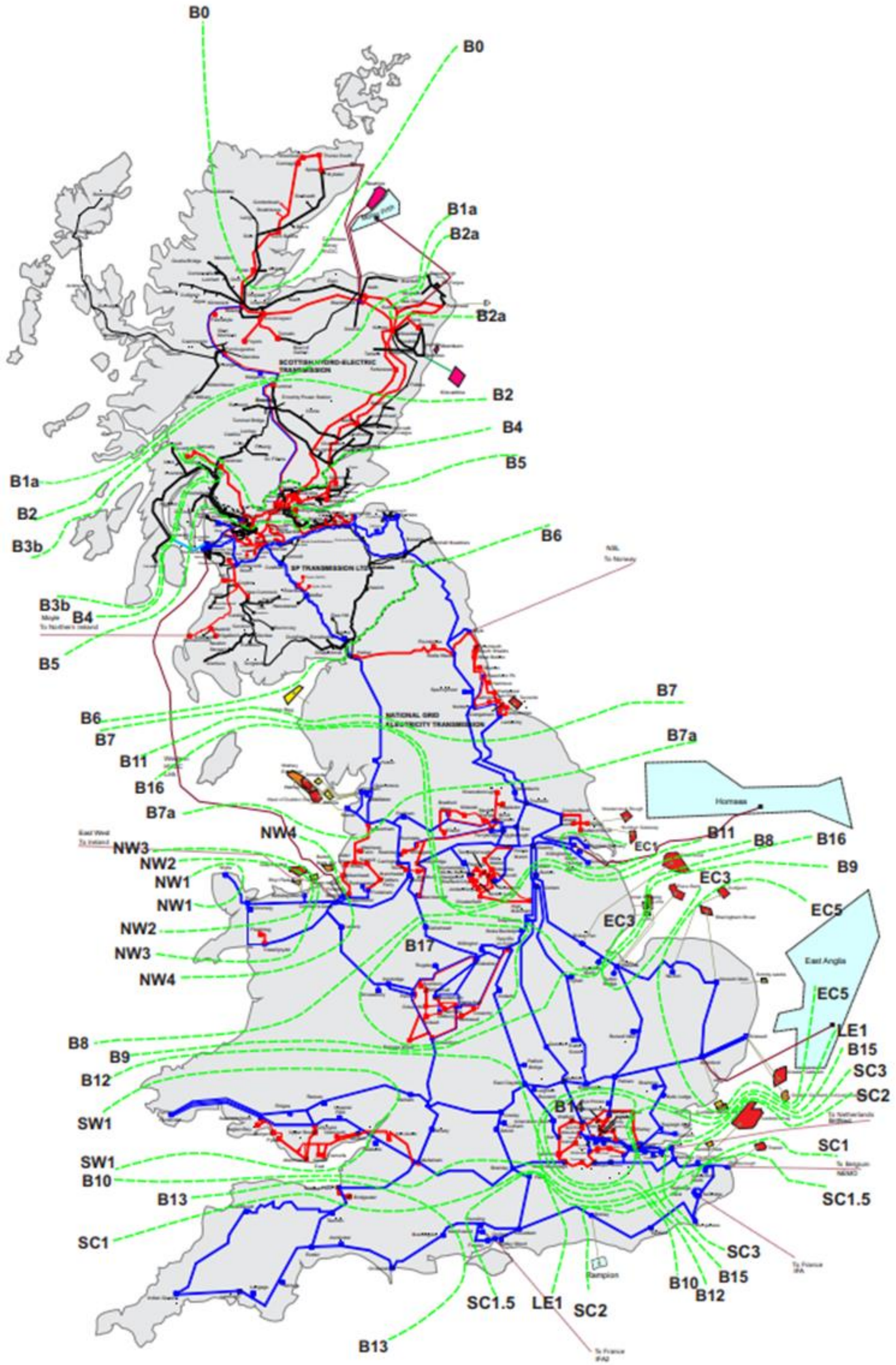
Limiting factors on transmission capacity include:

- Thermal circuit rating
- Voltage constraints
- Dynamic stability

From the network assessment, the lowest known limitation is used to determine the network boundary capability. This will be used in the NOA 2021/22, to help us assess the reinforcement options that will address the potential future NETS boundary needs.

When significant transmission system changes occur, new boundaries may be defined and some existing boundaries either removed or amended (we are transparent about 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. The same capability as the previous year is assumed for these boundaries.

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



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Analysing the NETS boundaries

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

Local boundaries

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

Wider boundaries

Large areas containing significant amounts of both generation and demand. The SQSS boundary scaling methodologies assess the capability of the wider boundaries.

These consider both the geographical and technological effects of generation, allowing for a consistent capability and requirements assessment.

We have continuously developed the transmission network to provide sufficient capacity to transport power efficiently and economically across the country.

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

The security criterion

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

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

The economy criterion

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

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

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

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Chapter 3

Electricity Transmission Network Requirements

Introduction

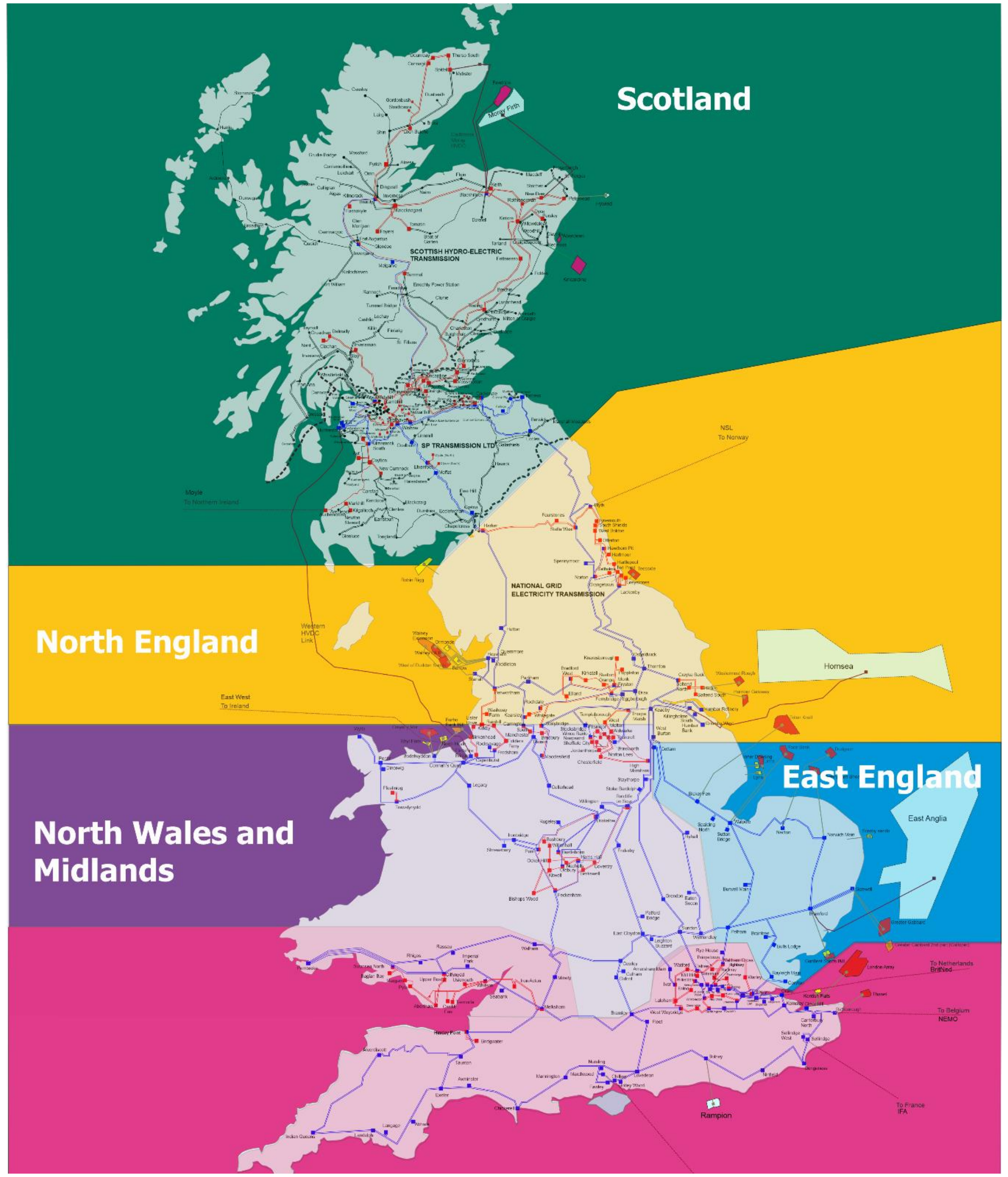
Great Britain's National Electricity Transmission System (NETS) must continue to adapt and be developed so power can be transported from source to demand, reliably and efficiently.

The results in this chapter will be used in the NOA 2021/22 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 by region, to help you gain an overview of requirements by boundary and regionally.
- Provide analysis to show how and when, in the years to come, the NETS will potentially face growing future networks needs in a number of regions.

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



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How to interpret the boundary graphs?

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

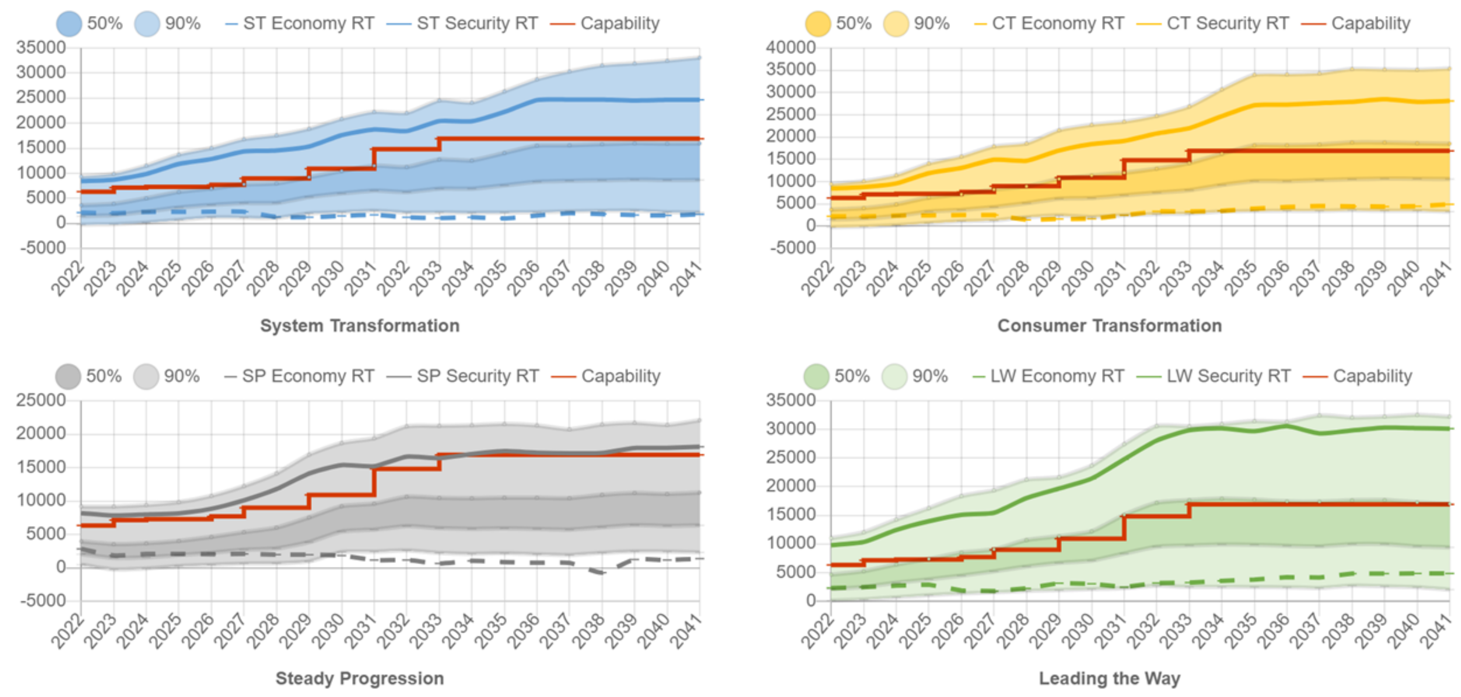
Each scenario has different generation and demand so produces different boundary power flow expectations. From applying the methodology in the NETS SQSS for wider boundary planning requirements (as discussed in chapter 2), we determine for each scenario:

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

Due to the NOA being published after the ETYS, the boundary capability line (**red line**) is prepared from the 2020/21 (previous year's) NOA optimal path released in January 2021 which uses the 2020/21 FES and ETYS data. This is the best information available at the time of publication and will change annually and over time as the network, generation, demand and more importantly the NOA optimal path changes. More information about the NOA methodology can be found here. The 50%, 90%, Economy RT and Security RT are calculated from the 2021/22 FES and ETYS processes. Where the NOA transfer capability is not available, there is a **black line** that provides the current ETYS 2021/22 transfer capability

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

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



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

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

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

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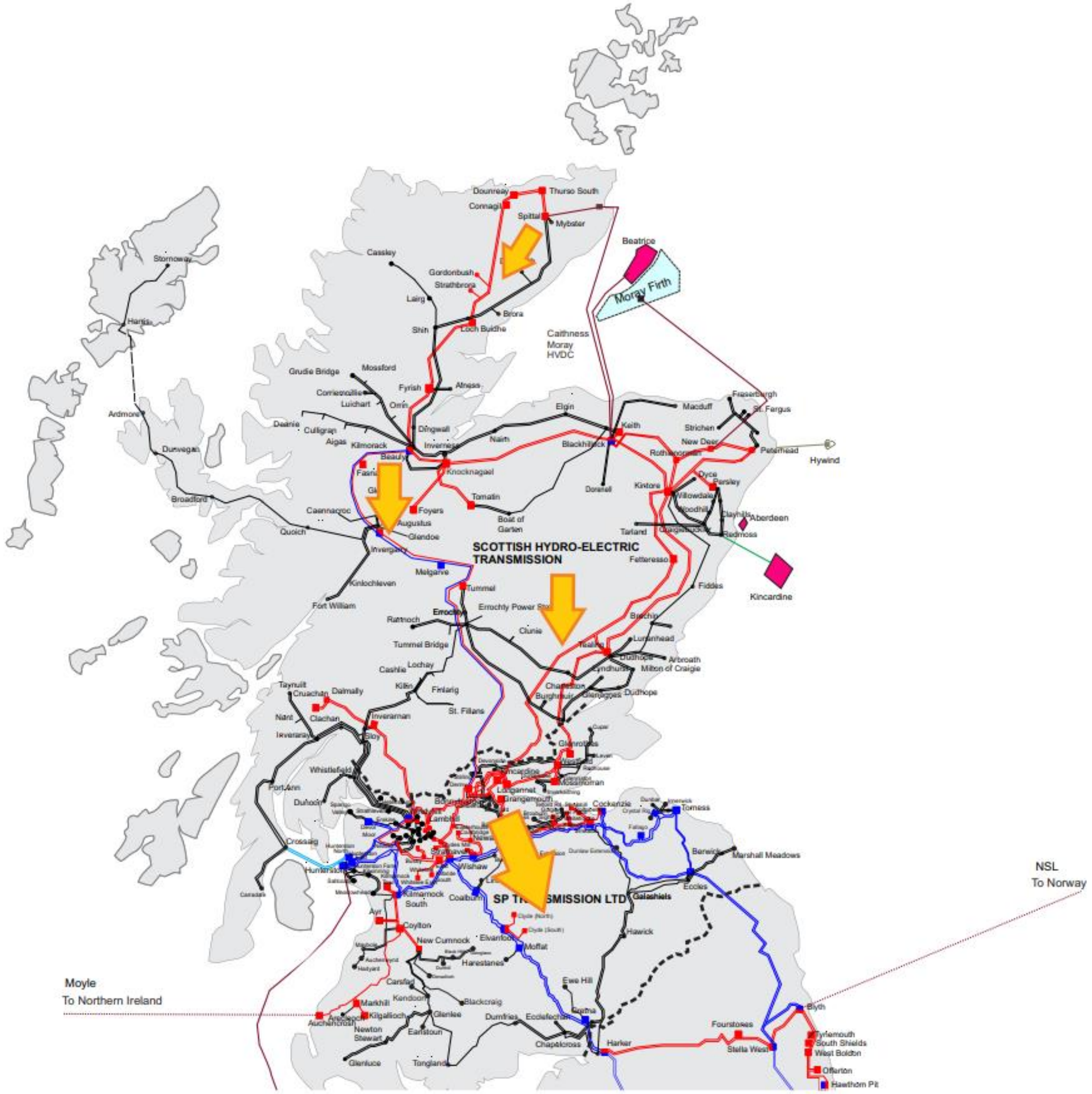
Scotland

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

The Scottish NETS is divided into 7 boundaries –

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

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



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Regional Drivers

Scotland 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.

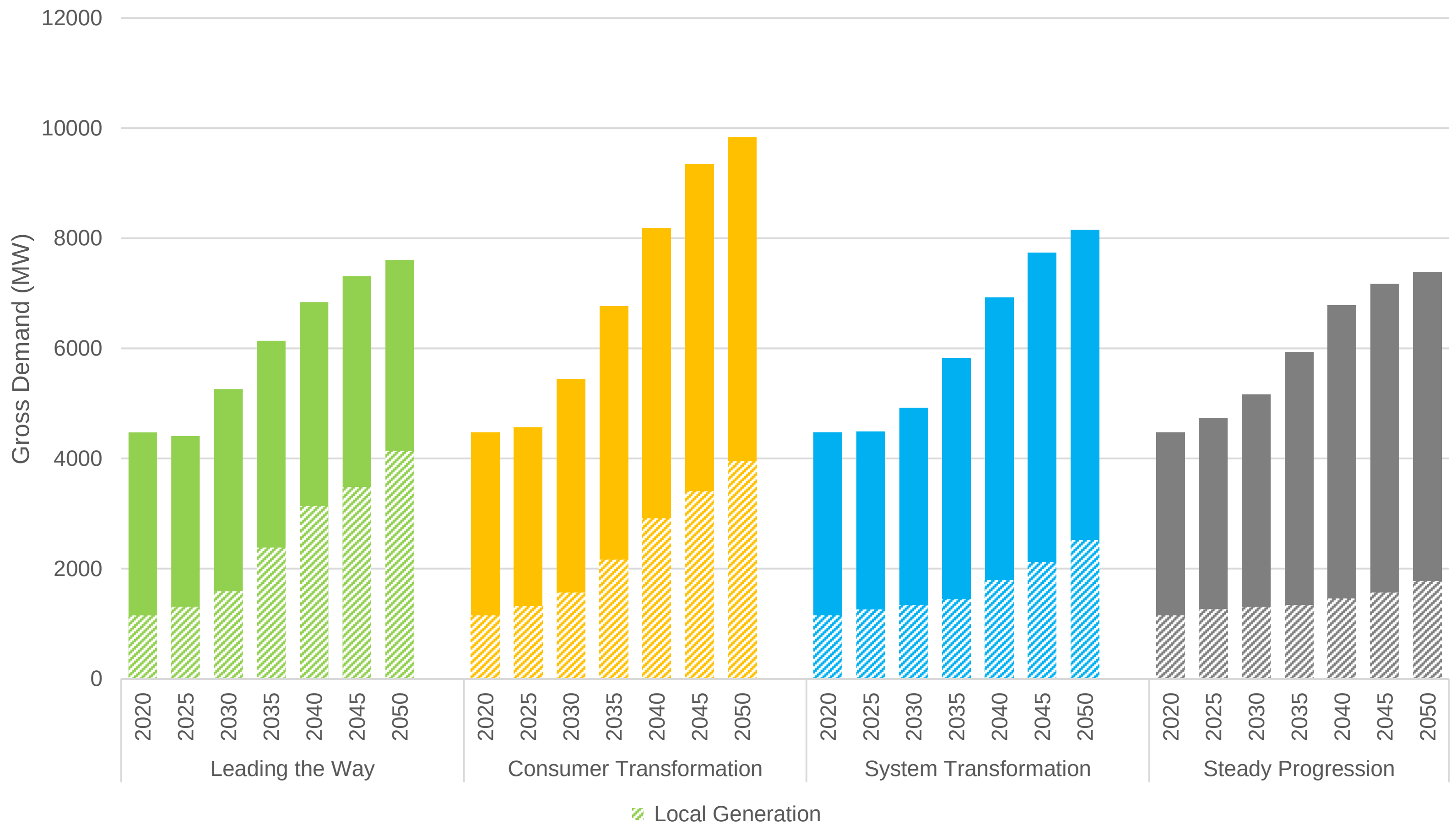
Across all the scenarios in the FES, the fossil fuel generation capacity in Scotland reaches nearly zero. By 2030, all scenarios show an increase in interconnector and storage capacities and a total Scottish generating capacity of between 30 and 41GW.

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. The NOA Stability Pathfinder is looking to procure cost-effective services to meet our immediate and future short-circuit level and inertia needs in the Scottish region.

With gross demand in Scotland not expected to exceed 6GW by 2030, which is much less than the Scottish generation capacity, Scotland will be expected to export power into England most of the time.

In a highly decentralised scenario like Leading the Way, local generation capacity connected at the distribution level in Scotland could reach more than 5.5GW by 2030. At times of low renewable output, Scotland may need to import power from England due to the low baseline generation capacity in the region.

Of that capacity, the total embedded generation output will average at around 1.6GW. This will vary depending on factors like wind speeds, and how other local generators decide to participate in the market.



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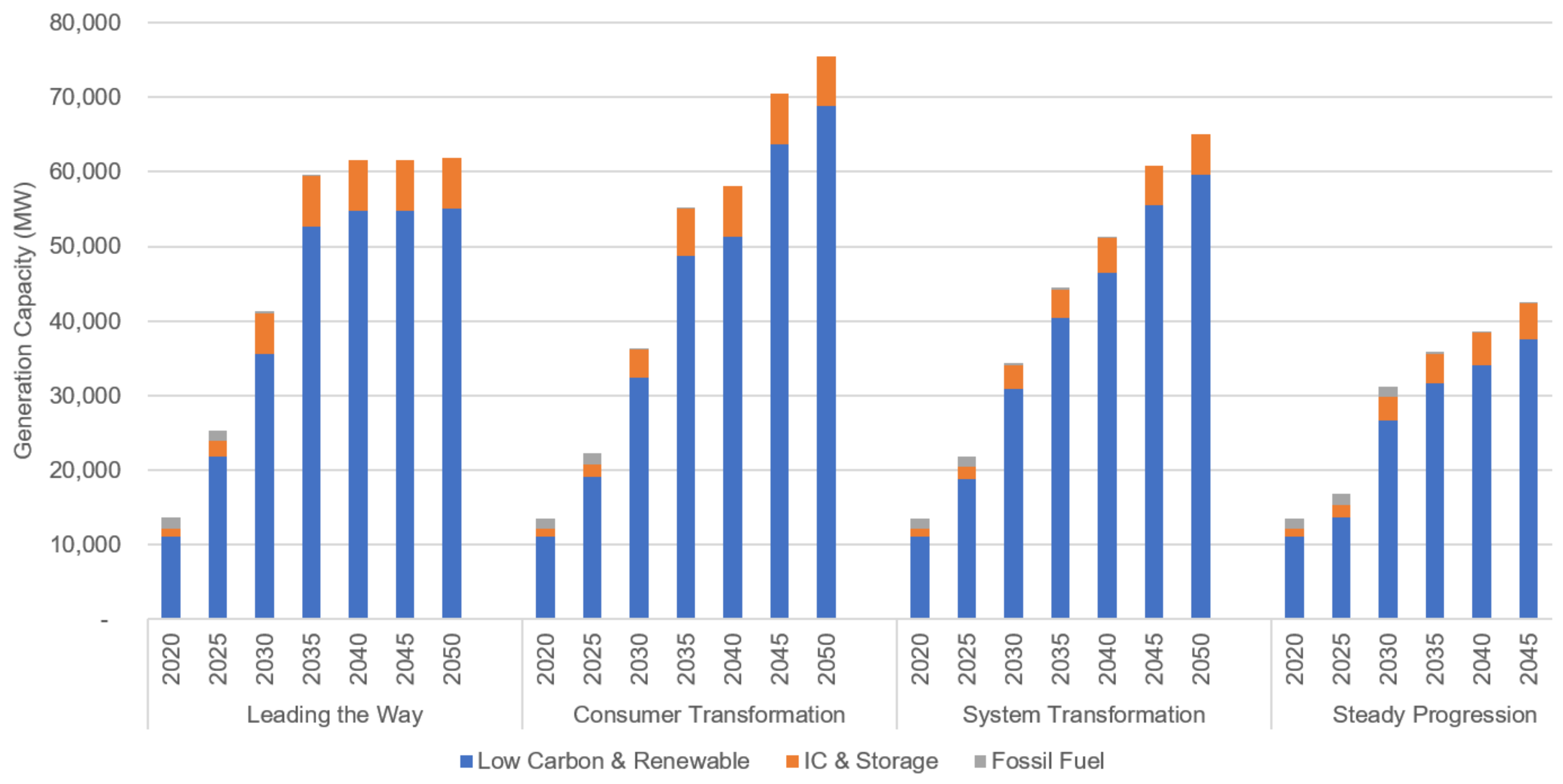
Regional Drivers - Continued

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 2021/22 CBA. Following the evaluation, the preferred reinforcements for the Scotland region will be recommended.



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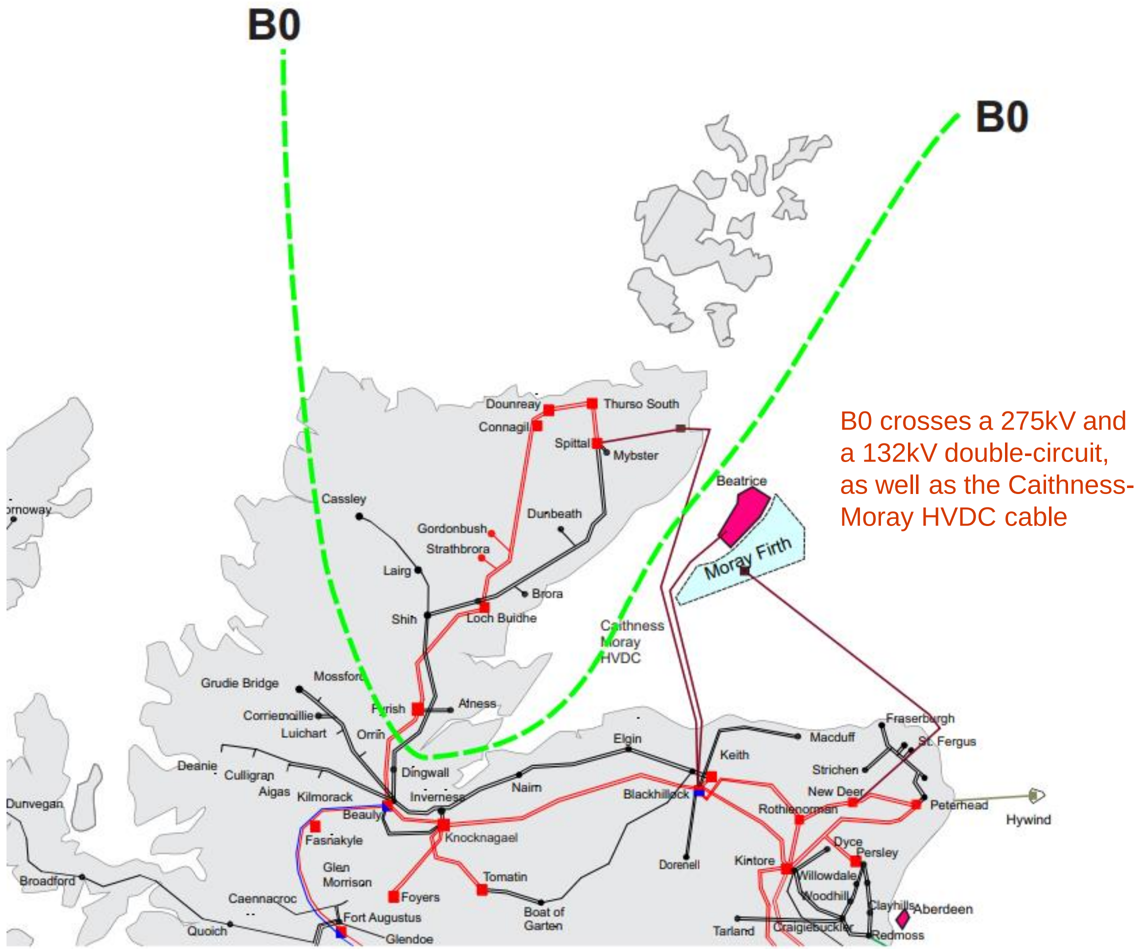
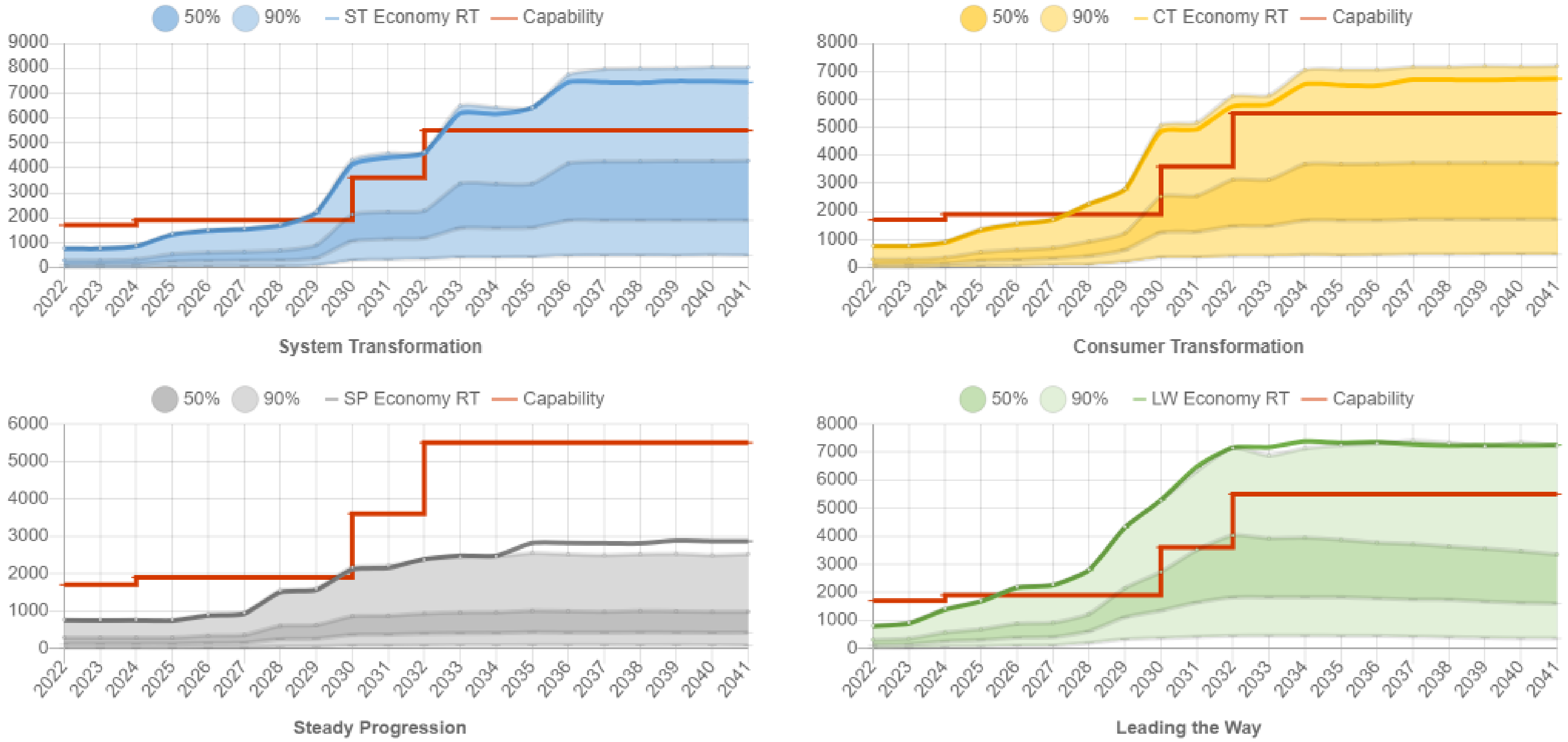
Boundary B0 – Upper North SSEN Transmission

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





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

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

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

* ETYS Transfer capability calculated using the 2021/22 FES data

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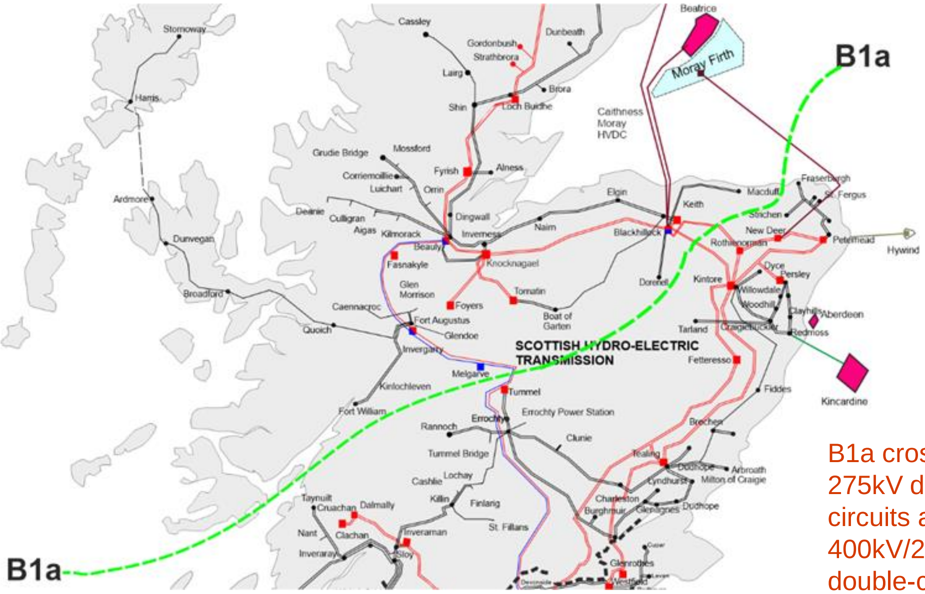
Boundary B1a – North West SSEN Transmission

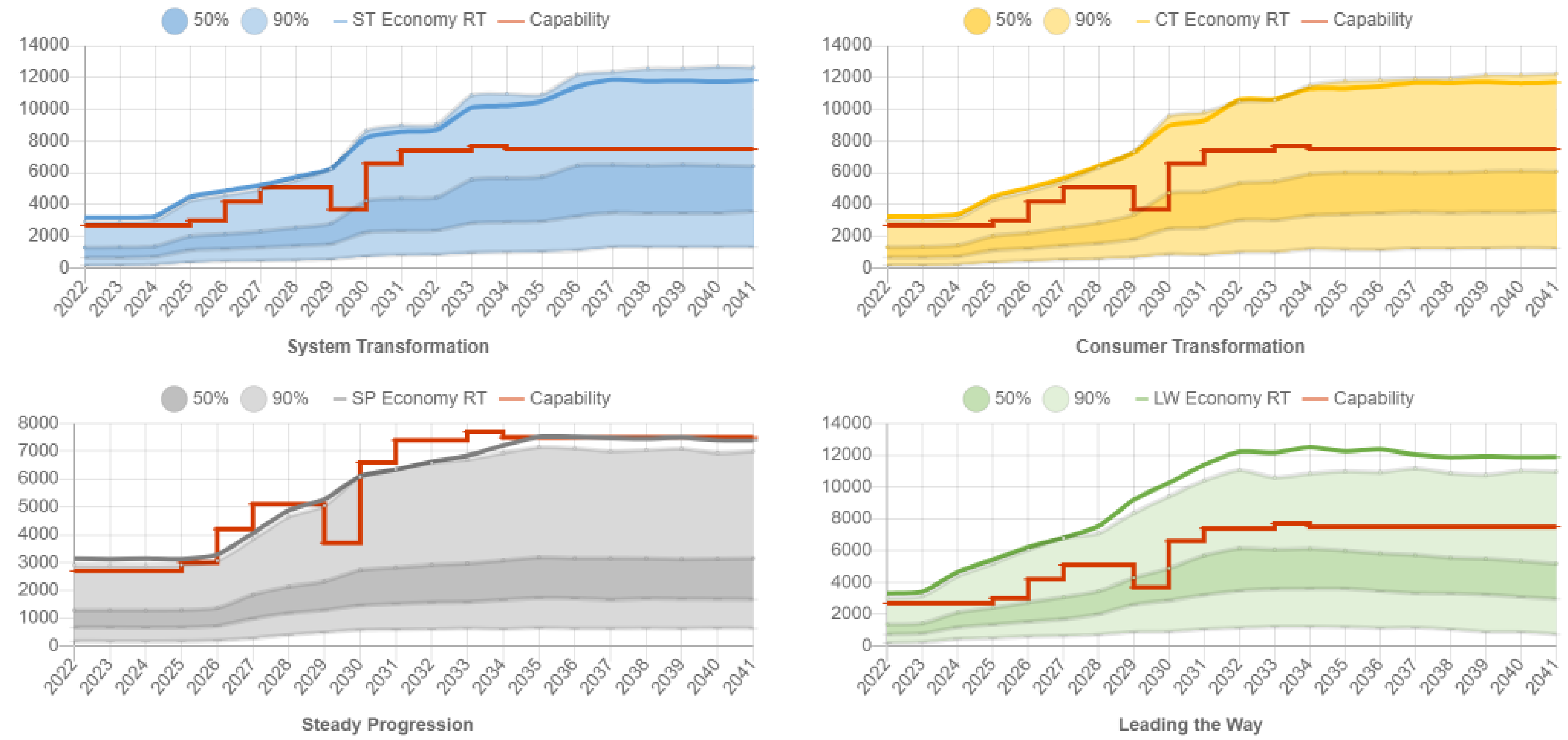
Boundary B1a runs from the Moray coast near Macduff to the west coast near Oban, separating the north west of Scotland from the southern and eastern regions.



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

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

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



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

The current boundary capability is limited to 1.85GW* due to a thermal constraint on the Errocthy - Killin 132kV circuit

* ETYS Transfer capability calculated using the 2021/22 FES data

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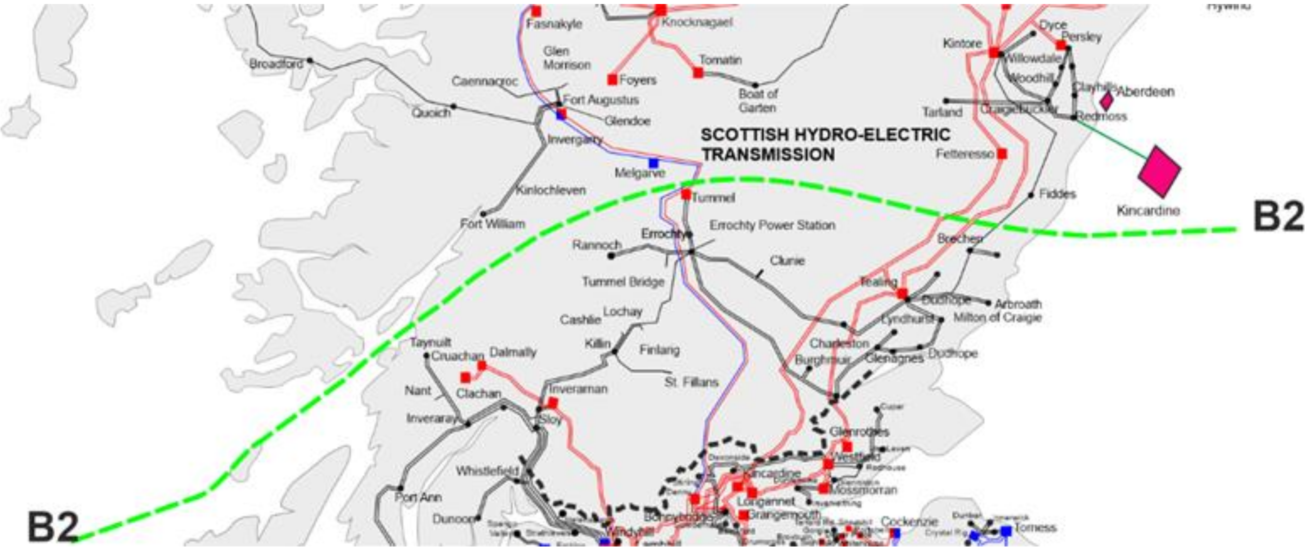
Boundary B2 – North to South SSEN Transmission

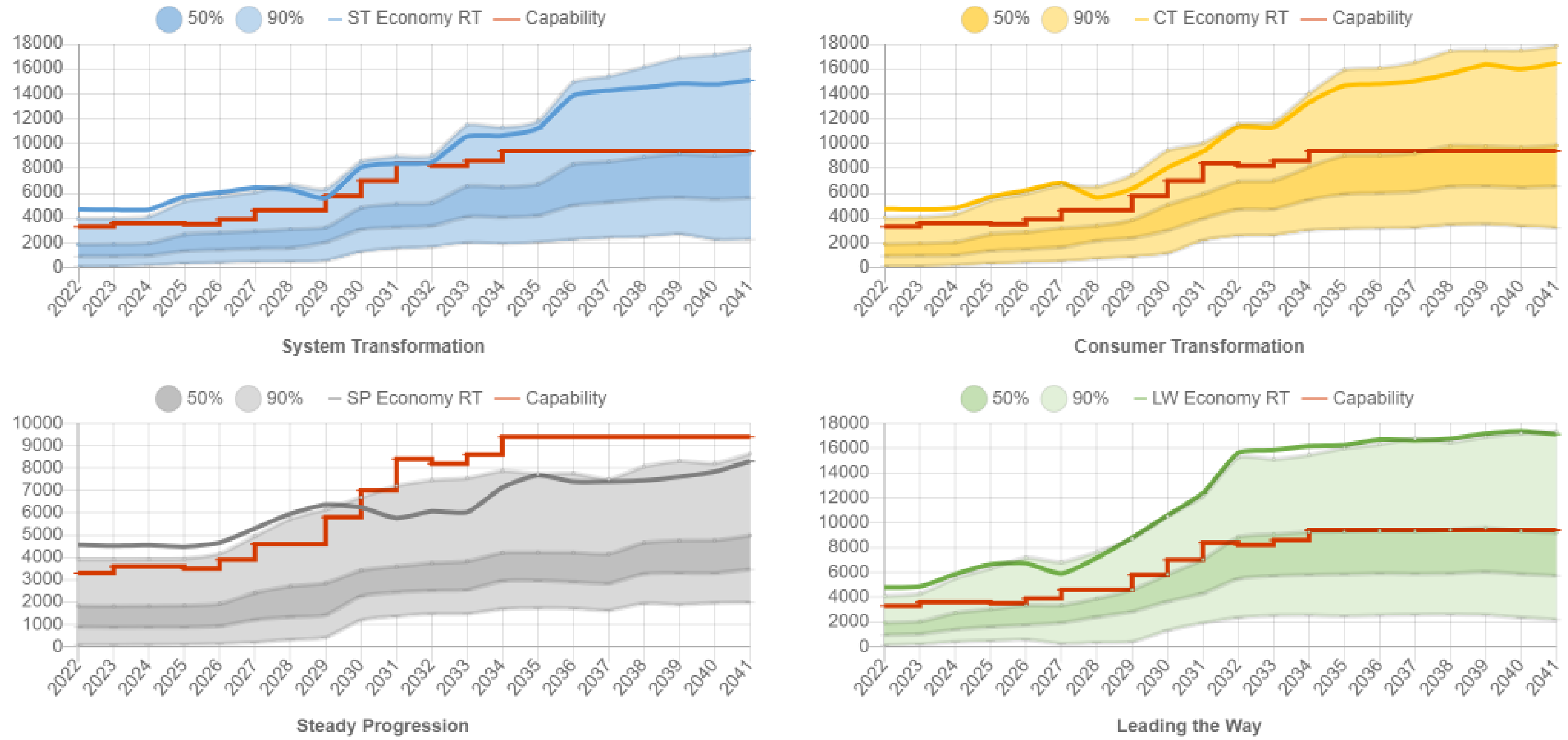
Boundary B2 cuts across the Scottish mainland from the east coast between Aberdeen and Dundee to near Oban on the west coast crossing the main north-south routes from the north of Scotland.



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

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

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



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

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

* ETYS Transfer capability calculated using the 2021/22 FES data

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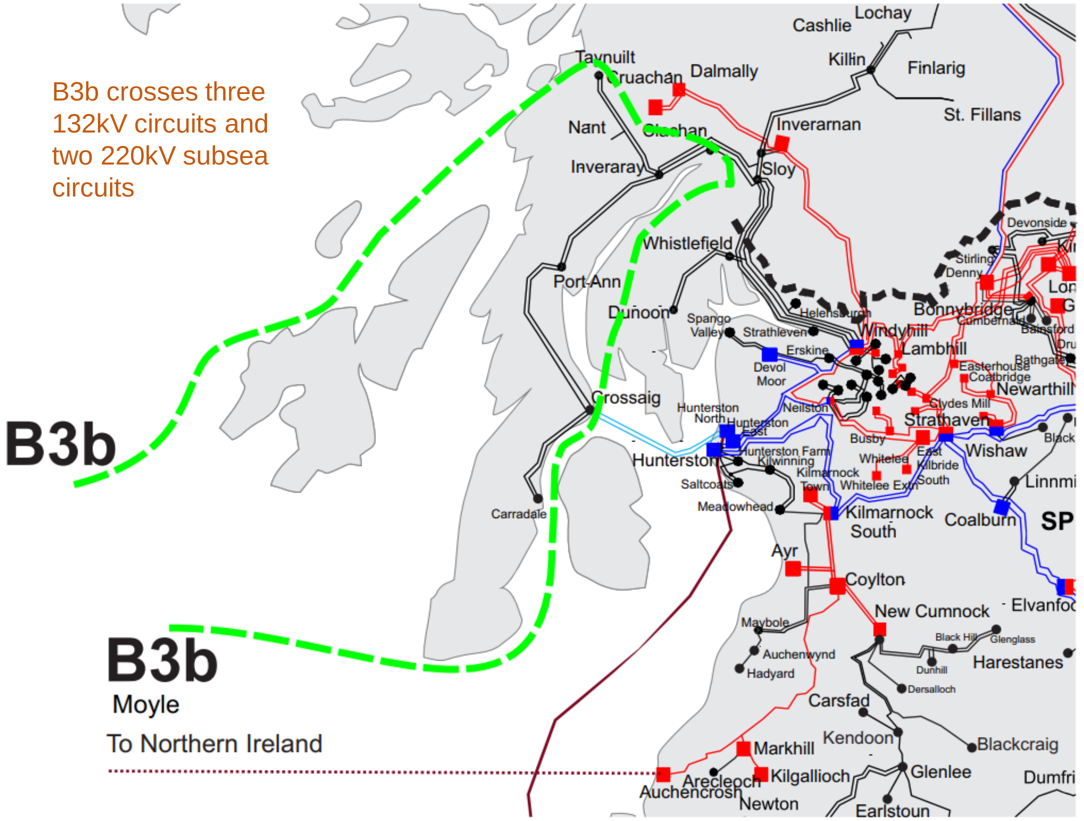
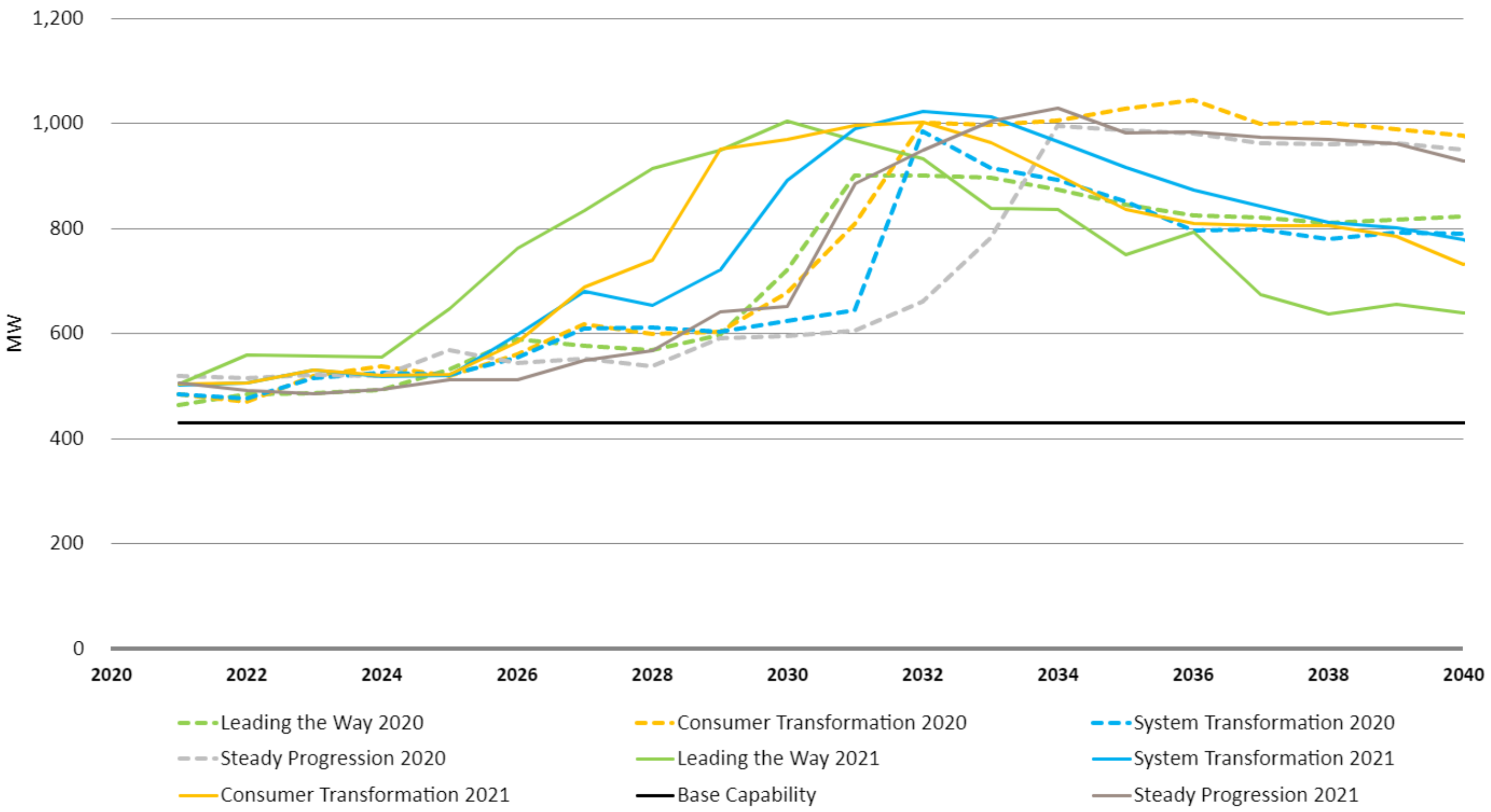
Boundary B3b – Kintyre and Argyll SSEN Transmission

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





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

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

The current boundary capability is limited to 0.45GW due to a thermal constraint on the Inveraray - Sloy 132kV circuit

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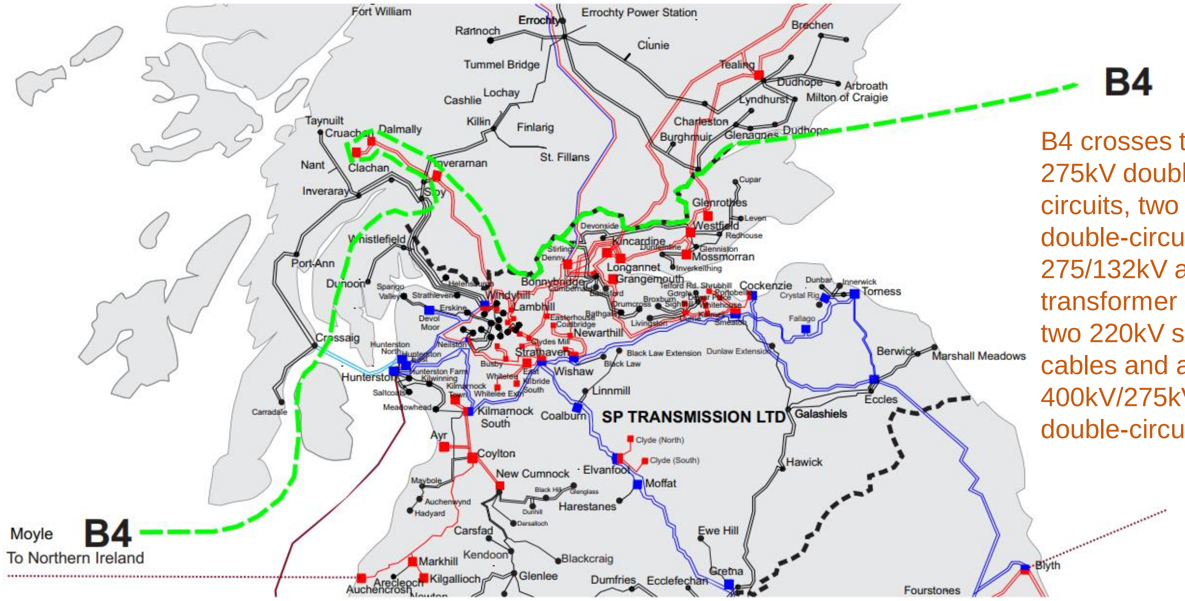
Boundary B4 – SSEN Transmission to SP Transmission

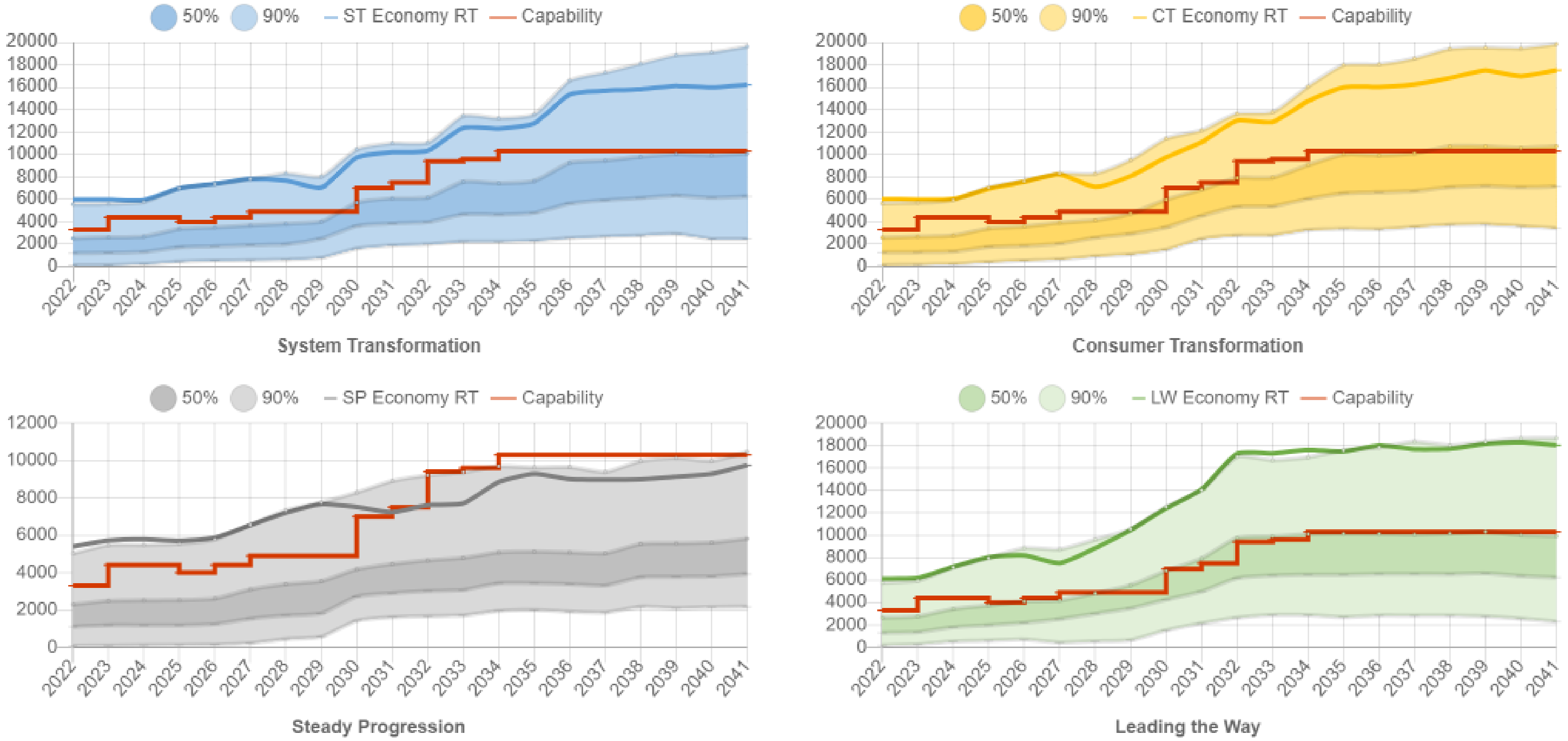
Boundary B4 separates the transmission network at the SP Transmission and SSEN Transmission interface running from the Firth of Tay in the east to the north of the Isle of Arran in the west.



B4 crosses two 275kV double-circuits, two 132kV double-circuits, two 275/132kV auto-transformer circuits, two 220kV subsea cables and a 400kV/275kV double-circuit

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

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



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

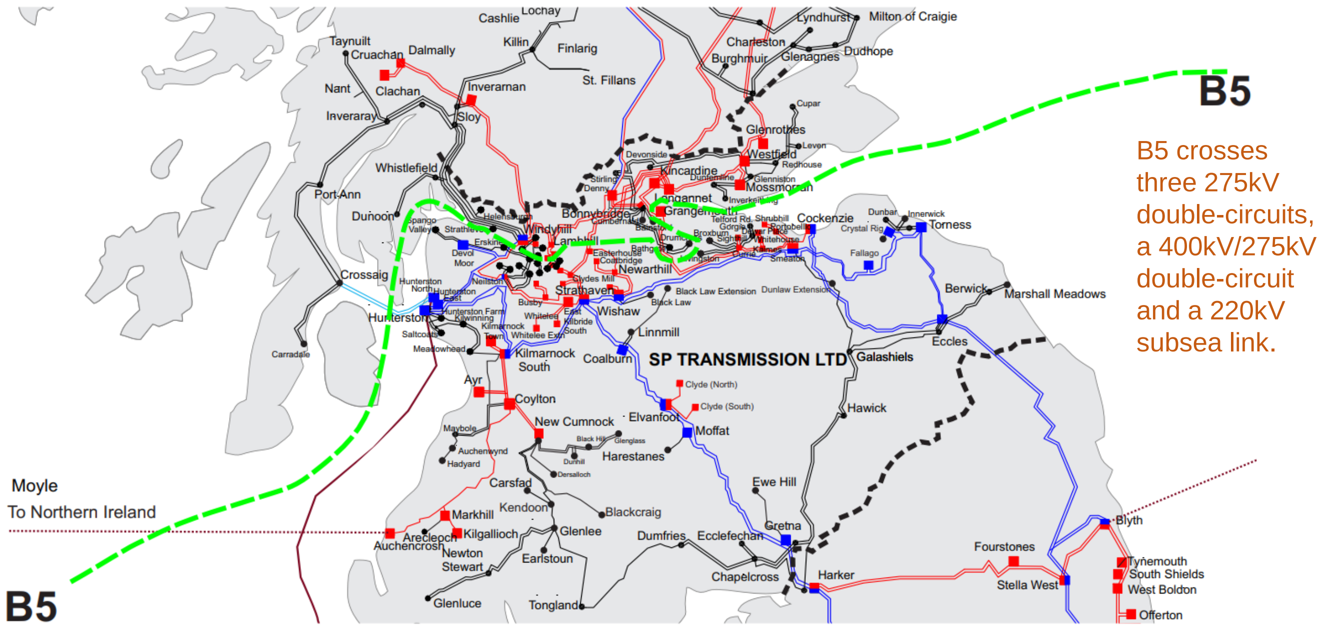
The current boundary capability is limited to 3.2GW* due to a thermal constraint on the Westfield - Longannet 275kV circuit

* ETYS Transfer capability calculated using the 2021/22 FES data

ETYS 2021 / Scotland 25

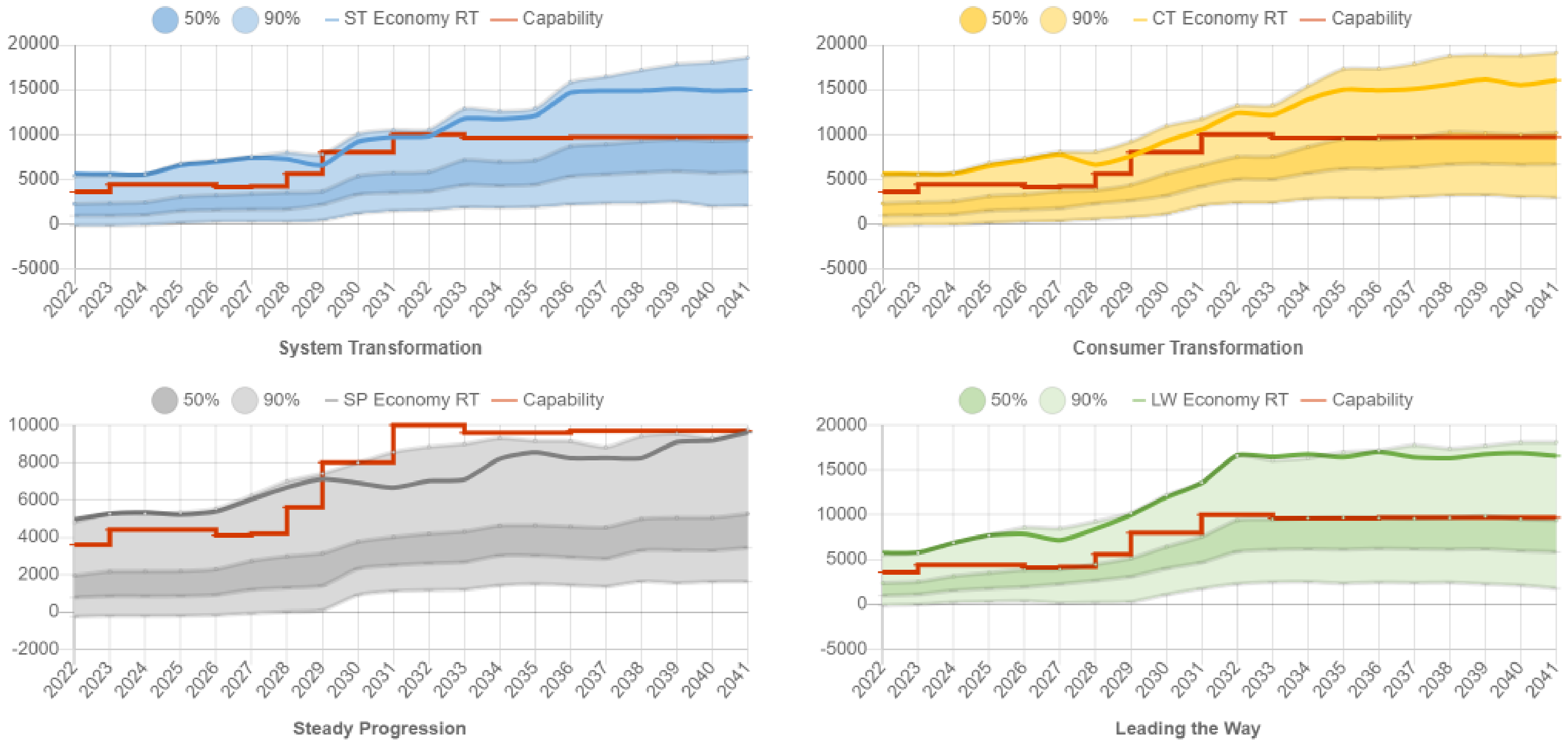
Boundary B5 – North to South SP Transmission

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



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

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



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

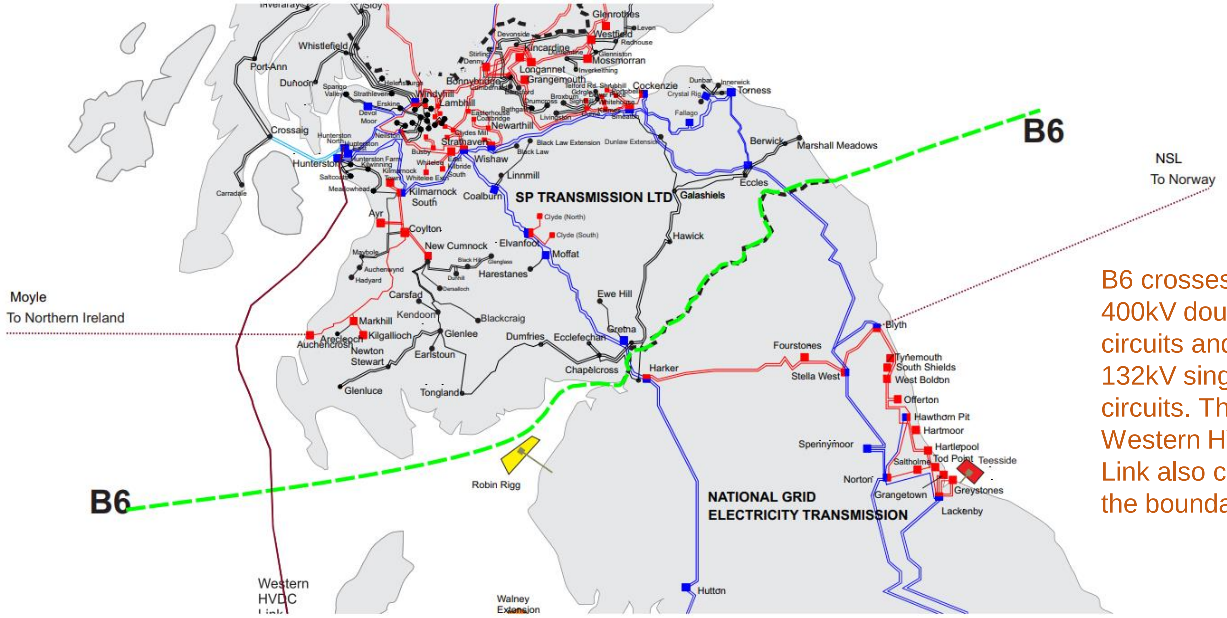
The current boundary capability is limited to 3.6GW* due to a thermal constraint on the Kincardine - Tealing 275kV circuit

* ETYS Transfer capability calculated using the 2021/22 FES data

ETYS 2021 / Scotland 26

Boundary B6 – SP Transmission to NGET

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

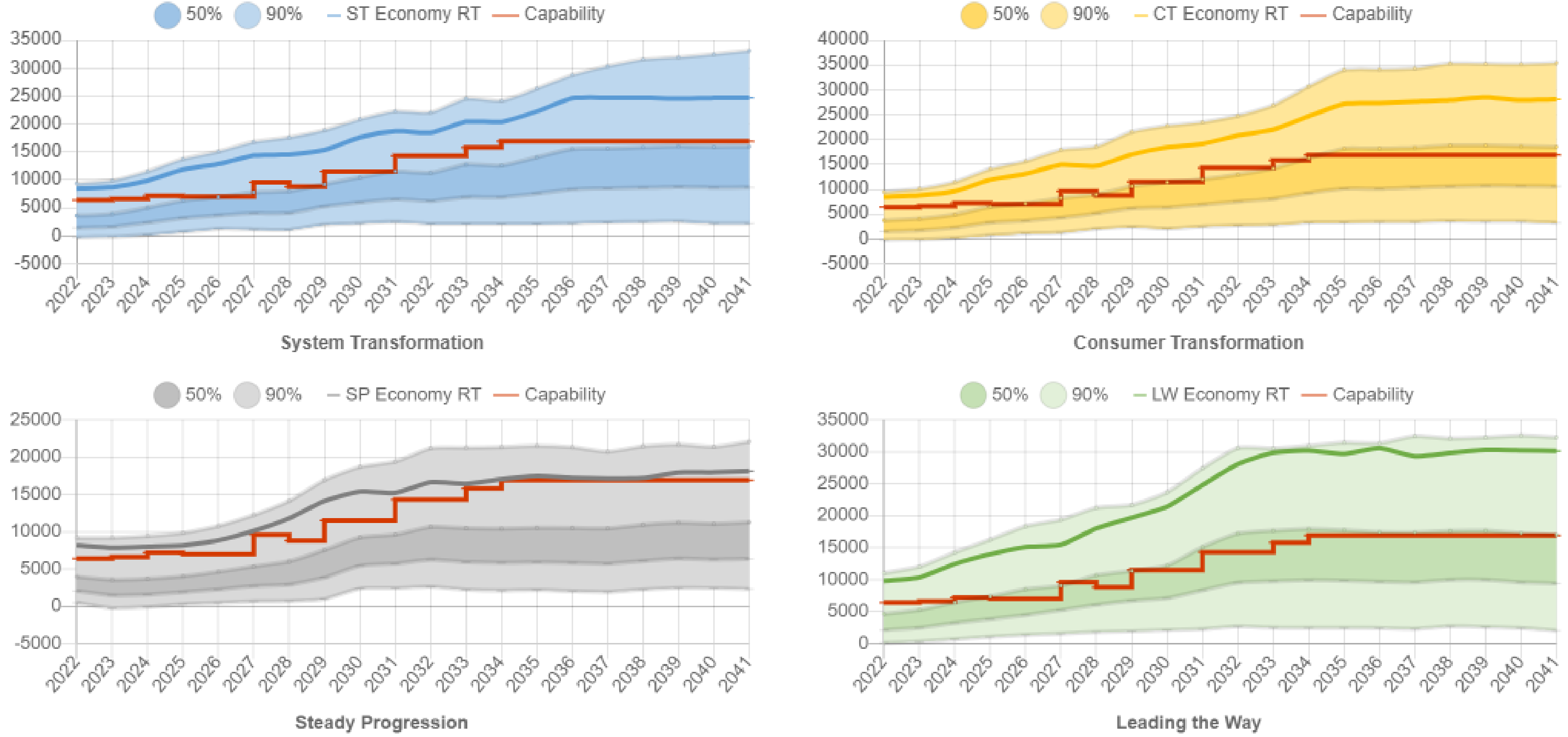


B6 crosses two 400kV double-circuits and two 132kV single-circuits. The Western HVDC Link also crosses the boundary.

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.

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

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



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

The current boundary capability is limited to 6.1GW* due to a thermal constraint on an SGT at Harker

* ETYS Transfer capability calculated using the 2021/22 FES data

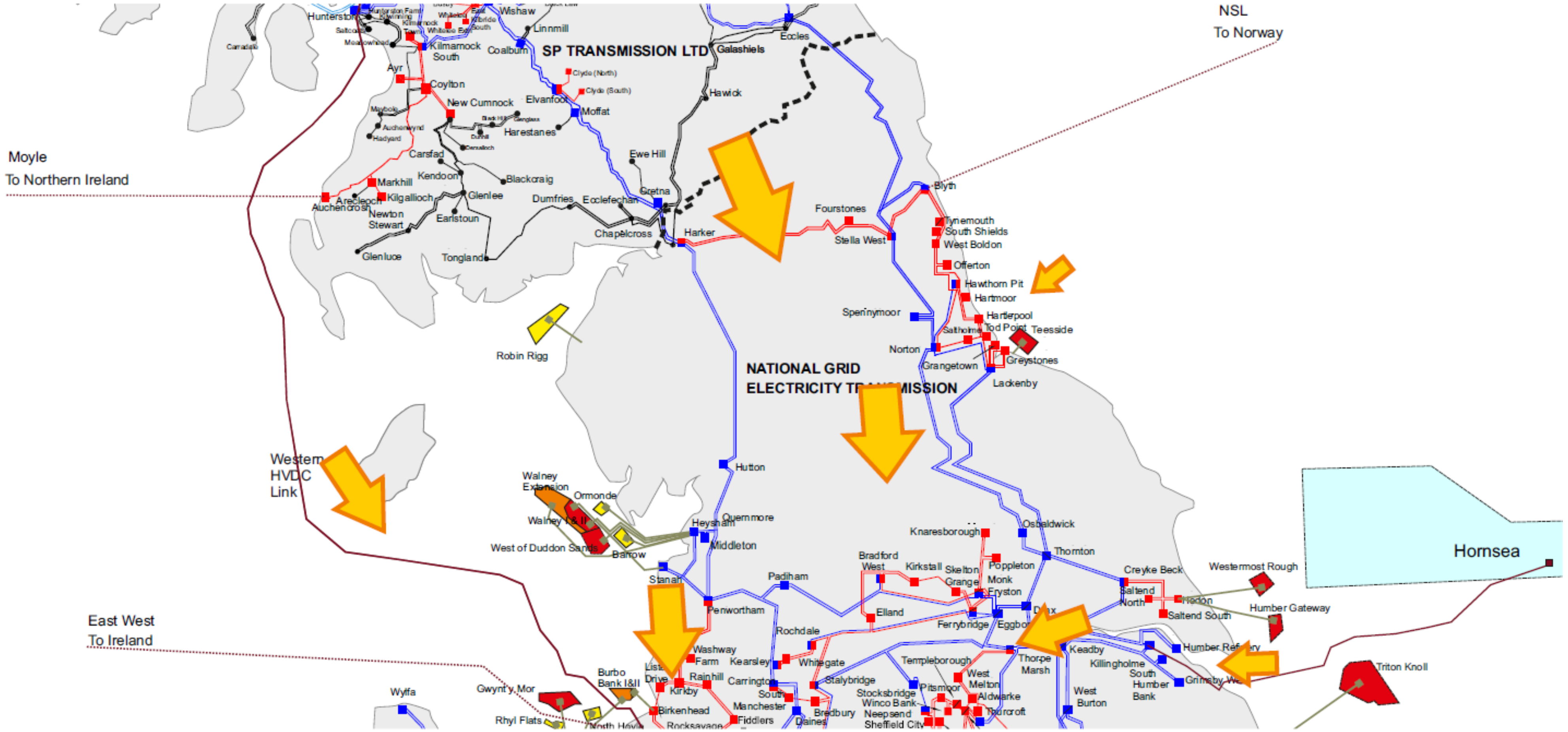
ETYS 2021 / Scotland 27

North of England

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

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

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



ETYS 2021 / North of England 28

Regional Drivers – North of England

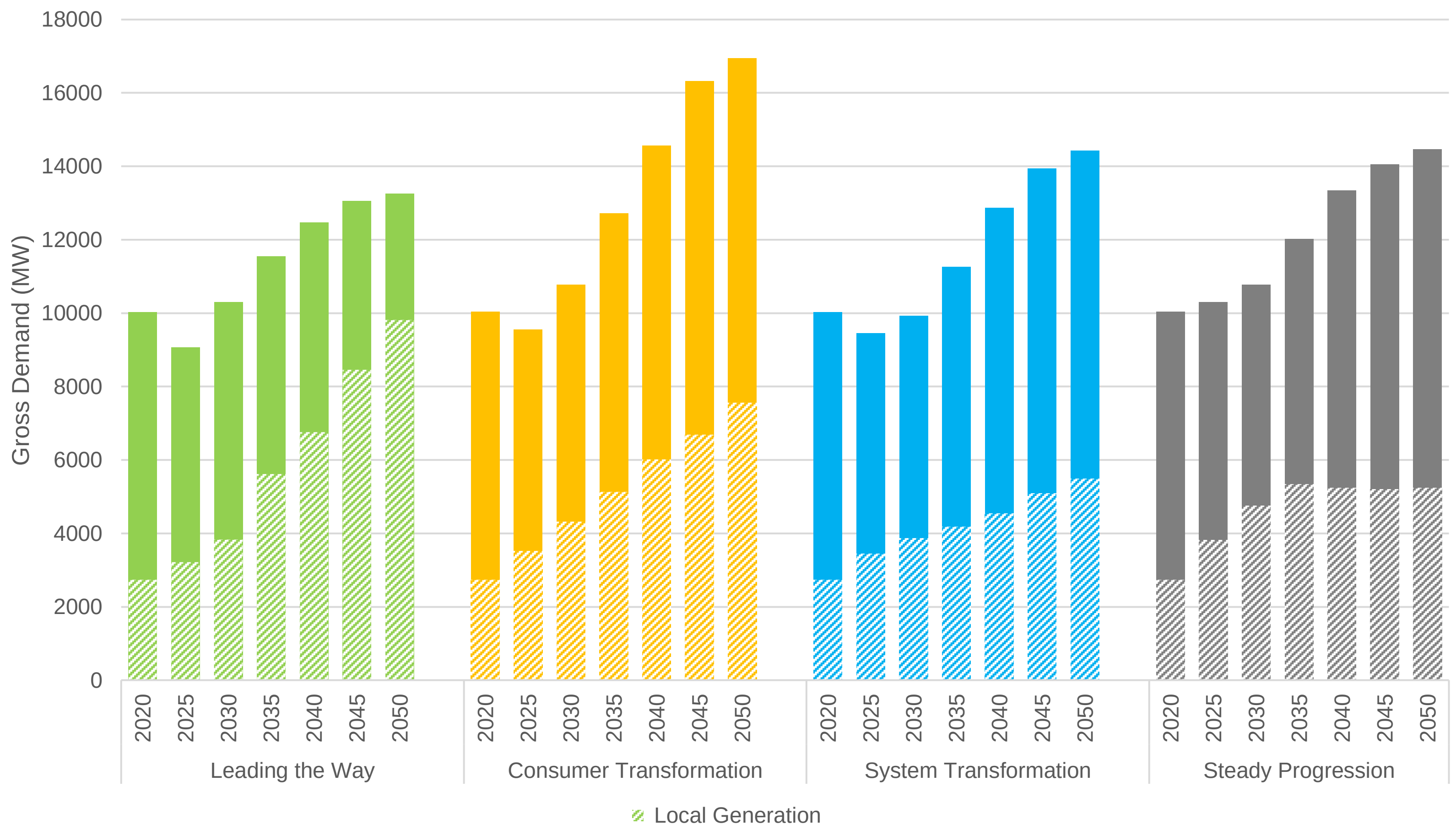
The connection of large amounts of new generation, most of which is intermittent renewables, in Scotland and the north will cause overloading in the northern transmission network unless appropriate reinforcements are in place. Future power transfer requirements could be more than double compared to what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

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

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

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

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



Regional Drivers – North of England

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

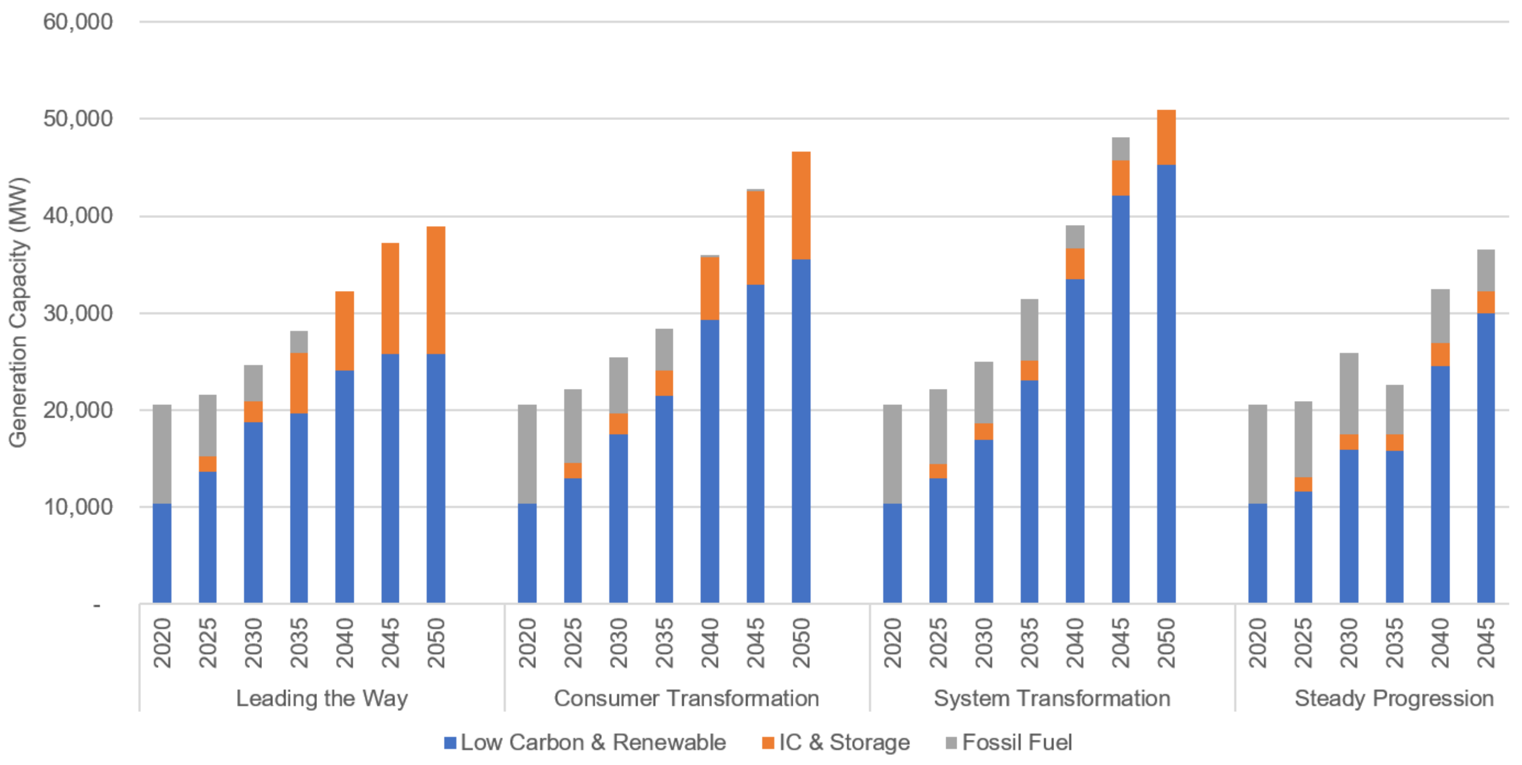
At times of high wind generation, the power flow will mostly be from north to south, with power coming from both internal boundary generation and generation further north in Scotland.

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

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

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

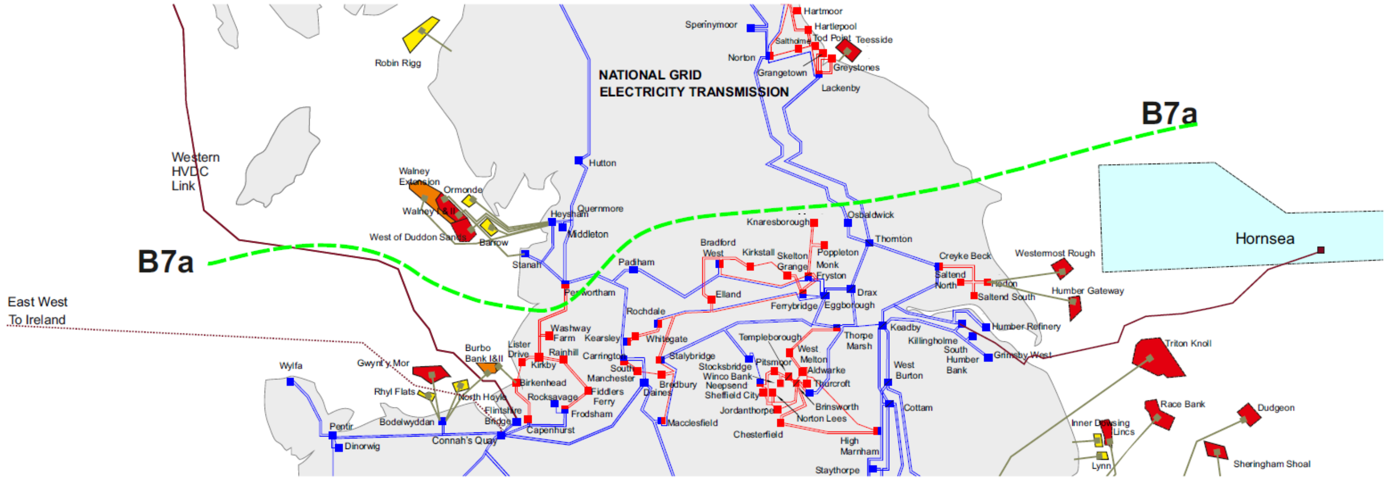
The need for network reinforcement to address the potential capability issues will be evaluated in the NOA 2021/22 CBA.



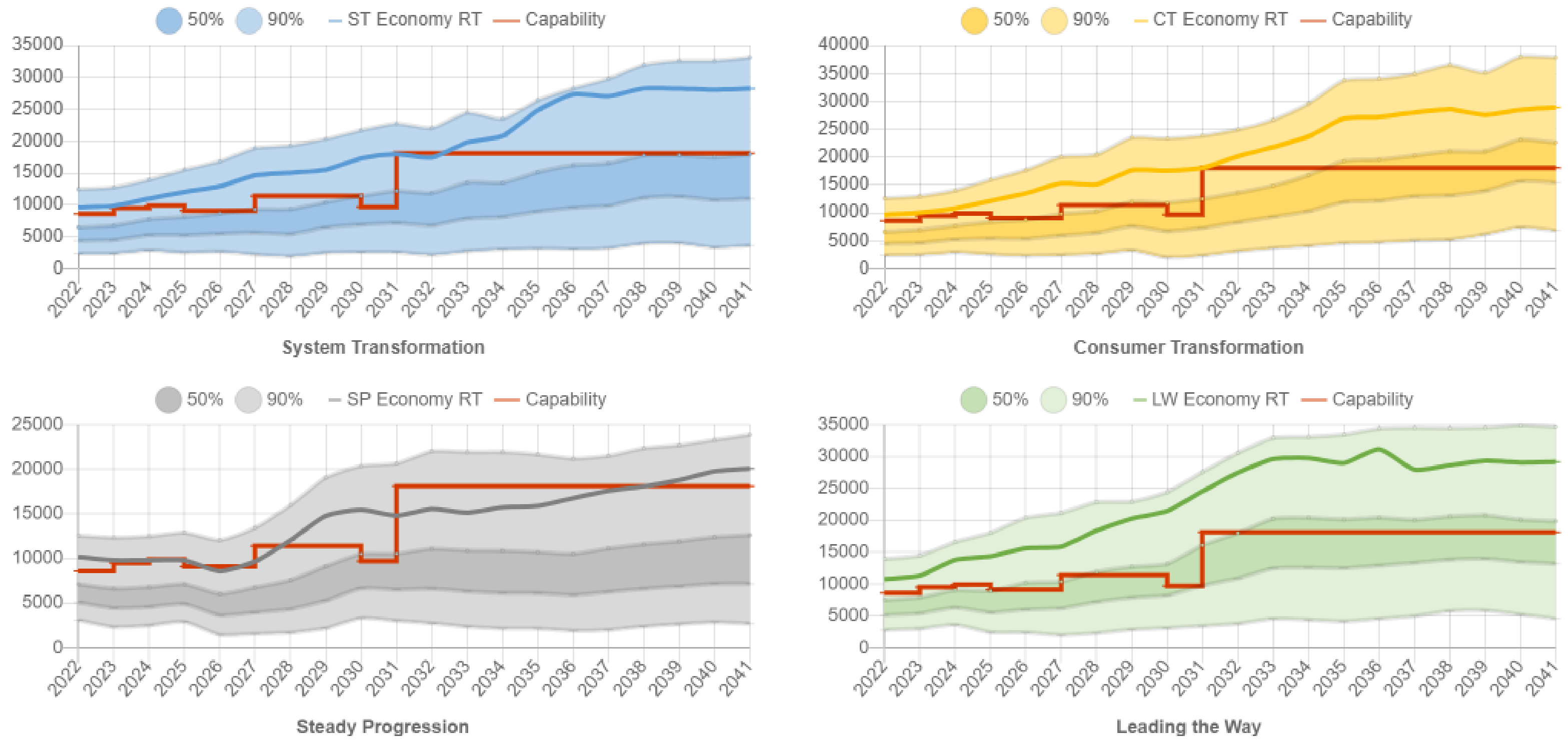
ETYS 2021 / North of England 30

Boundary B7a – Upper North of England

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



B7a crosses three 400kV double-circuits and one 275kV circuit. The Western HVDC Link also crosses the boundary.



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

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

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

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

The current boundary capability is limited to 9.43GW* due to a thermal constraint on the Offerton - West Boldon 275kV circuit

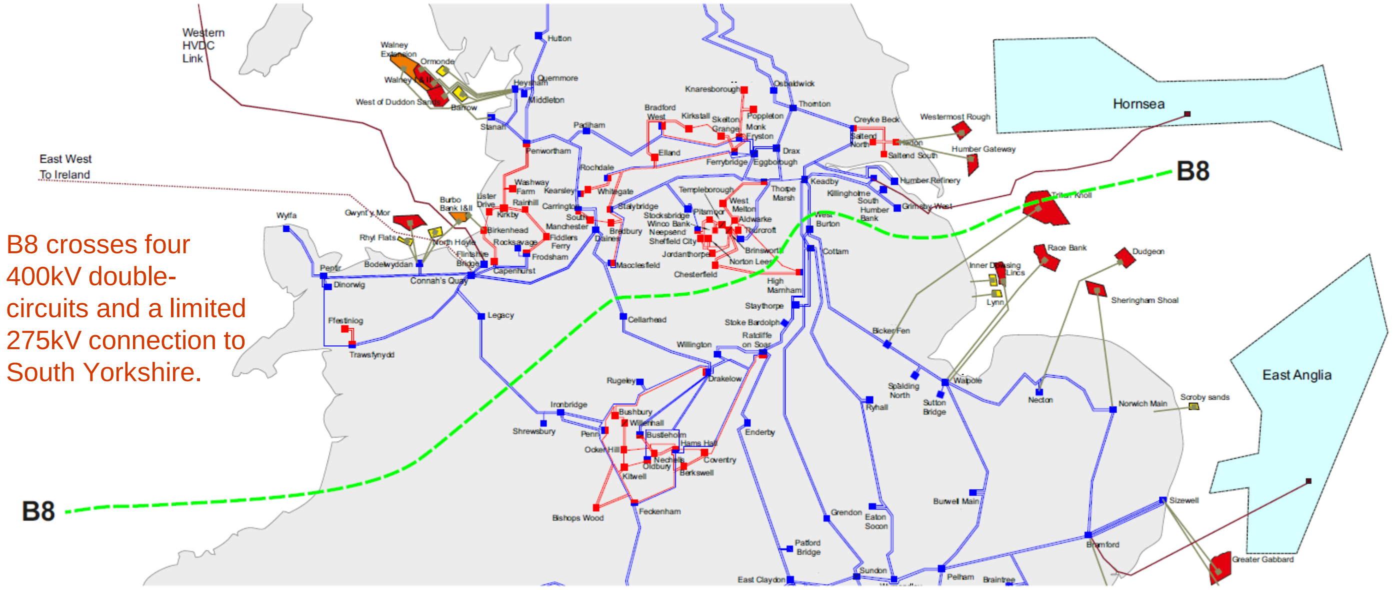
* ETYS Transfer capability calculated using the 2021/22 FES data

ETYS 2021 / North of England 31

Boundary B8 – North of England to Midlands

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

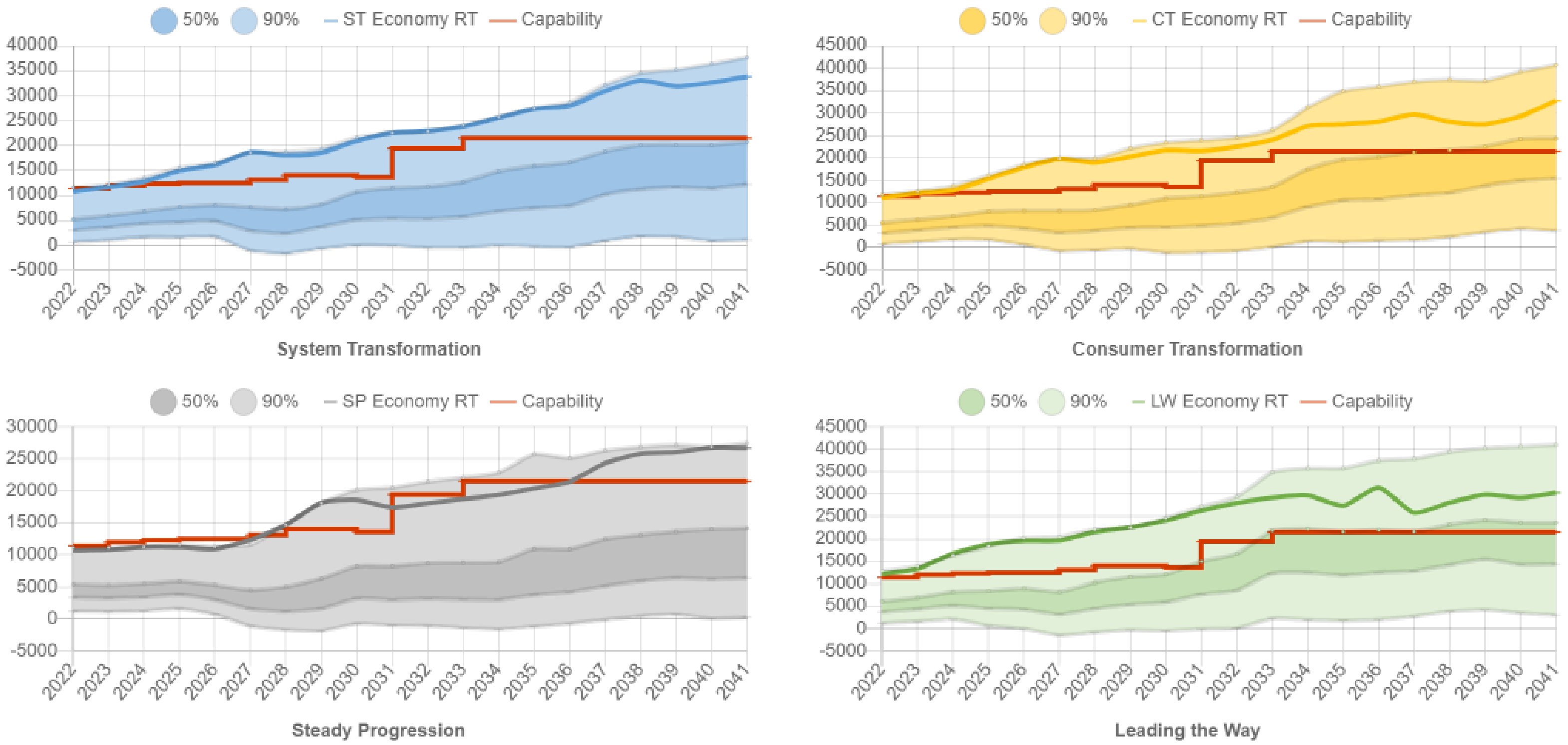
B8 crosses four 400kV double-circuits and a limited 275kV connection to South Yorkshire.



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

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

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



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

The current boundary capability is limited to 11.4GW* due to a thermal constraint on the Cellerhead - Drakelow 400kV circuit

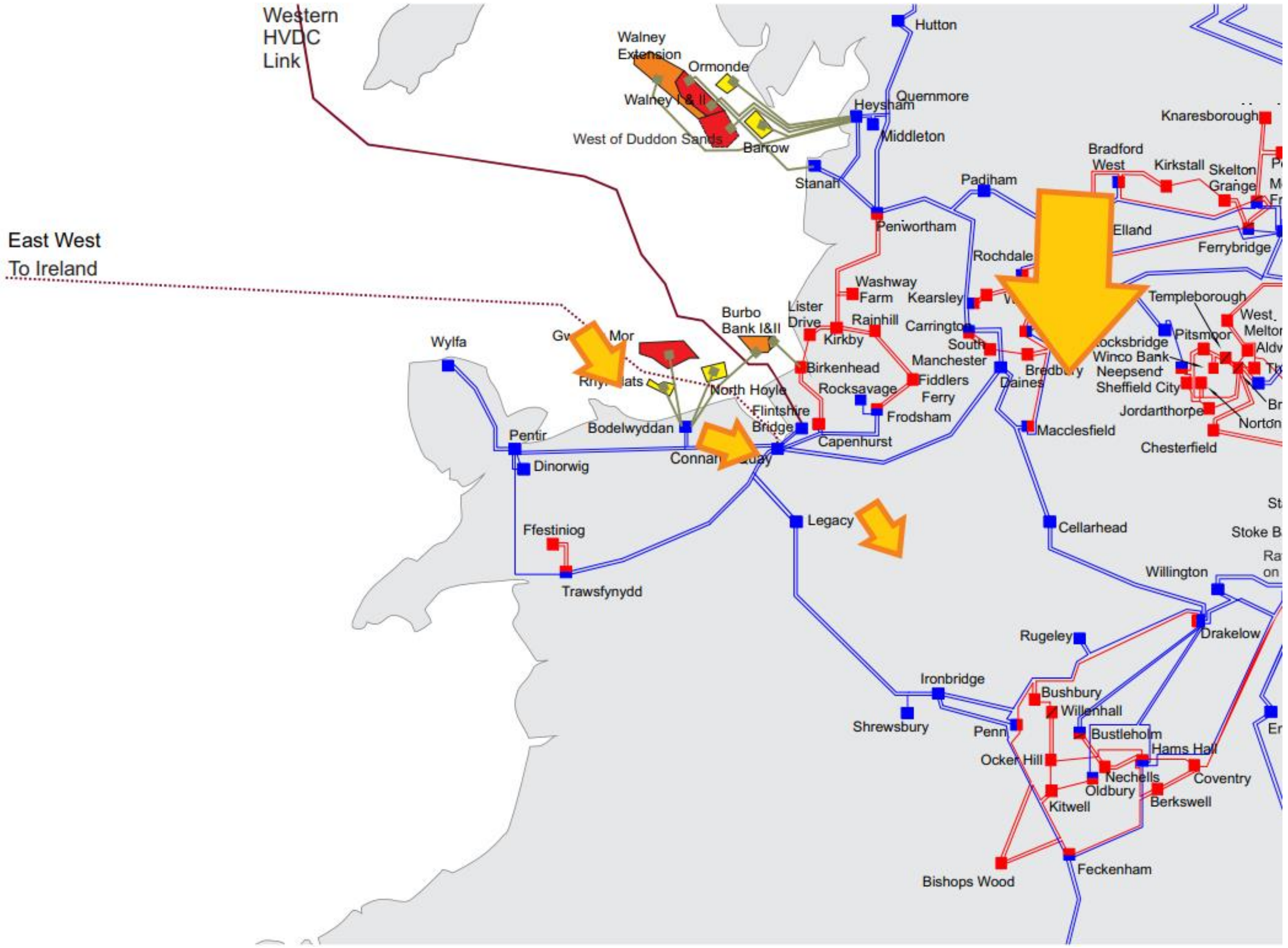
* ETYS Transfer capability calculated using the 2021/22 FES data

North Wales and the Midlands

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

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

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



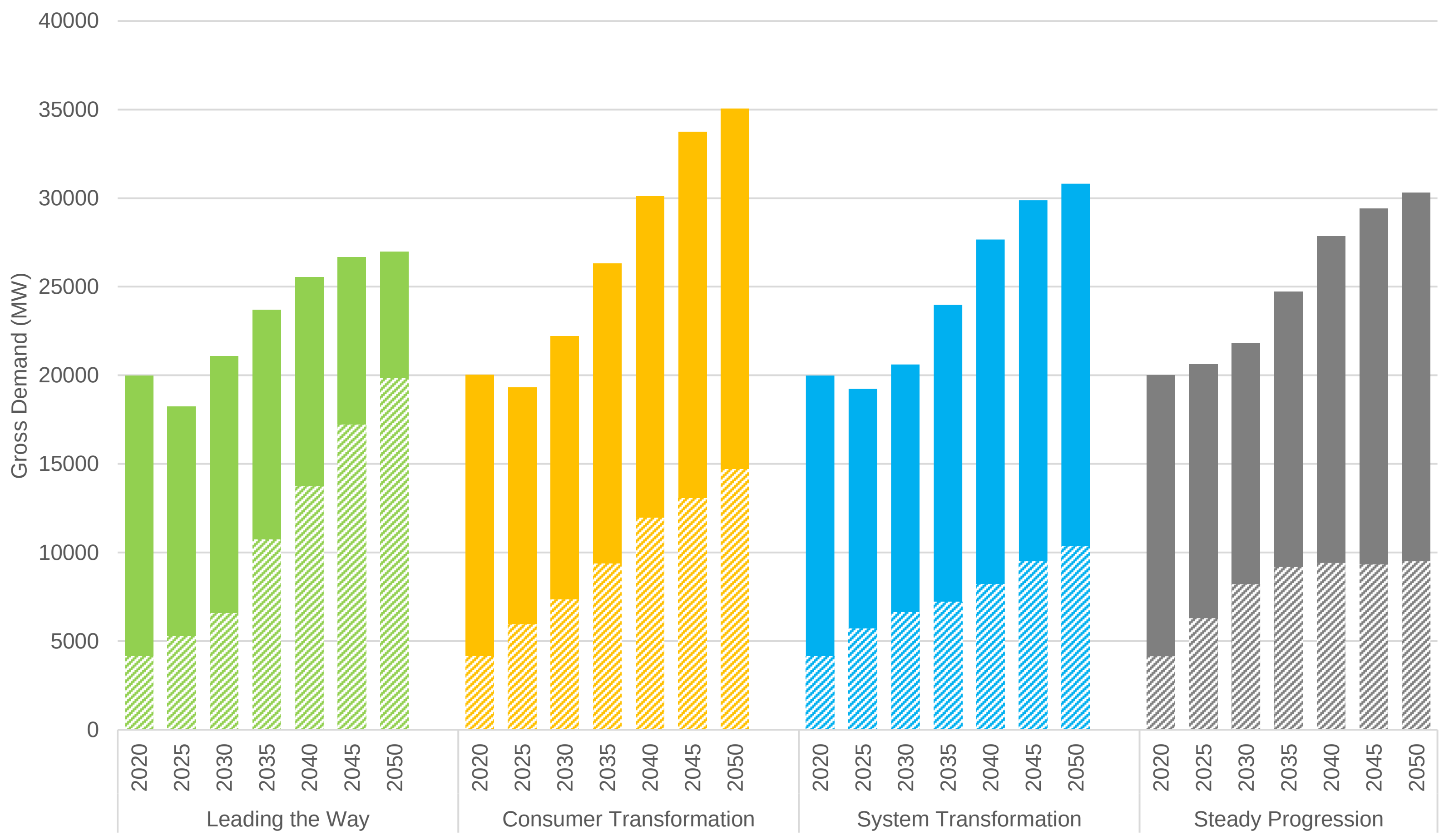
Regional Drivers – North Wales & Midlands

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

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

In a highly decentralised scenario like Leading the Way, local generation capacity connected at the distribution level in this western region could reach 23GW by 2030. Of that capacity, a typical embedded generation output on average might be around 7GW. This will vary depending on factors like wind speeds, and how other local generators decide to participate in the market.

Across all scenarios, this region maintains a relative balance between its growth in both gross demand and transmission connected generation capacity. North Wales and the Midlands is not and is not expected to become a heavily exporting or importing region before 2050.



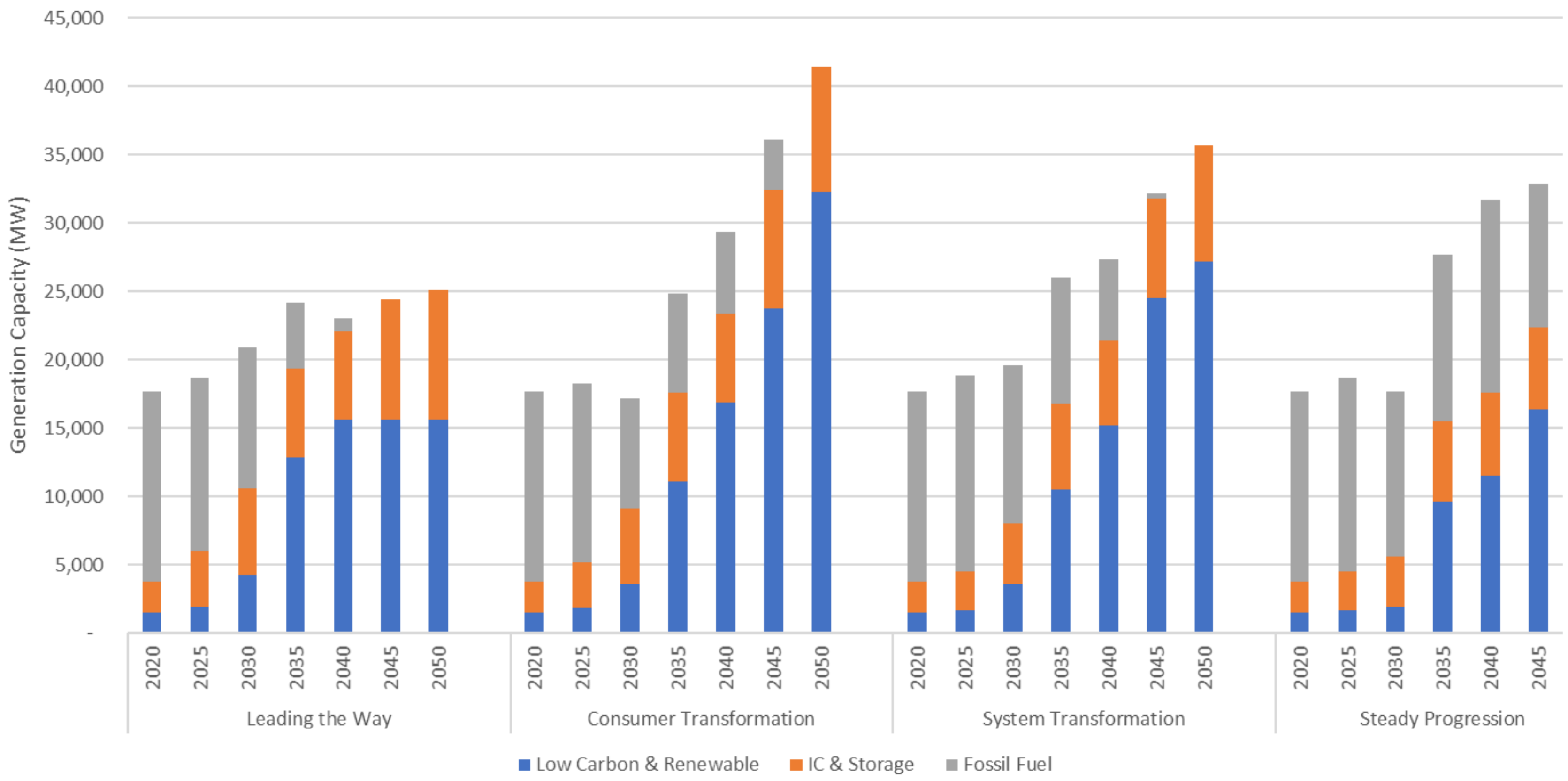
ETYS 2021 / North Wales & Midlands 34

Regional Drivers – North Wales & Midlands

By 2030, the scenarios suggest a total amount of transmission-connected generation capacity of between 17GW to 21GW, from the current 17GW. At present, this region has significant levels of fossil fuel (about 14GW). All scenarios show a decline in fossil fuel with slight growth in interconnectors and storage and a significant growth in low-carbon technologies. For all scenarios other than Steady Progression, fossil fuel generation is not present in the region by 2050.

A new 0.5GW interconnector to Ireland will be connecting in this region from 2024 and in additions there will be between 1 – 3.5 GW of additional storage connecting in this region by 2030.

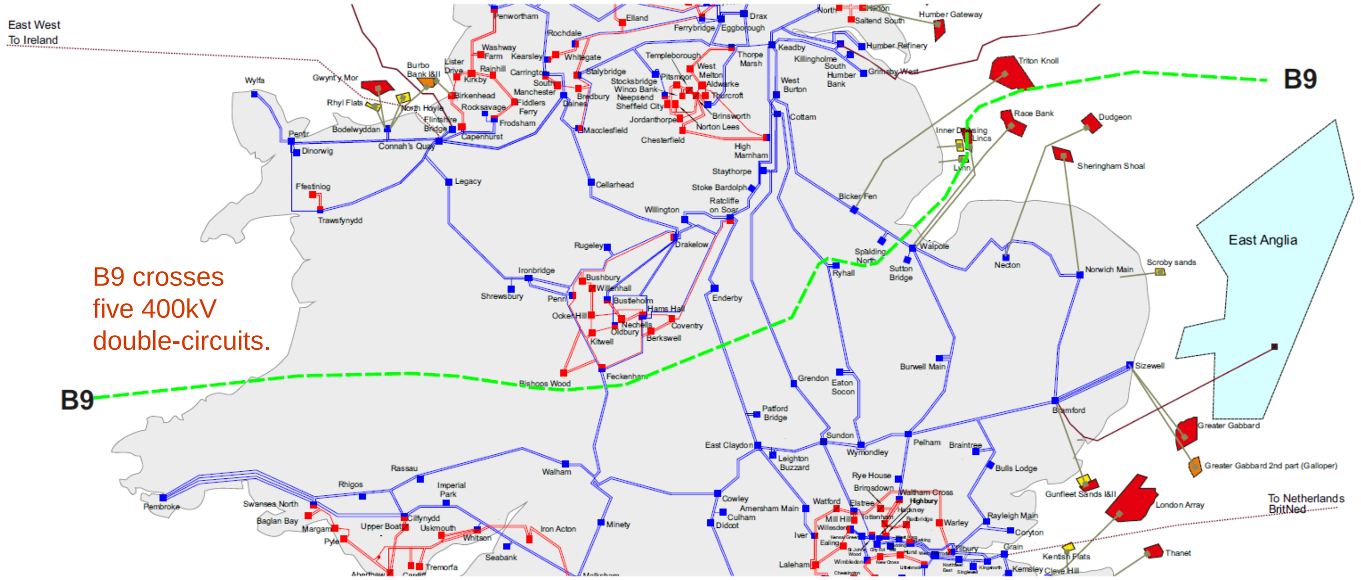
The need for network reinforcement to address the above mentioned potential capability issues will be evaluated in the NOA 2021/22 CBA.



ETYS 2021 / North Wales & Midlands 35

Boundary B9 – Midlands to South of England

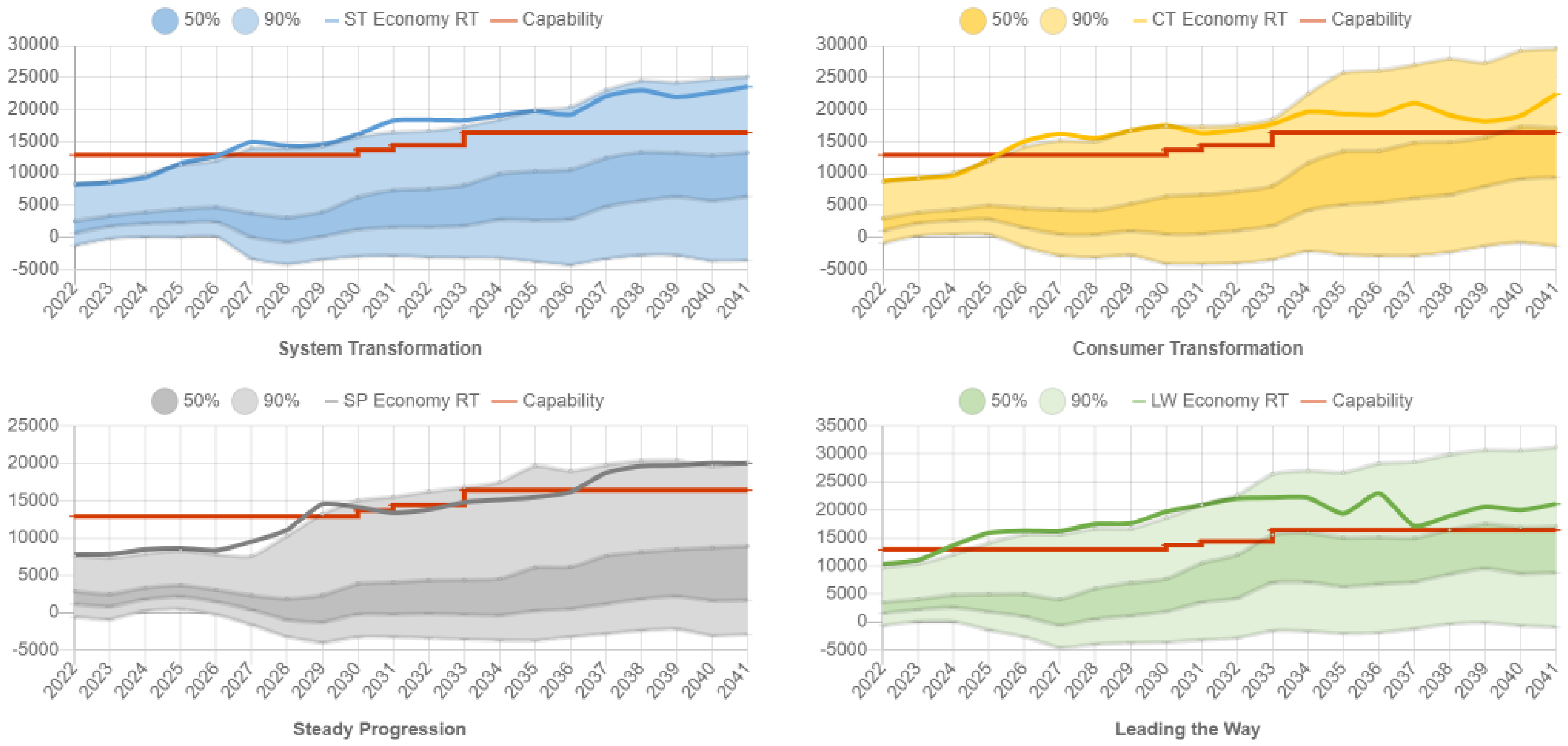
Boundary B9 separates the northern generation zones and the southern demand centres.



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

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

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



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

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

* ETYS Transfer capability calculated using the 2021/22 FES data

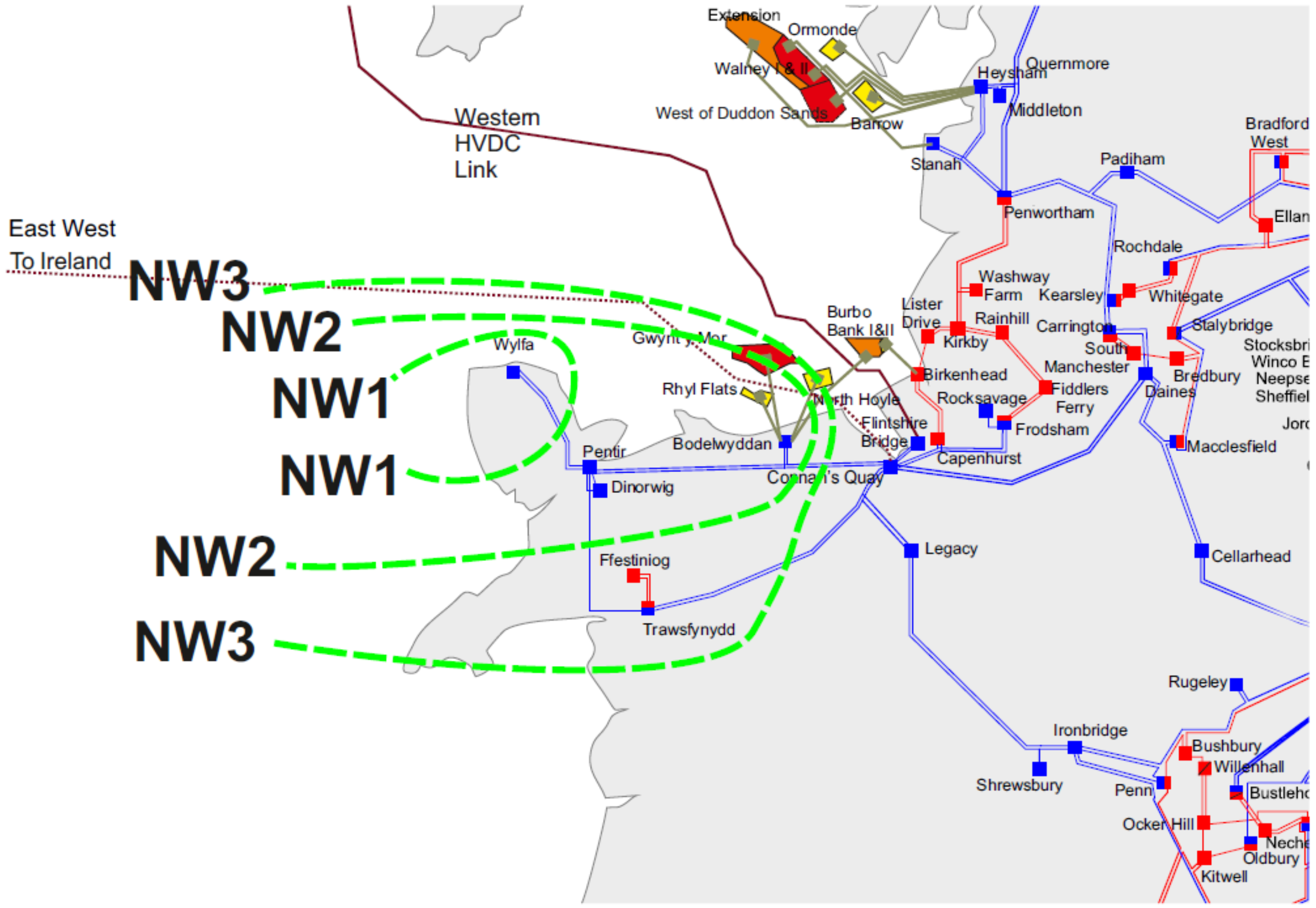
ETYS 2021 / North Wales & Midlands 36

North Wales

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

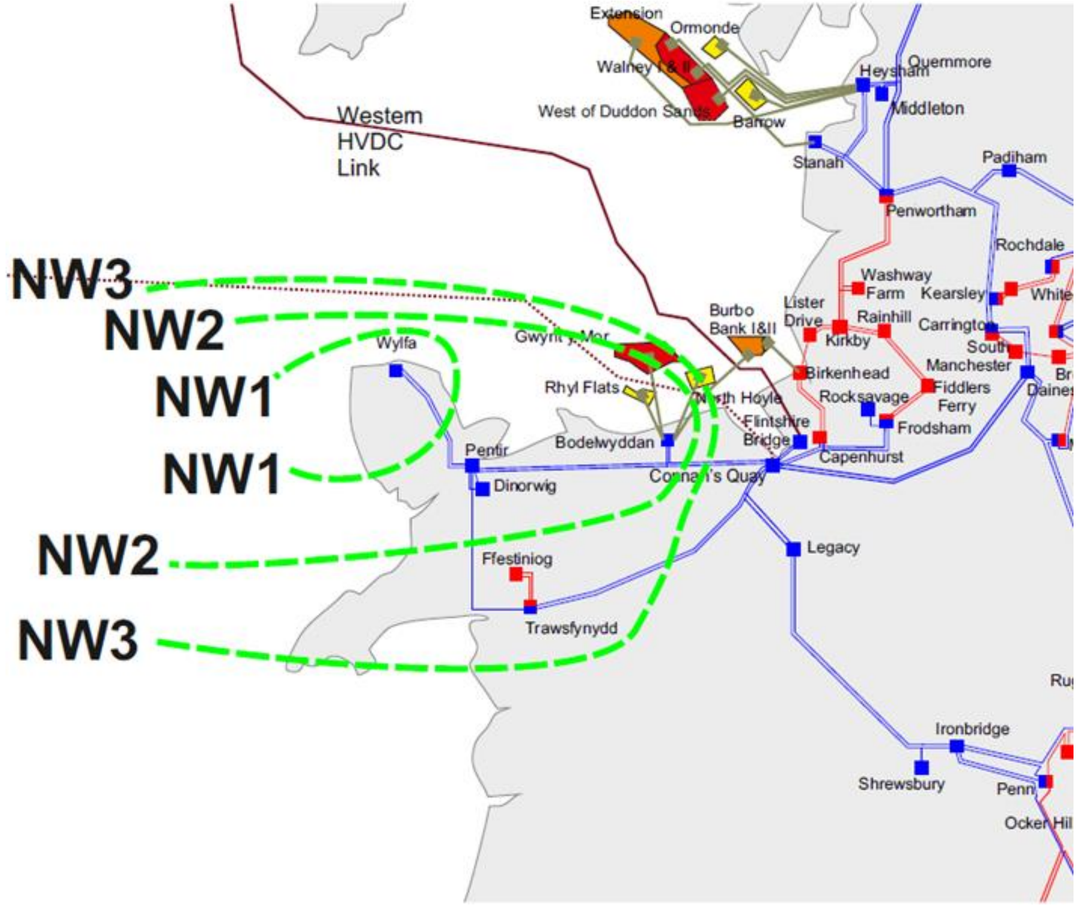
A 400kV double-circuit spur crossing the Menai Strait and running the length of Anglesey connects the now decommissioned nuclear power station at Wylfa to Pentir. A short 400kV double-circuit cable spur from Pentir connects Dinorwig pumped storage power station. In addition, a 275kV spur traverses north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

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

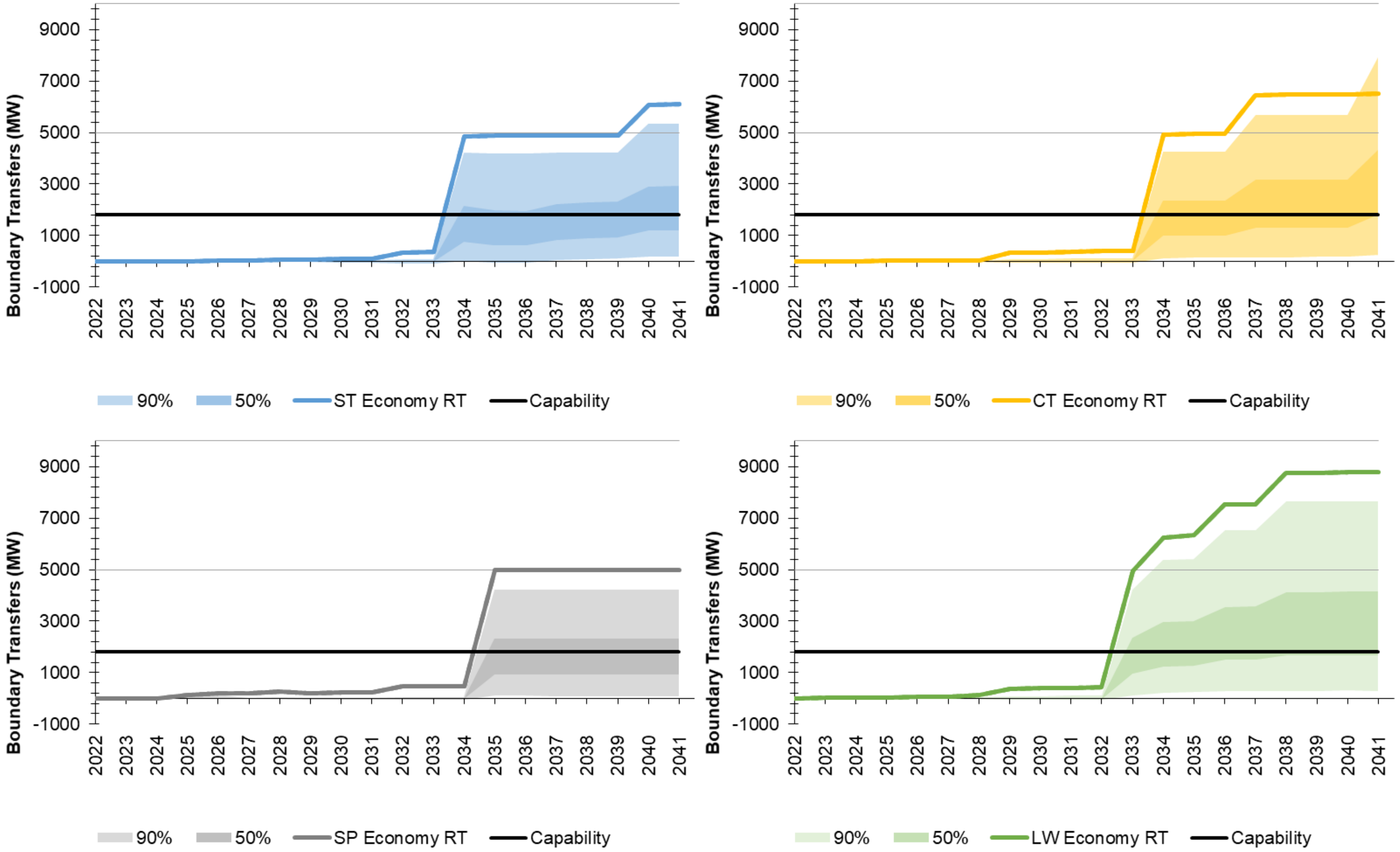


ETYS 2021 / North Wales & Midlands 37

Boundary NW1 - Anglesey



For all scenarios in the FES, the requirements increase to above the boundary capability for NW1. Last year, only the System Transformation and Consumer Transformation scenarios did so. This increase suggests a need for additional boundary capability in the near future for NW1 to support the increasing amounts of generation behind it.

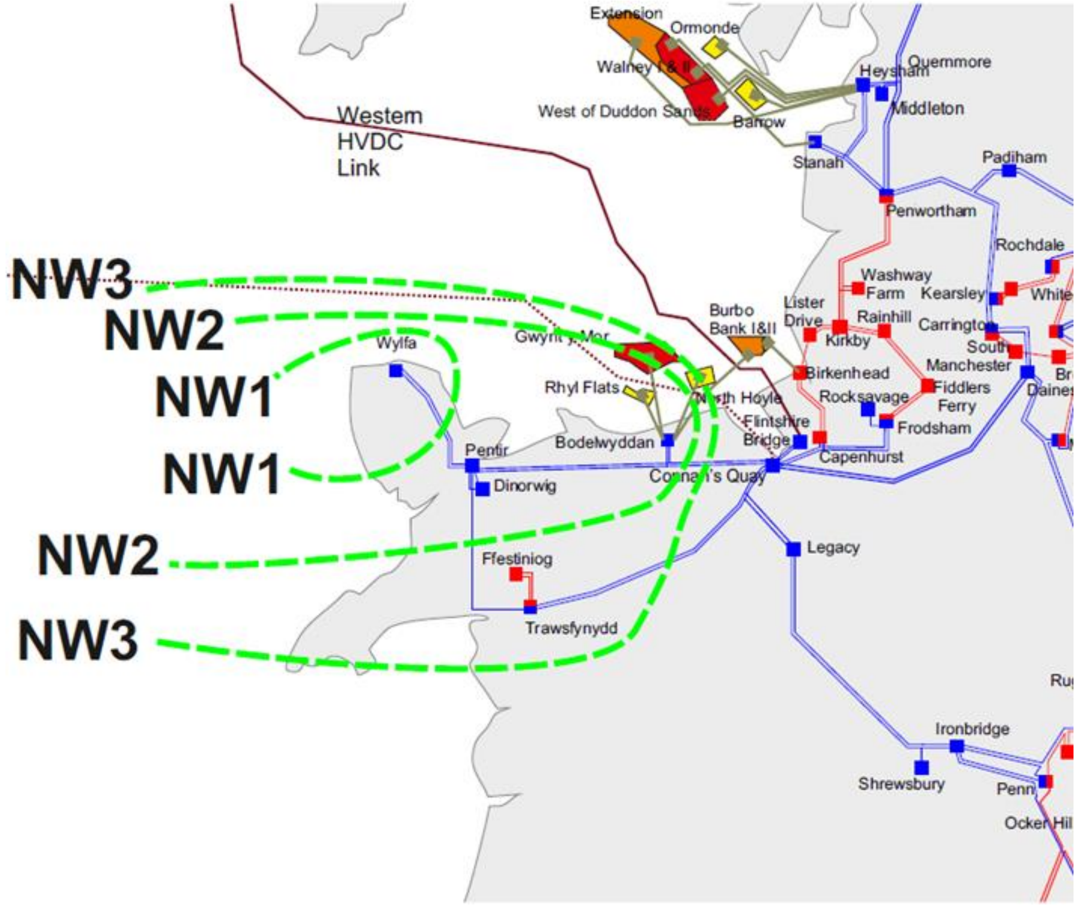


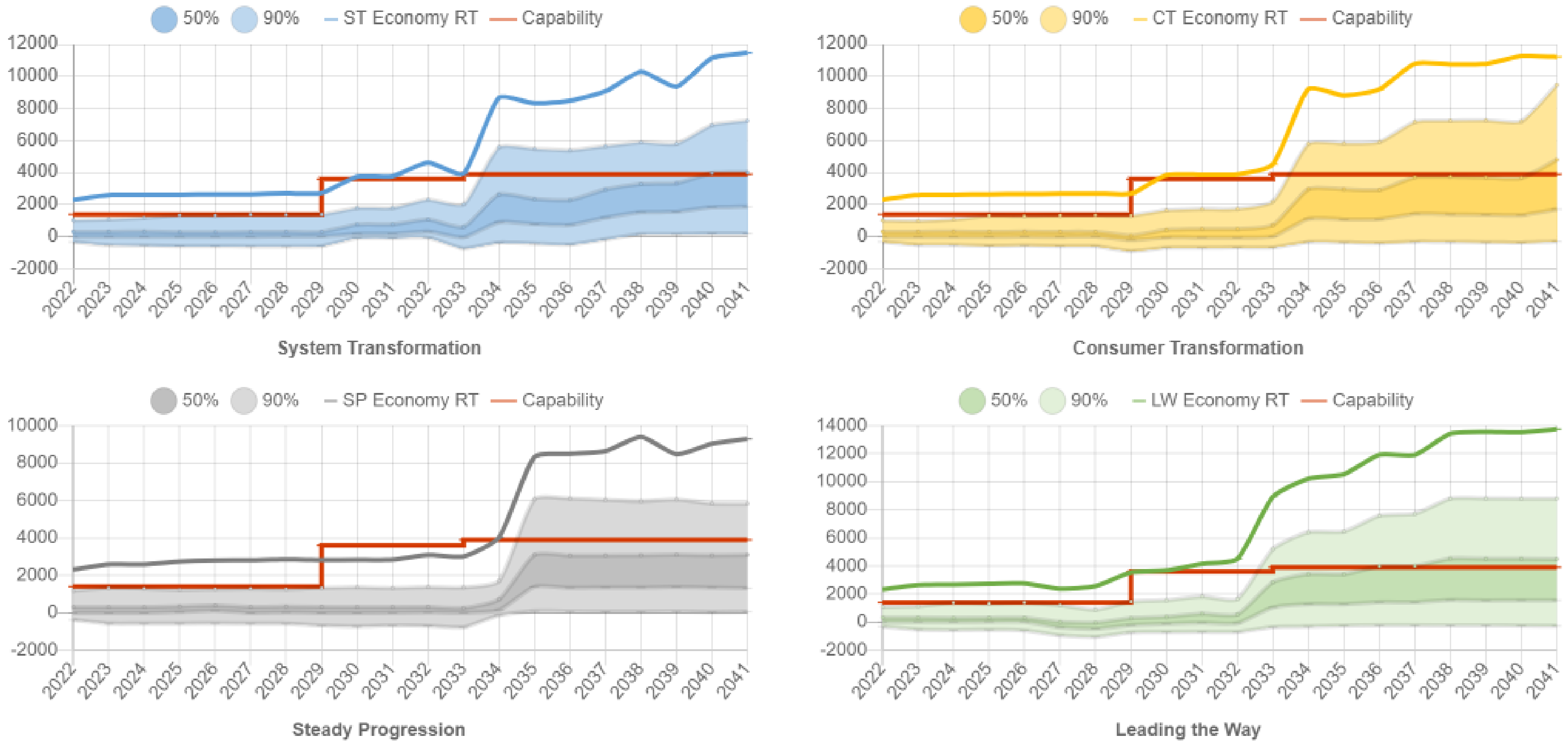
The capability line (in black) is based on the ETYS transfer capability using FES 2021/22 data, shown below.

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

ETYS 2021 / North Wales & Midlands 38

Boundary NW2 – Anglesey and Caernarvonshire





Across all four FES scenarios, the SQSS economy required transfer is higher than the current capability. The expected power flows only see significant changes from around 2033 when they increase very sharply as large new offshore wind projects come online.

The scenarios show a similar requirements until 2033 where they diverge due to different assumptions of connection time and dispatching of potential offshore wind and biomass generation behind this boundary.

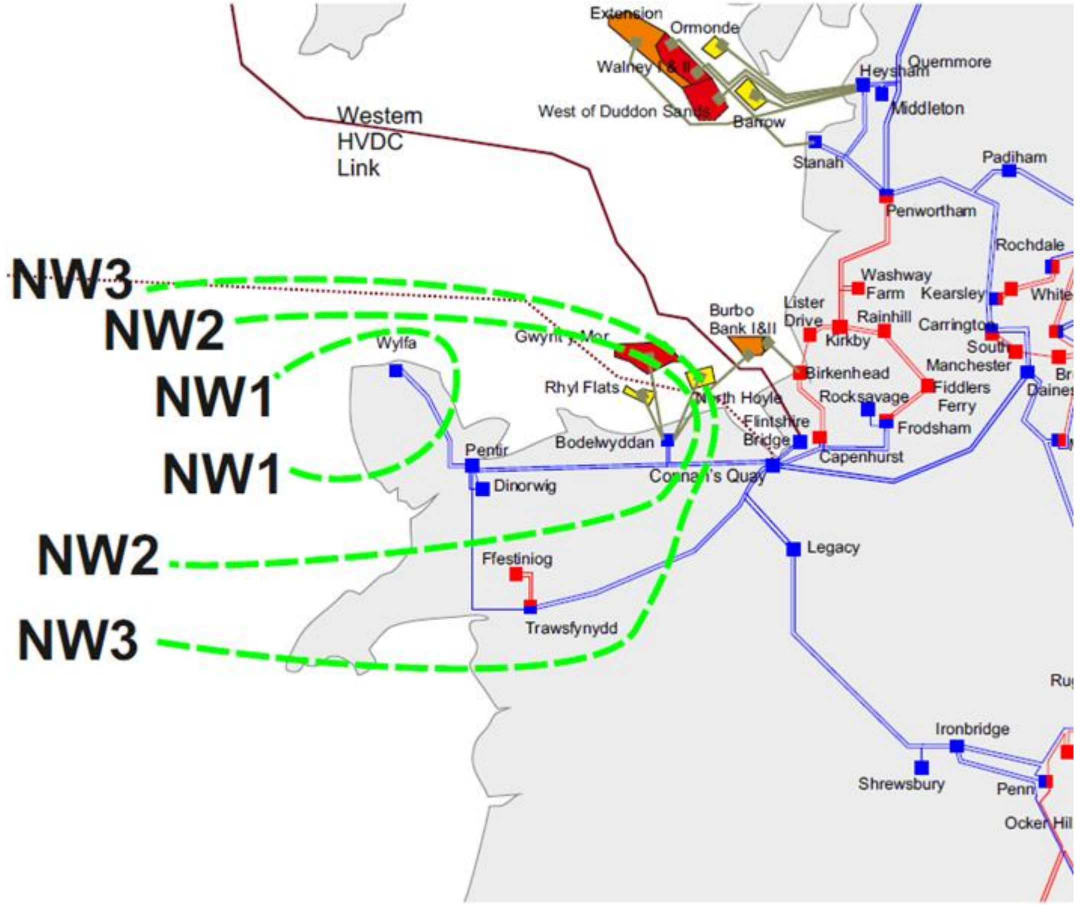
The capability line (in red) is based on the recommendations from the NOA 2021/22 optimal path which uses the 2021 FES and ETYS data as inputs. The 50%, 90% Economy RT and Security RT lines are based on FES 2021. The ETYS and NOA methodologies for this boundary are different and can result in different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

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

* ETYS Transfer capability calculated using the 2021/22 FES data

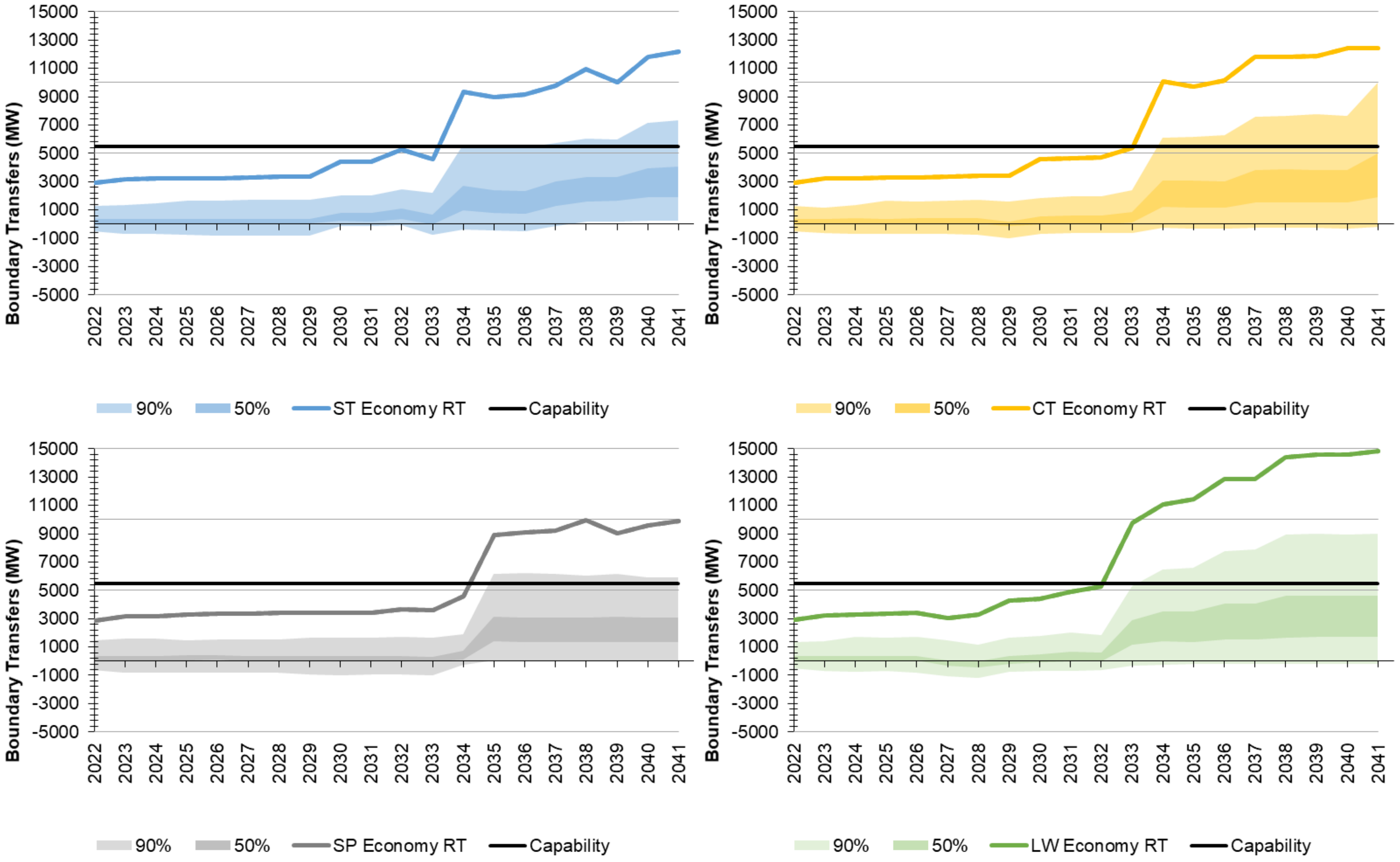
ETYS 2021 / North Wales & Midlands 39

NW3 – Anglesey, Caernarvonshire and Merionethshire



Across all four FES scenarios, the SQSS economy required transfer grows beyond the present boundary capability only after 2033 onwards. The expected power flows only see significant changes from around 2033 when they increase very sharply as large new offshore wind projects come online.

The scenarios show a similar requirement until 2033 where they diverge due to different assumptions of connection time and dispatching of potential offshore wind and biomass generation behind this boundary



The capability line (in black) is based on the ETYS transfer capability using FES 2021/22 data, shown below.

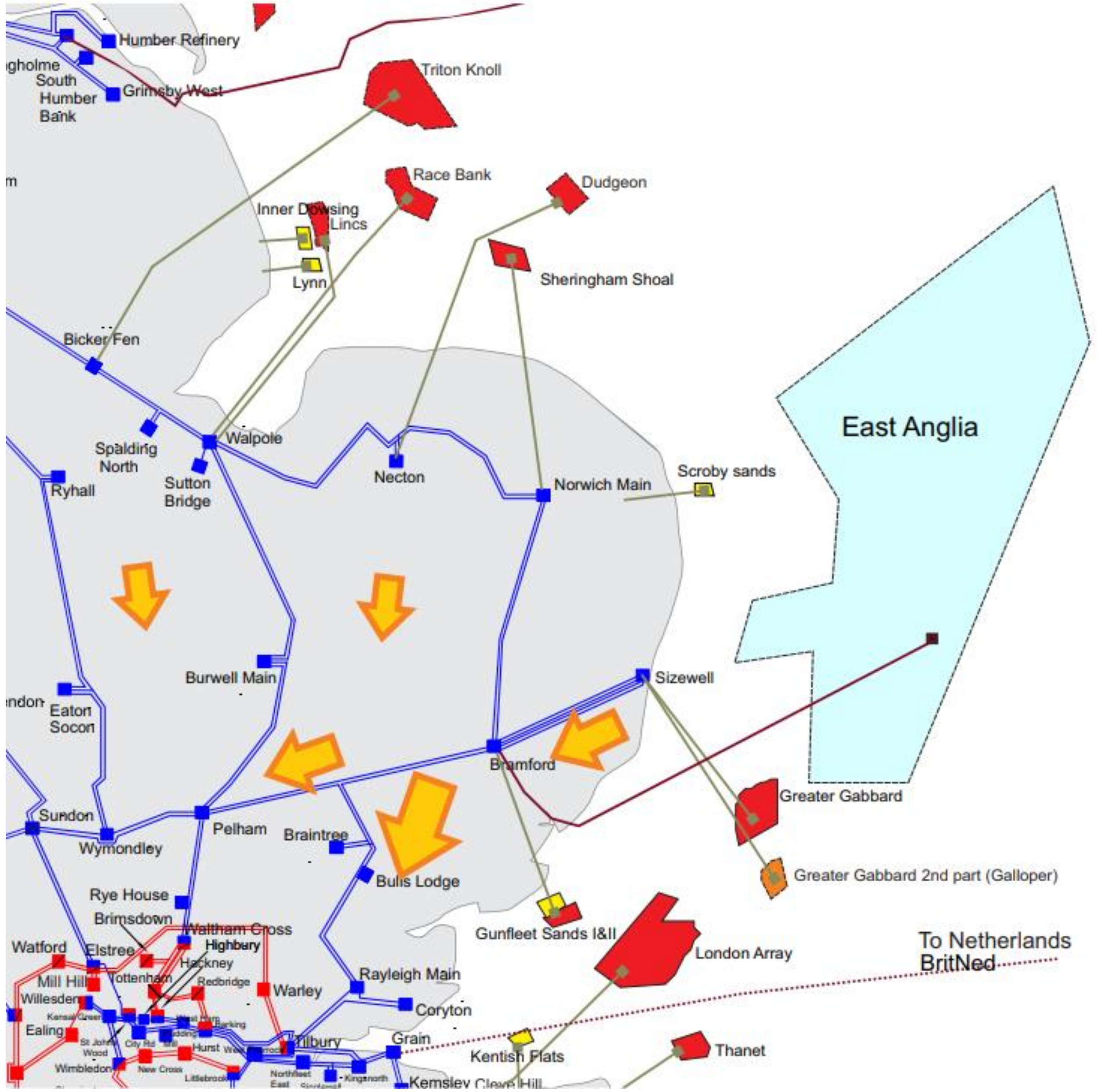
The current boundary capability is limited to 5.5GW due to a thermal constraint on the Connah's Quay - Bodelwyddan - Pentir circuit

ETYS 2021 / North Wales & Midlands 40

East of England

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

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



ETYS 2021 / East of England 41

Regional Drivers – East of England

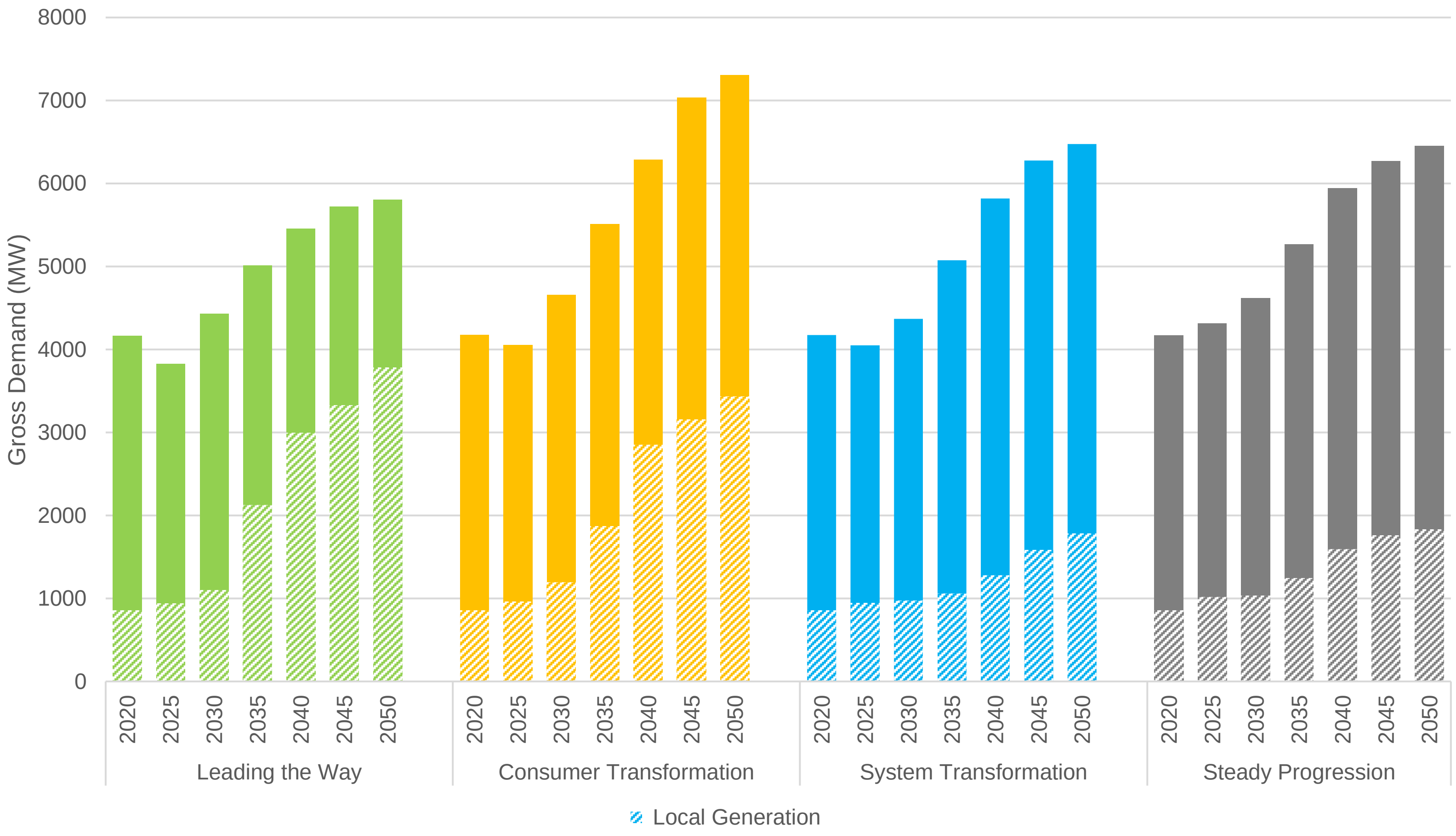
The future energy scenarios highlight that generation between 8-18GW could be expected to connect within this region by 2030. Peak gross demand in the East of England region is expected to be remain steady or potentially rise by up to 1GW.

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 is expected to remain steady within this region and interconnector capacity is expected to rise. The total generation in all the scenarios will exceed the local demand; thus the East of England will be a power exporting region.

The graph to the right shows snapshots of the peak gross demand and local embedded generation for the East of England across the four different scenarios.

In a highly decentralised scenario like Leading the Way, local generation capacity connected at the distribution level in this eastern region could reach over 7GW by 2040. Of that capacity, a typical embedded generation output on average might be around 2GW. This will vary depending on factors like wind speeds, and how other local generators decide to participate in the market.

The need for network reinforcement to address the potential capability issues will be evaluated in the NOA 2021/22 CBA.



ETYS 2021 / East of England 42

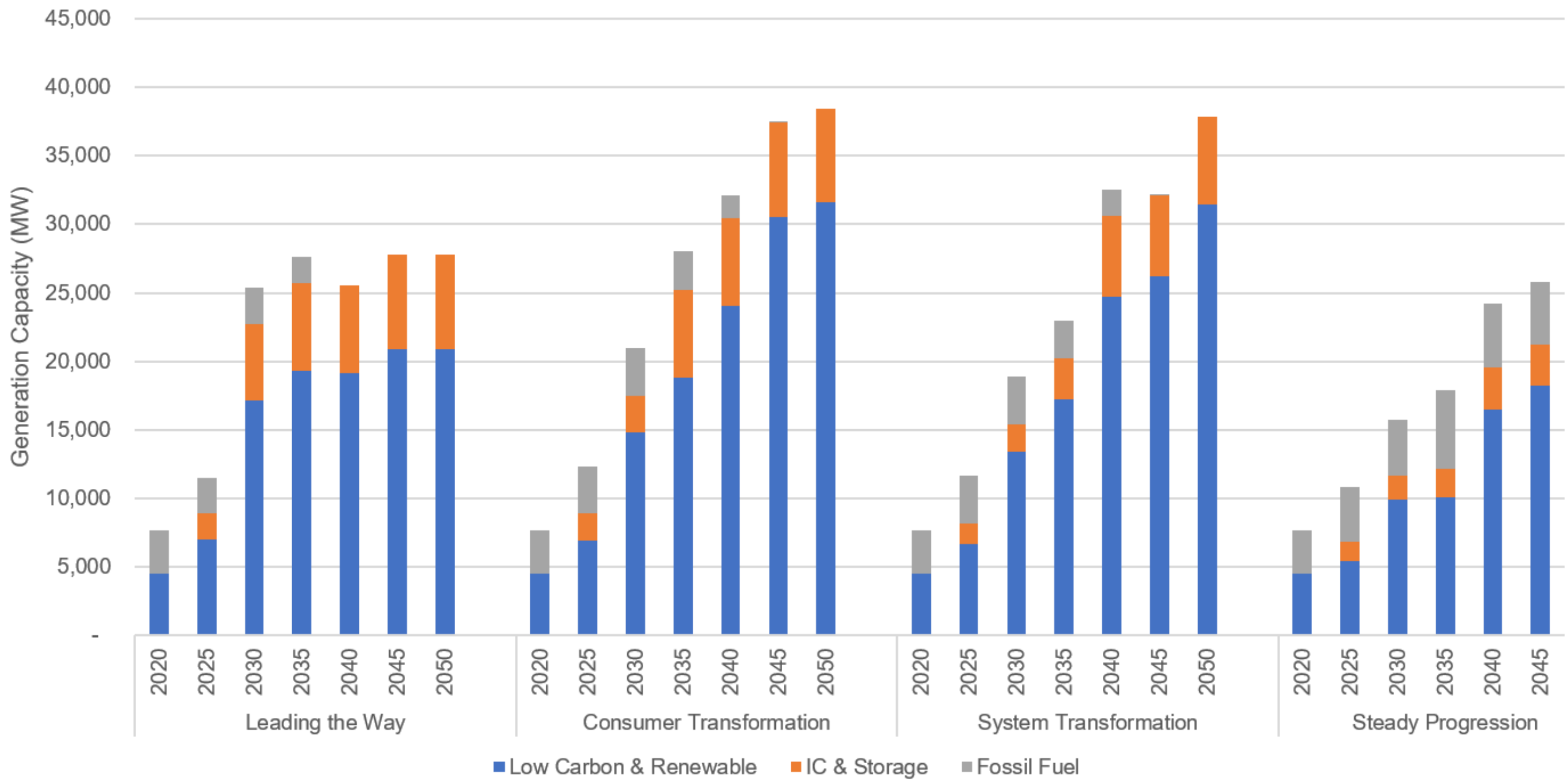
Regional Drivers – East of England

Currently, there is around 8GW of transmission-connected generation in the region, by 2030 this is expected to increase to between 16 – 25 GW, due to the increasing amounts of offshore wind and interconnectors connecting in this region in the near future. Renewable generation capacity in the region rises from 4.5GW to between 10 – 17 GW across the four scenarios. Large offshore wind projects will be landing and connecting in this region within the next ten years.

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

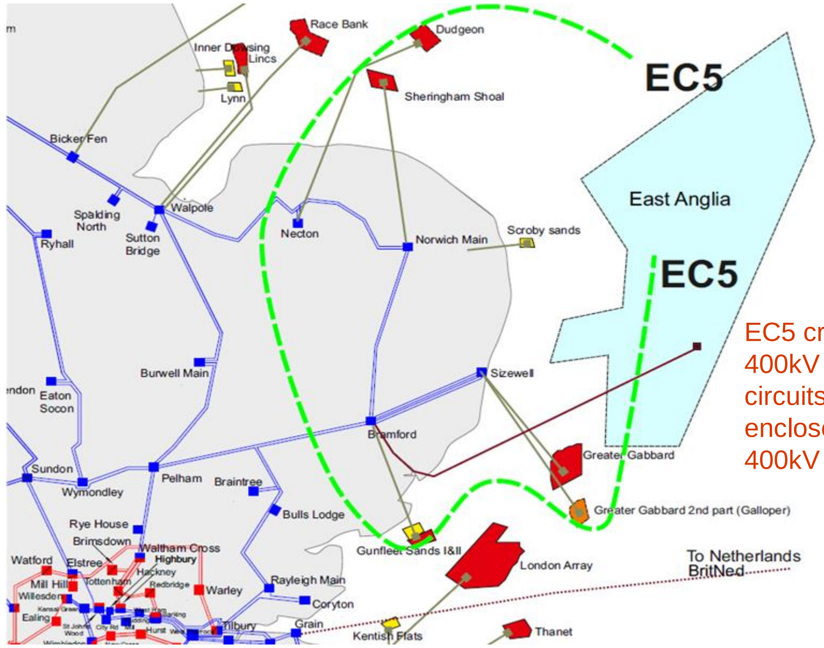
- The East of England region is connected by several sets of long 400kV double circuits, including Bramford-Pelham/Braintree, Walpole–Spalding North/Bicker Fenn and Walpole–Burwell Main. During a fault on any one set of these circuits, power exported from this region is forced to reroute. This causes some of the power to flow through a much longer distance to reach the rest of the system, predominantly the Greater London and South East England networks via the East Anglia region.

- Stability becomes 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.



Boundary EC5 – East Anglia

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



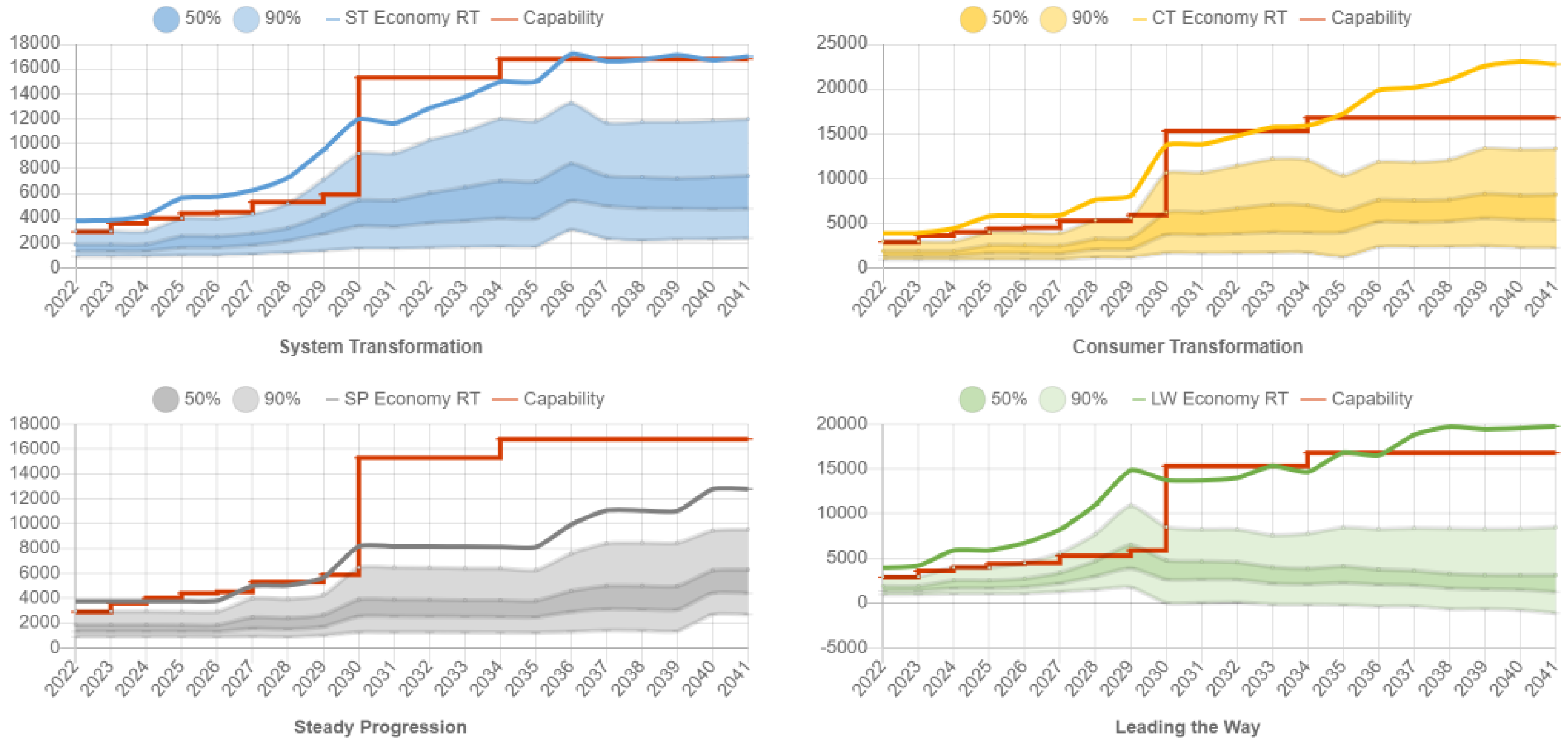
EC5 crosses four 400kV double-circuits and encloses four 400kV substations.

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

The current boundary capability is limited to 3.5GW* due to a voltage compliance constraint at the Burwell Main substation

* ETYS Transfer capability calculated using the 2021/22 FES data

ETYS 2021 / East of England 44

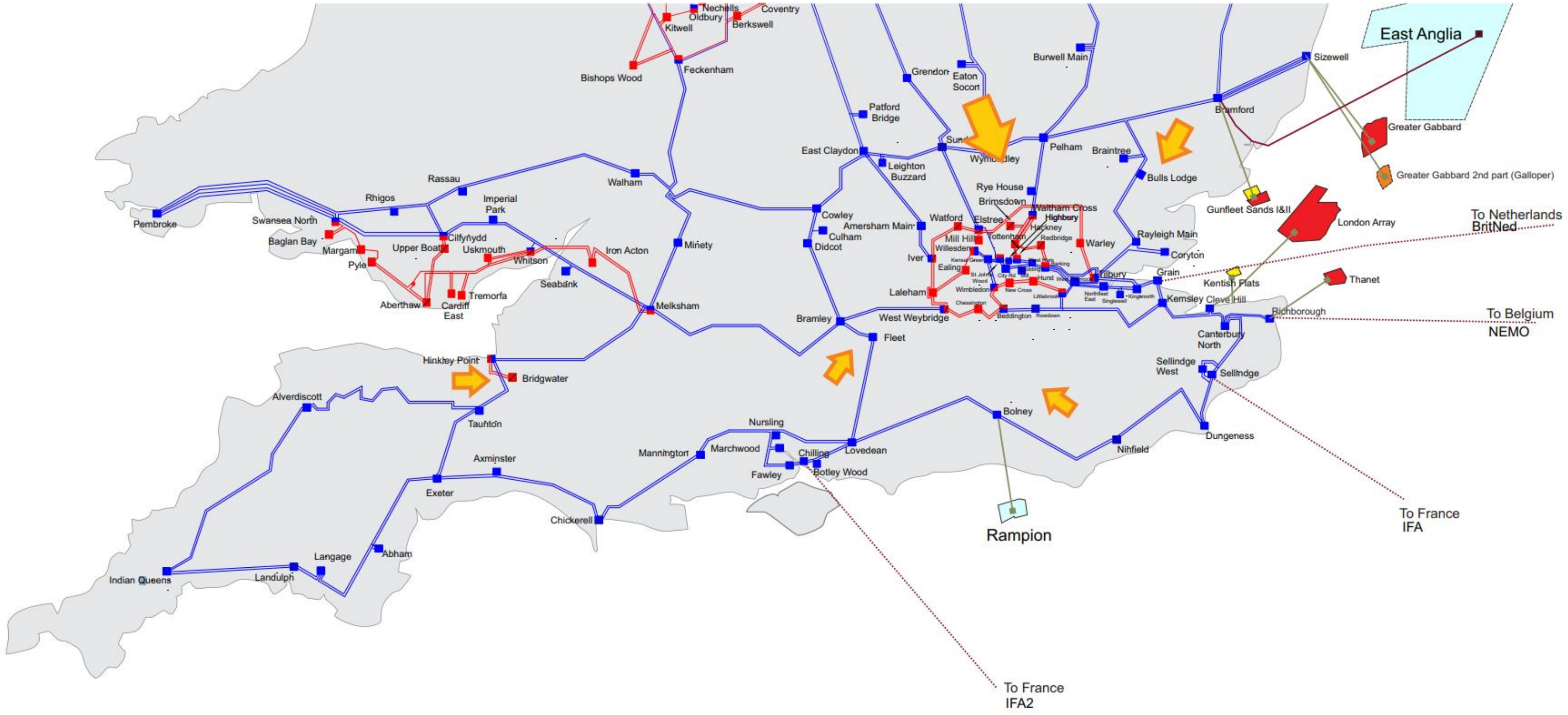
South Wales and South of England

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

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

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

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



ETYS 2021 / South of England 45

Regional Drivers – South Wales & South England

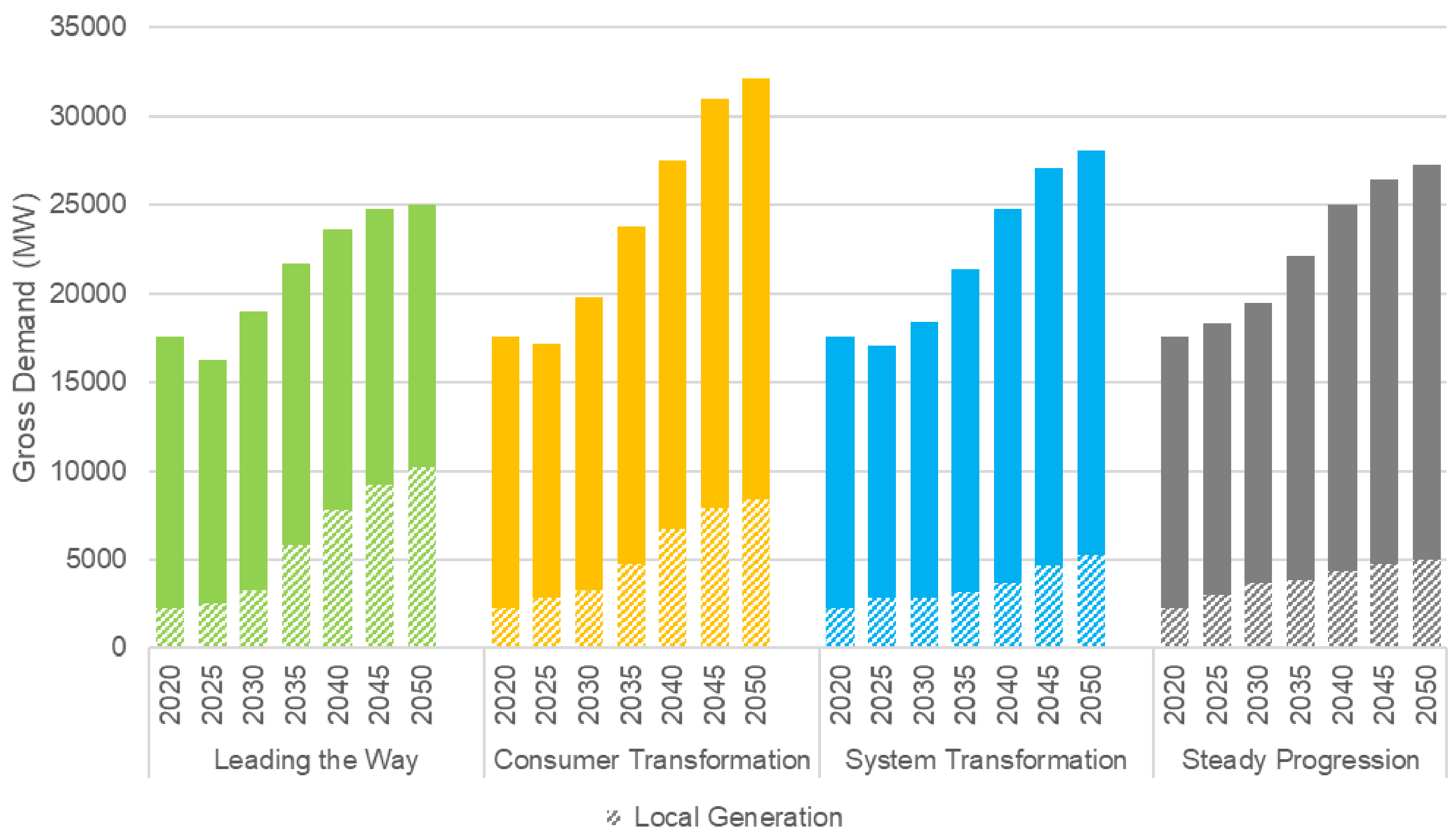
European interconnector developments along the south coast could potentially drive very high circuit flows causing circuit overloads, voltage management and stability issues.

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

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

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.



ETYS 2021 / South of England 46

Regional Drivers – South Wales & South England

The Leading the Way scenario suggests that over 10GW of additional interconnectors and energy storage capacity may connect in the south by 2030, for a total of over 14GW.

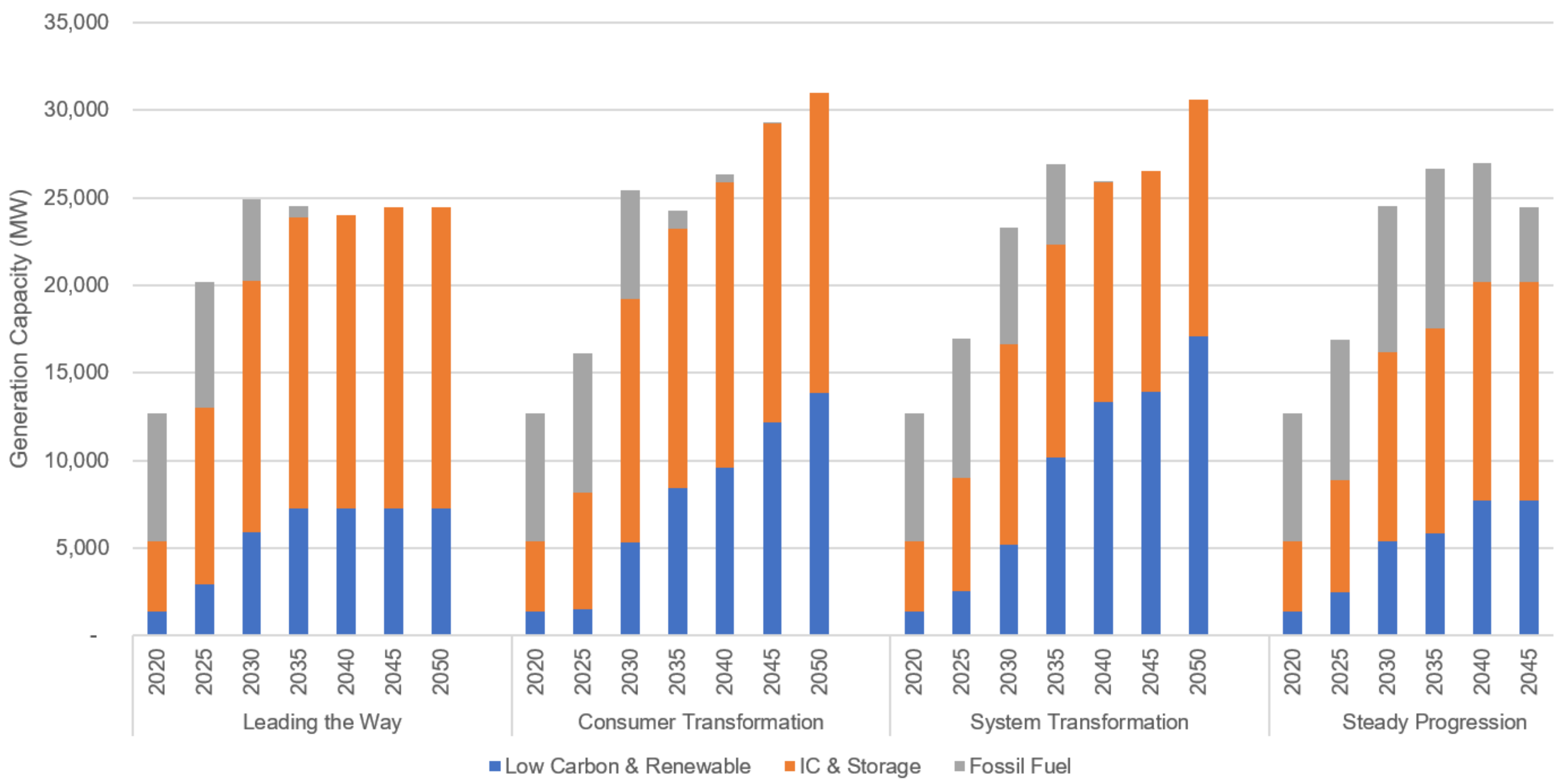
As interconnectors and storage are bi-directional, the south could therefore see their capacity provide up to 14GW power injection or 14GW increased demand. This variation could place a very heavy burden on the transmission network.

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

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.

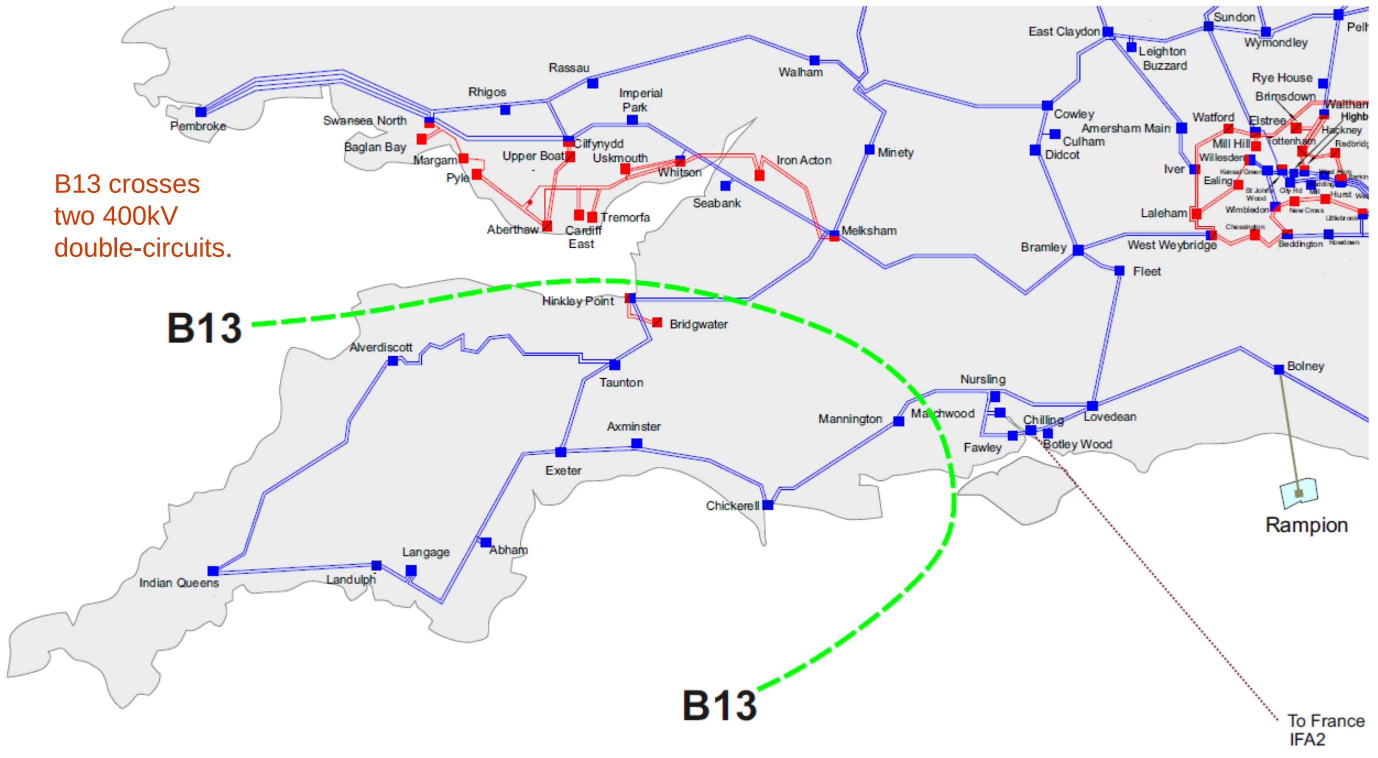
The connection of the new nuclear generating units at Hinkley may also require reinforcing the areas surrounding Hinkley. With new interconnector and generation connections, boundaries SC1, SC1.5, SC2, SC3, LE1 and B13 will need to be able to support large power flows in both directions. Wales has seen 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.

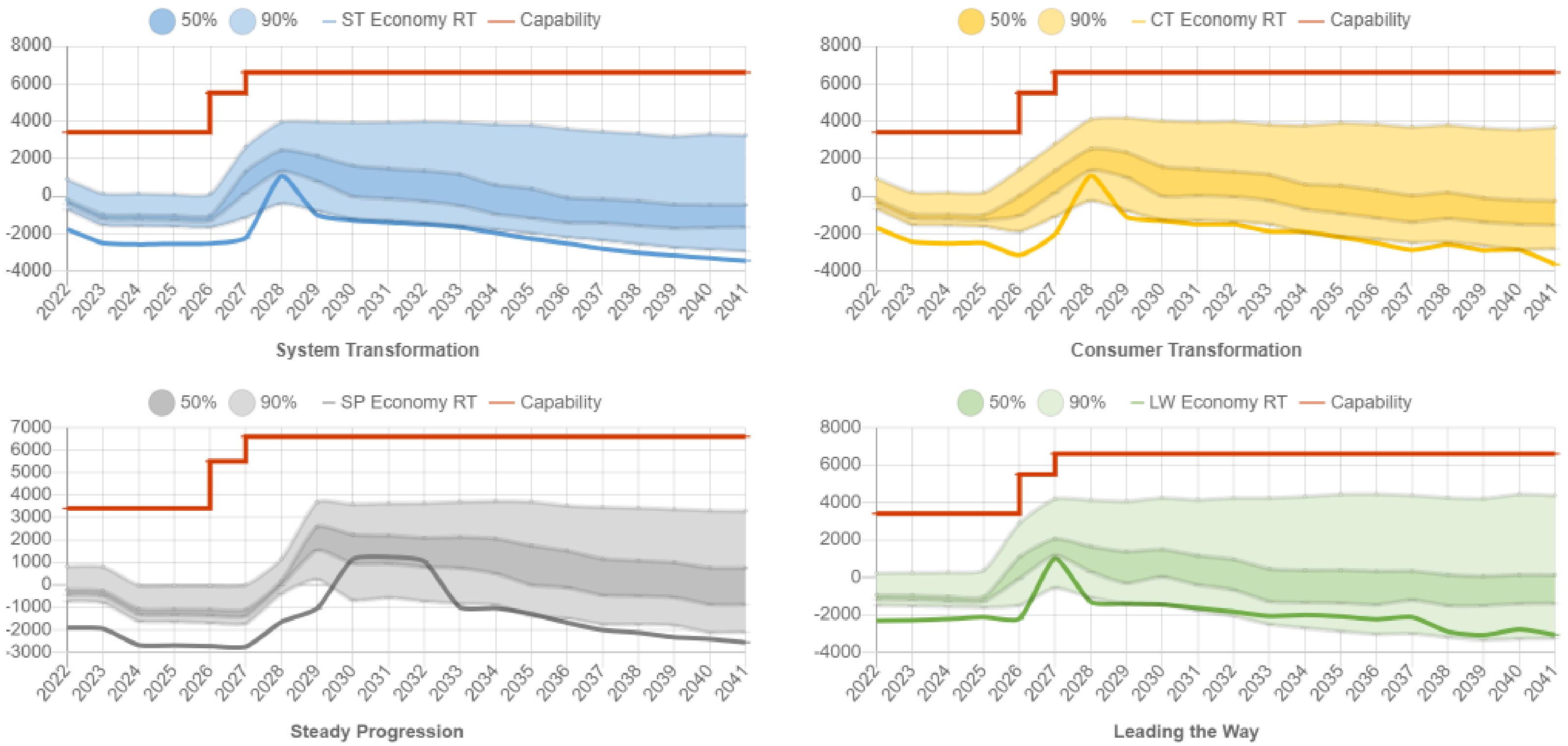


The need for network reinforcement to address the above mentioned potential capability issues will be evaluated in the NOA 2021/22 CBA.

Boundary B13 – South West

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





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

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

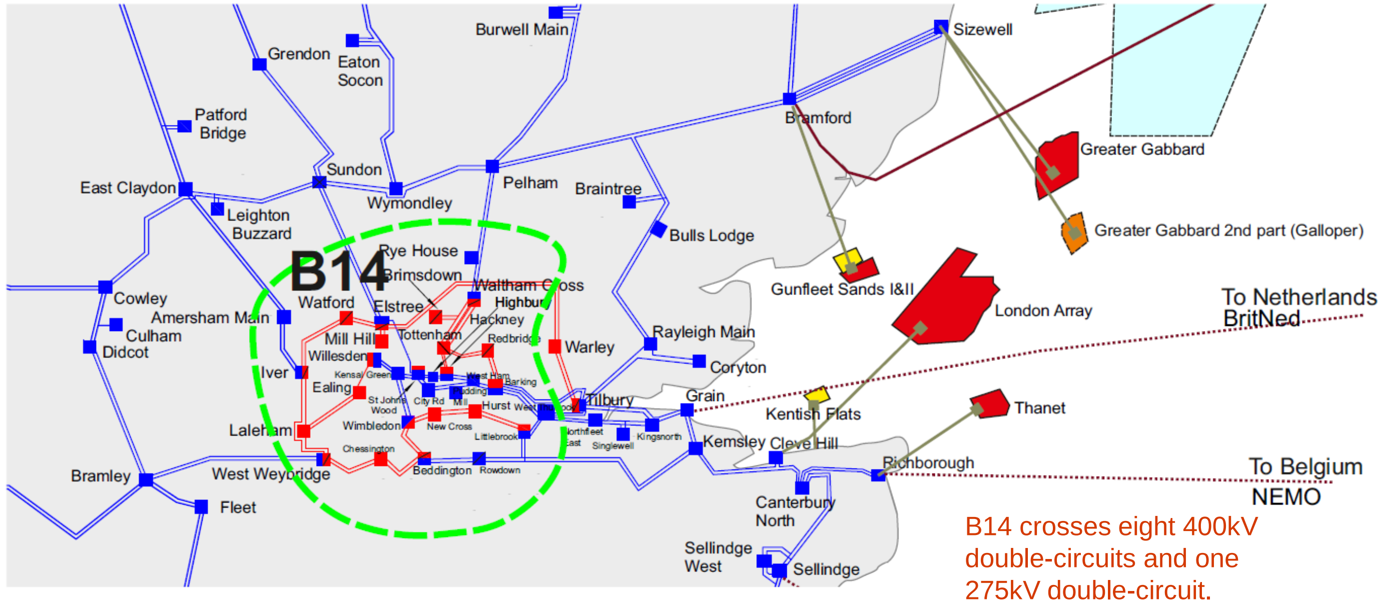
The capability line (in red) is based on the recommendations from the NOA 2021/22 optimal path which uses the 2021 FES and ETYS data as inputs. The 50%, 90% Economy RT and Security RT lines are based on FES 2021. The ETYS and NOA methodologies for this boundary are different and can result in different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

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

* ETYS Transfer capability calculated using the 2021/22 FES data

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.

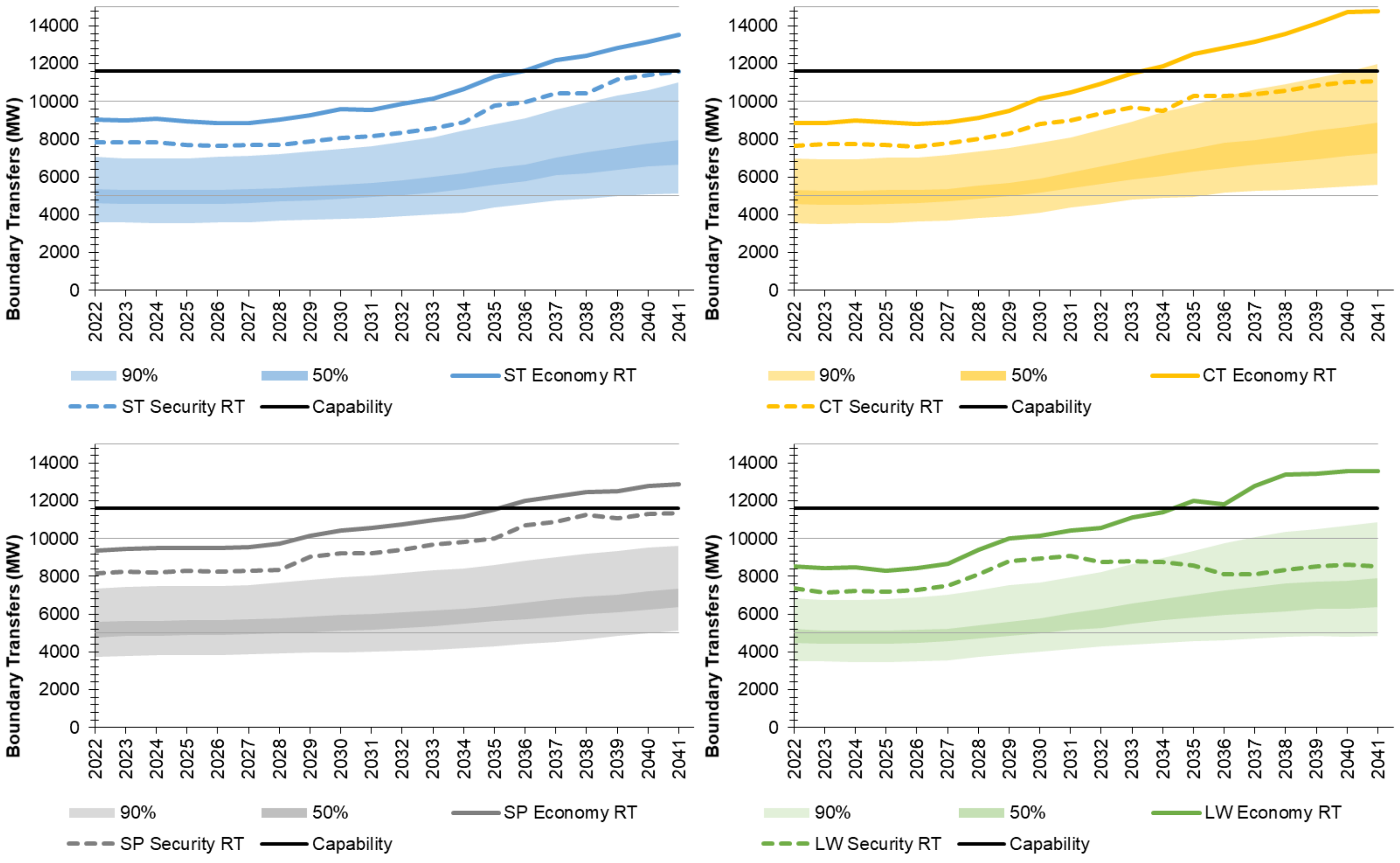


B14 crosses eight 400kV double-circuits and one 275kV double-circuit.

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

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

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



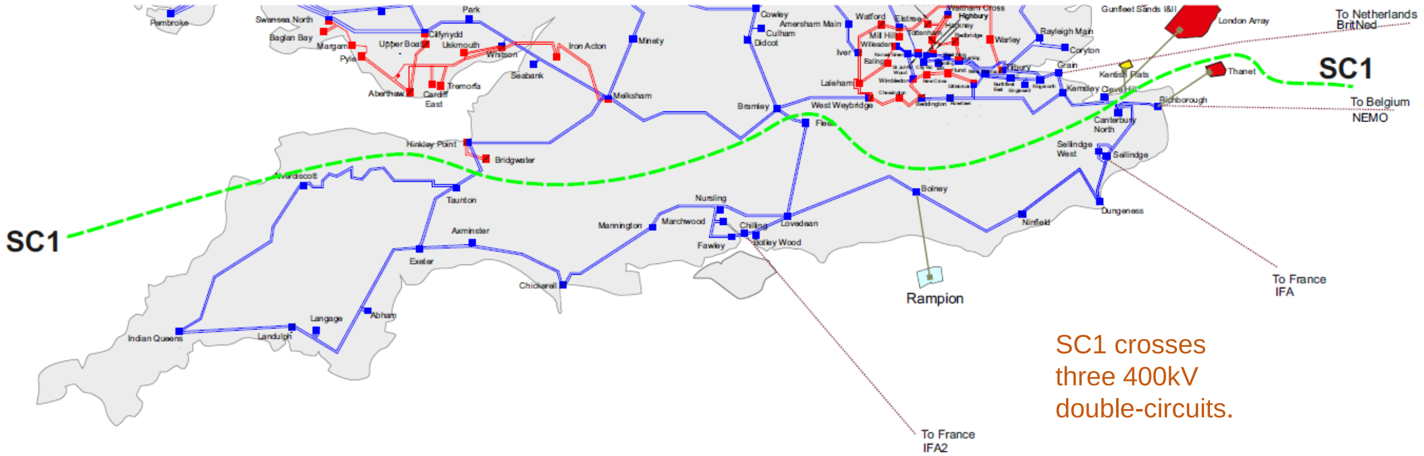
The capability line (in black) is based on the ETYS transfer capability using FES 2021/22 data, shown below.

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

ETYS 2021 / South of England 49

Boundary SC1 – South Coast

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



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

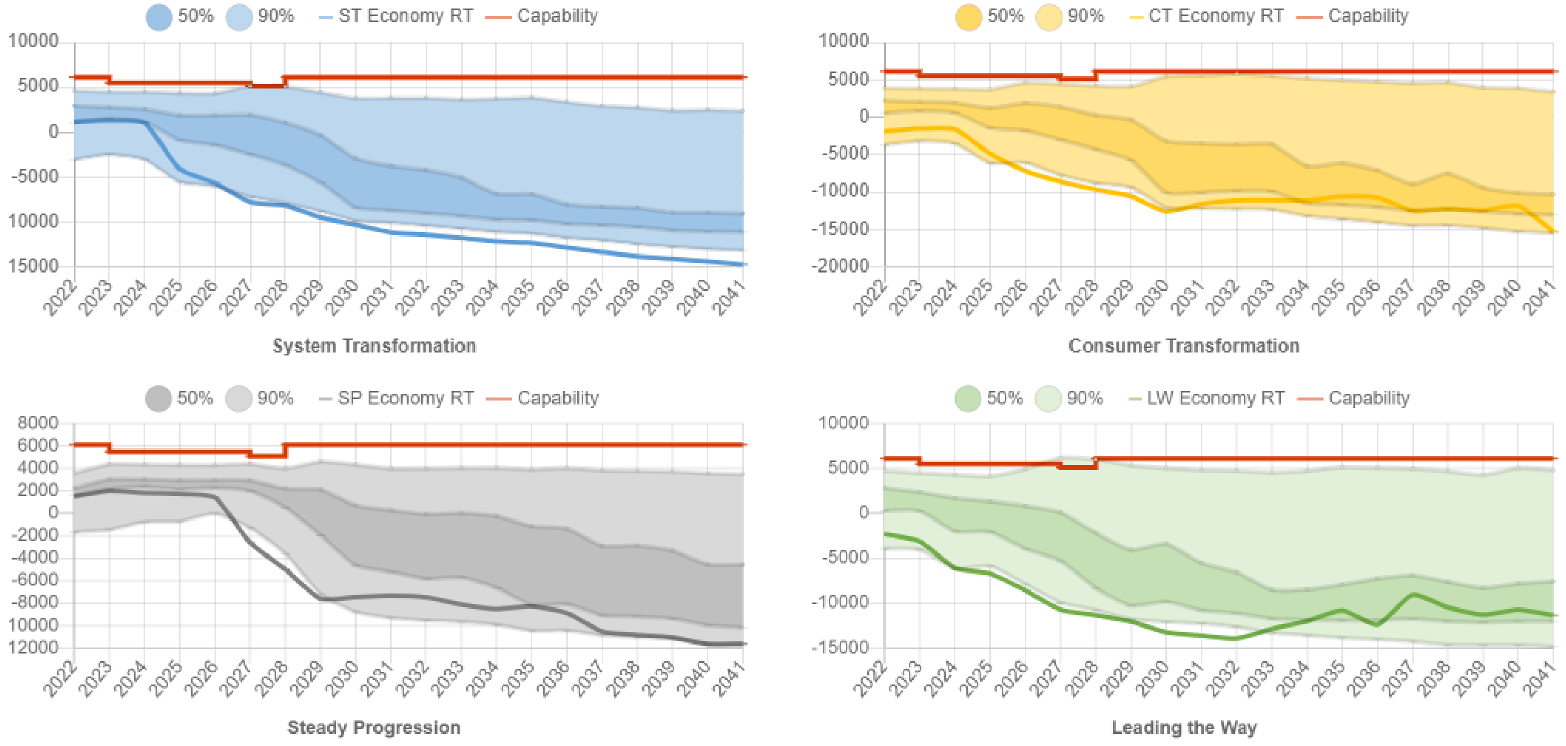
Interconnector activity can significantly influence the boundary power flow. The current interconnectors to France, the Netherlands and Belgium connect at Sellindge, Grain and Richborough respectively

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

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

Across all four scenarios in the FES, the SQSS security required transfer follows a generally flat pattern, whereas the economy required transfer moves from exporting to importing 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.



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

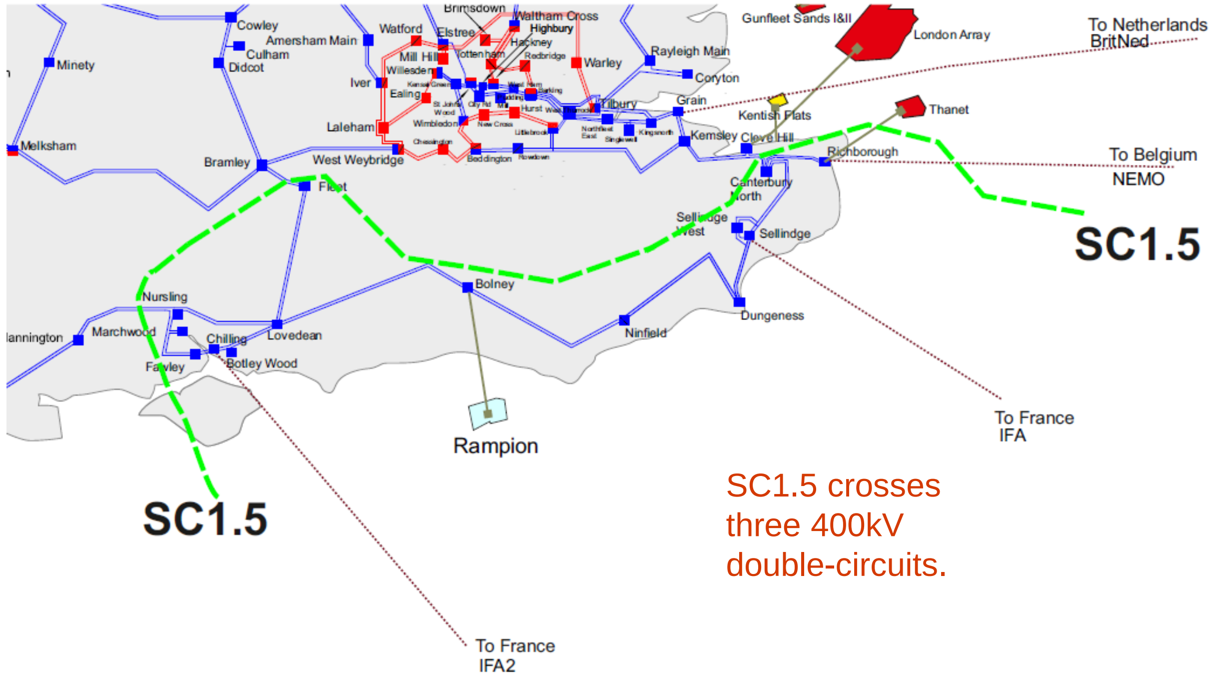
The current boundary capability is limited to 4.87GW* due to a voltage compliance constraint at the Ninfield 400kV substation

* ETYS Transfer capability calculated using the 2021/22 FES data

ETYS 2021 / South of England 50

Boundary SC1.5 – South Coast

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

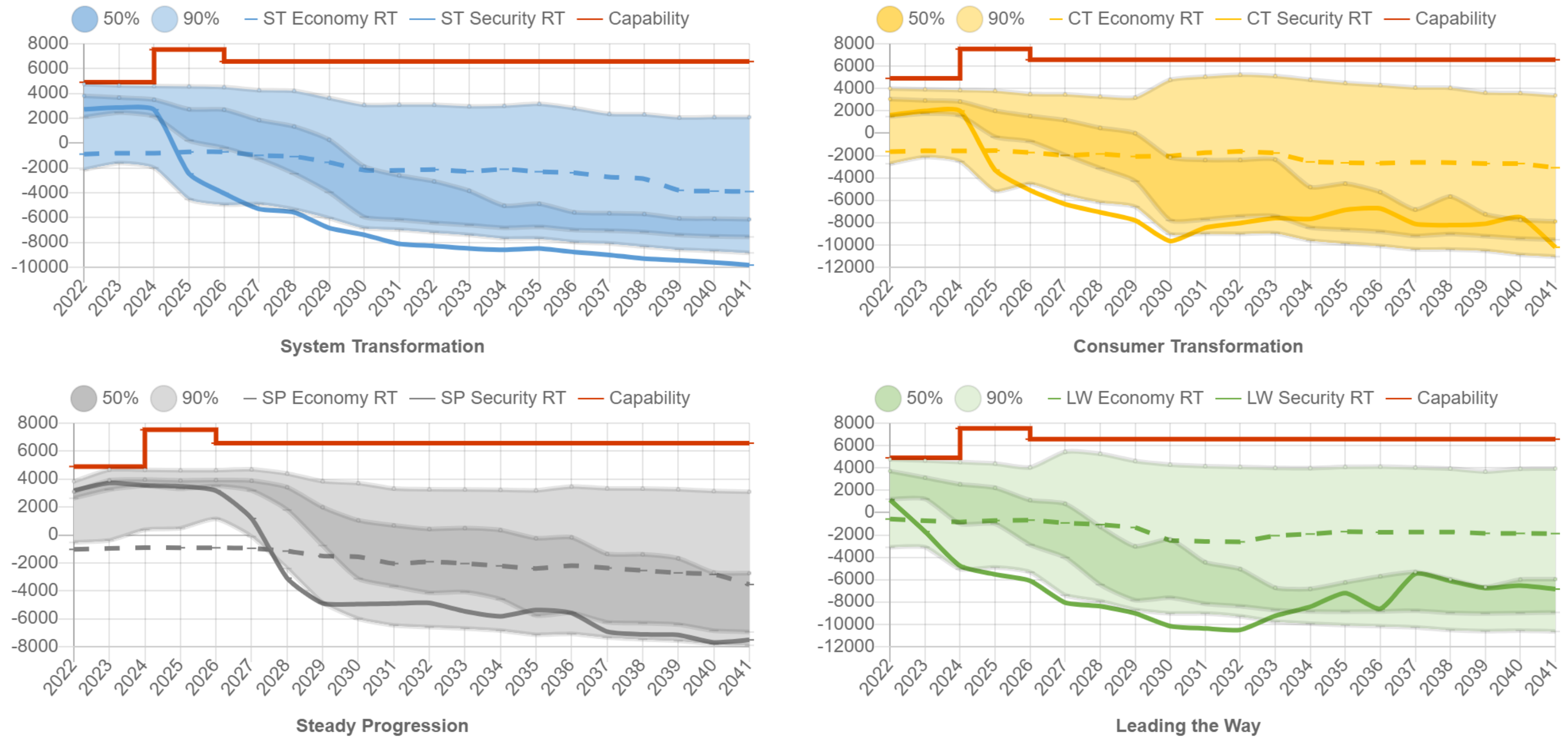


At times of peak winter GB demand, the power flow is typically north to south across the boundary, with more demand enclosed in the south of the boundary than supporting generation.

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

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

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



The capability line (in red) is based on the recommendations from the NOA 2020/21 optimal path which uses the 2020/21 FES and ETYS data as inputs. The 50%, 90% Economy RT and Security RT lines are based on FES 2021/22.

Variations in background FES flows can result in both increase and decrease of the boundary capabilities. This is due to the way power flows distribute on the available circuits.

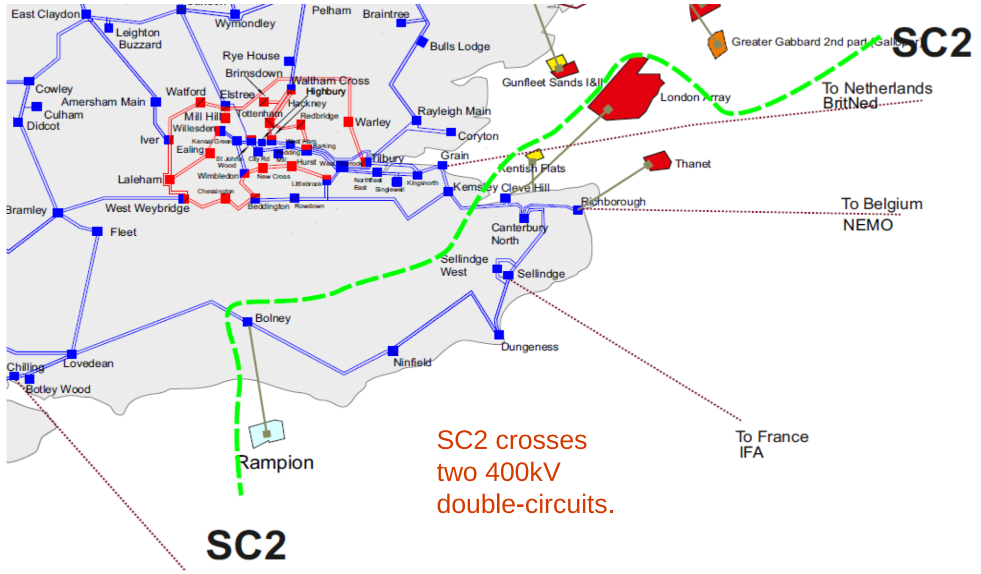
The current boundary capability is limited to 5.56GW* due to a thermal constraint on the Bramley - Fleet 400kV circuit

* ETYS Transfer capability calculated using the 2021/22 FES data

ETYS 2021 / South of England 51

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.

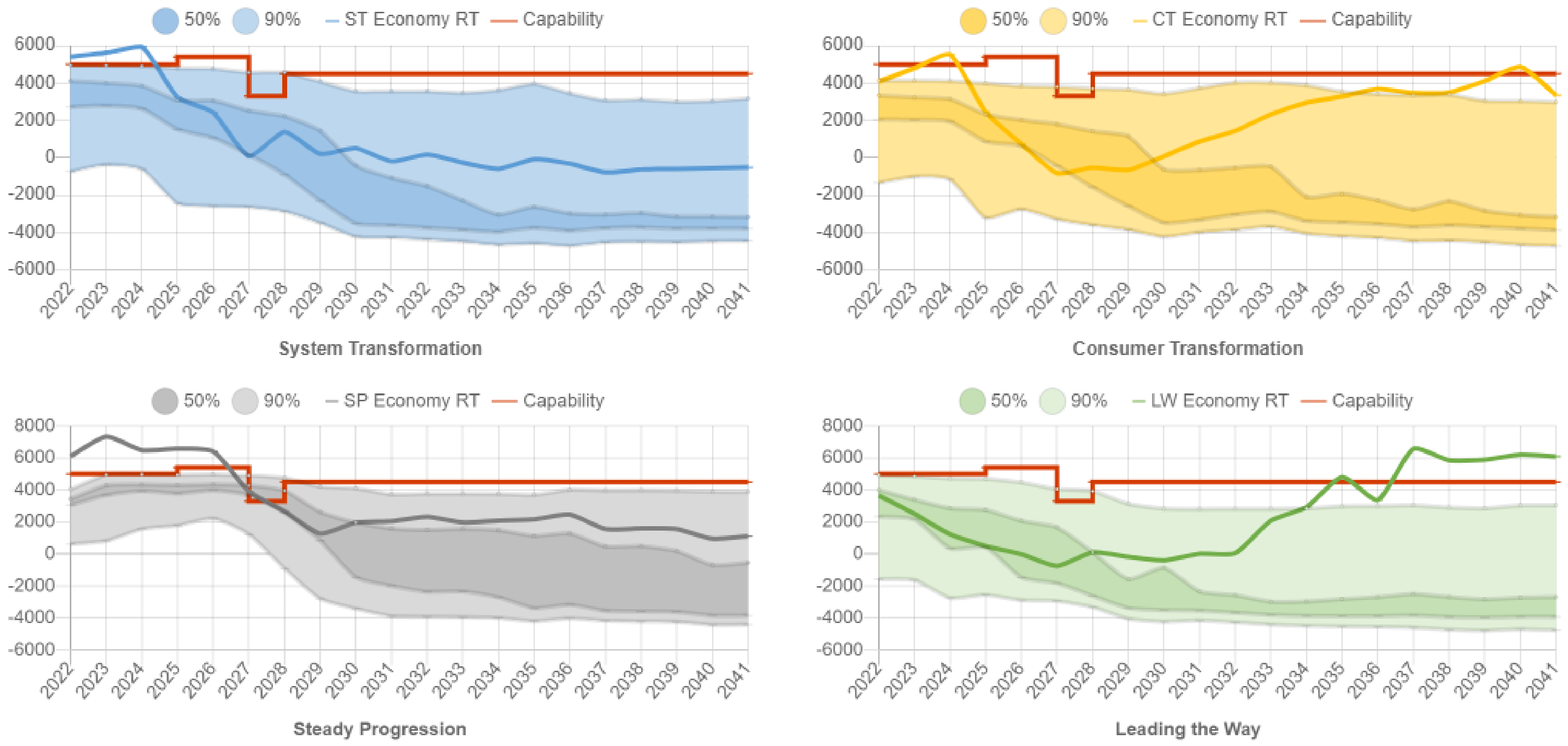


The relatively long 400kV route between Kemsley and Lovedean feeds significant demand and connects both large generators and interconnection to Europe. A fault at either end of the route can cause it to become a long radial feeder which puts all loading on the remaining two circuits which can be restrictive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

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

The interconnectors with Europe have a large impact on the power transfers across SC2 as a 2.0GW interconnector can make 4.0GW of difference on the boundary if it moves from import to export.

The volatility of interconnector activity can be seen in the wide spread of expected boundary flows depicted by the central darker band similar to SC1.5. Transfers do not place high loading on the interconnectors, so the transfers are not seen to peak at very high values here either.



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

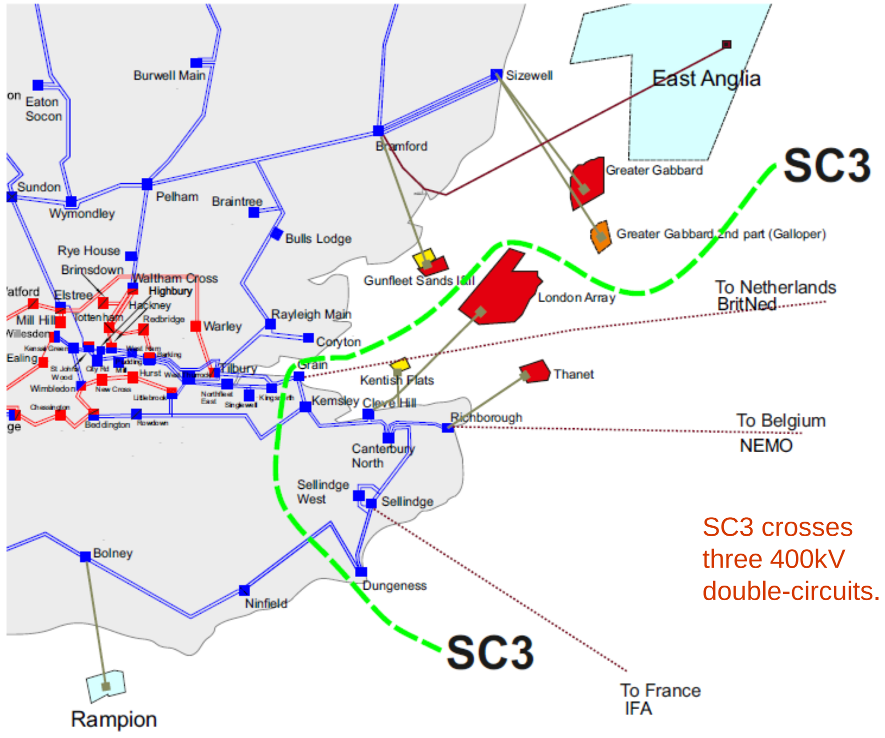
The current boundary capability is limited to 4.0GW* due to voltage stability constraints

* ETYS Transfer capability calculated using the 2021/22 FES data

ETYS 2021 / South of England 52

Boundary SC3 – South Coast

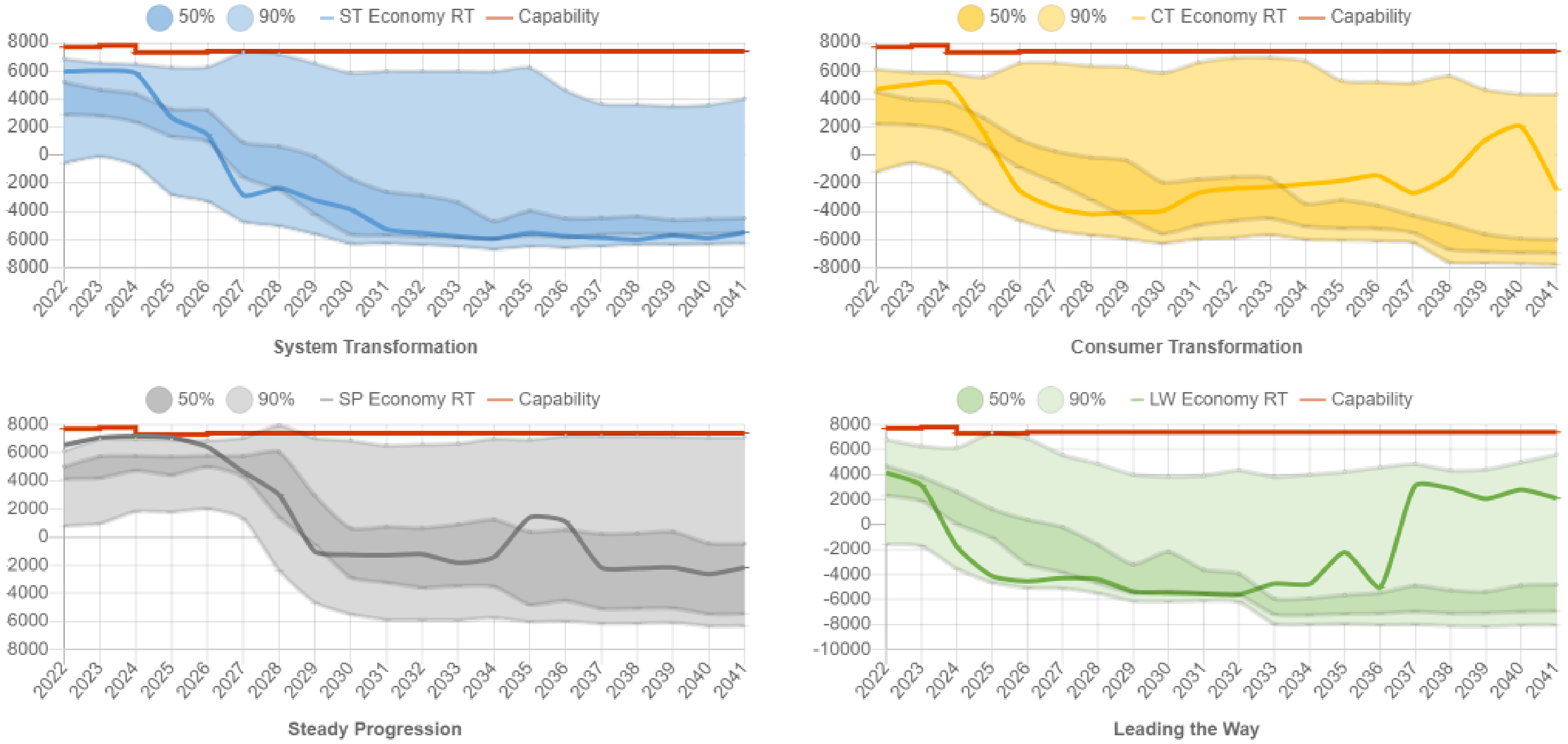
Boundary SC3 is created to capture transmission issues specifically in the south-east part of the network.



SC3 crosses three 400kV double-circuits.

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

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



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

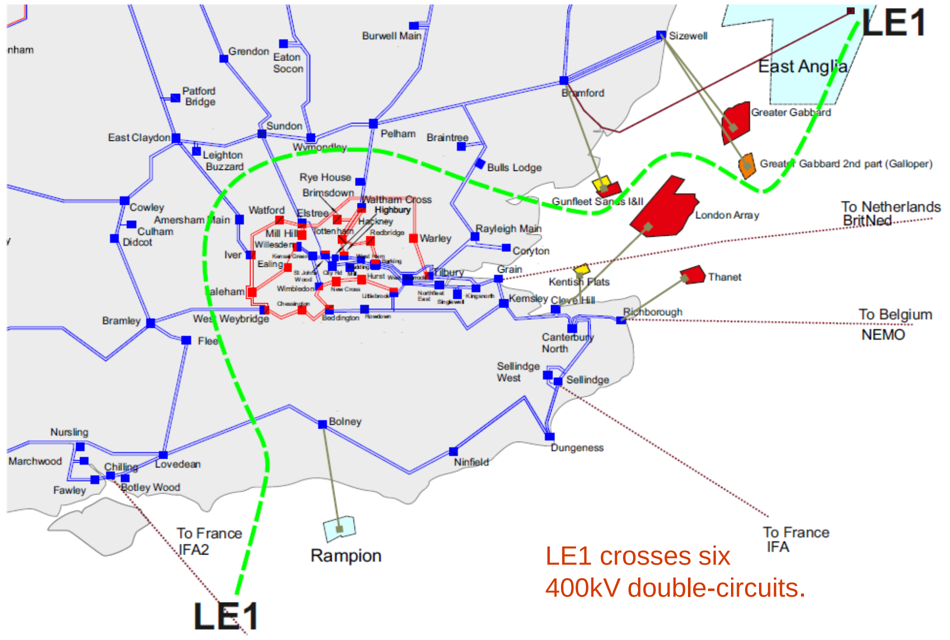
The current boundary capability is limited to 7.72GW* due to a thermal constraint

* ETYS Transfer capability calculated using the 2021/22 FES data

ETYS 2021 / South of England 53

Boundary LE1 – South East

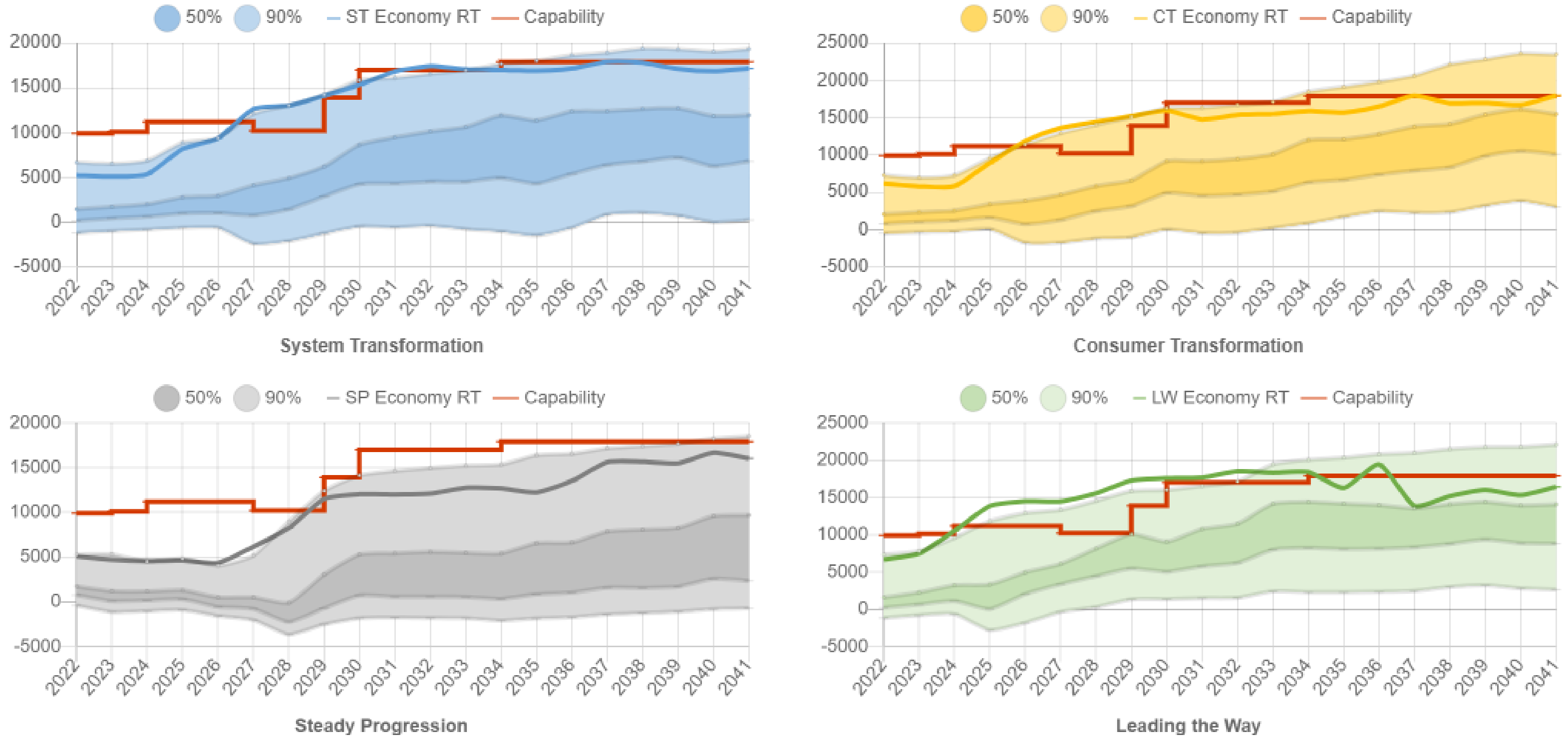
Boundary LE1 encompasses the south east of the UK, incorporating London and the areas to the south and east of it.



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.

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



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

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

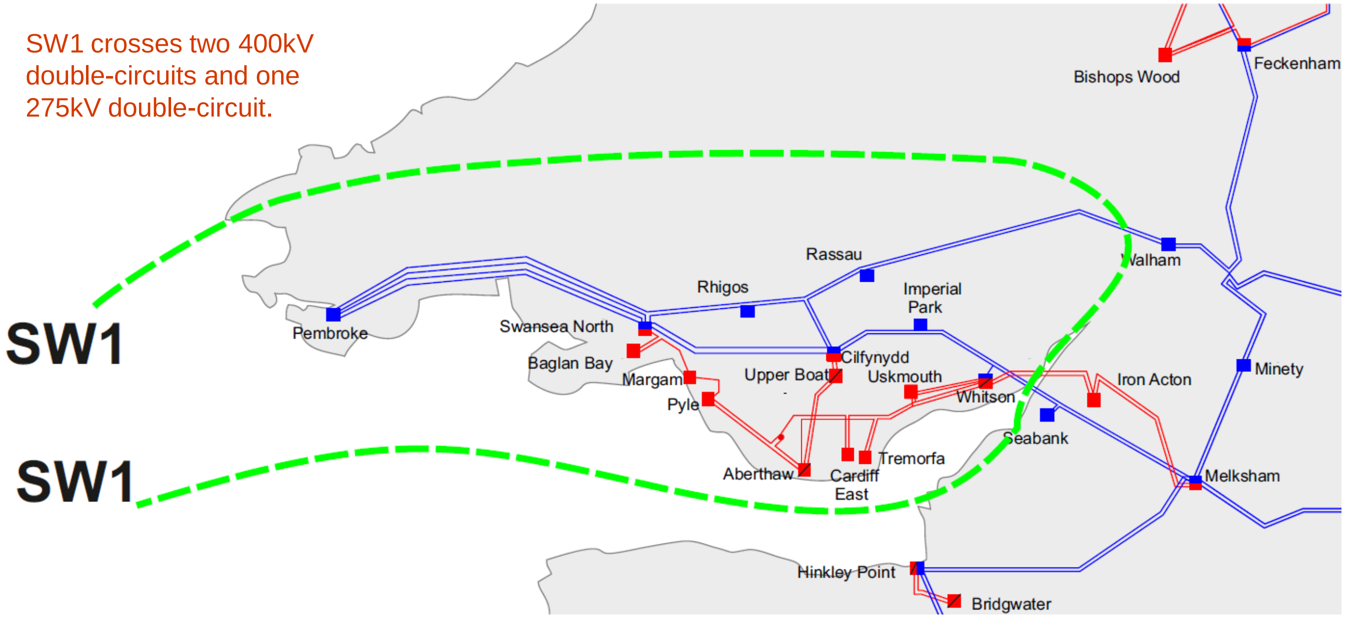
The current boundary capability is limited to 9.3GW* due to a thermal constraint on the Rayleigh Main – Tilbury circuit

* ETYS Transfer capability calculated using the 2021/22 FES data

ETYS 2021 / South of England 54

Boundary SW1 – South Wales

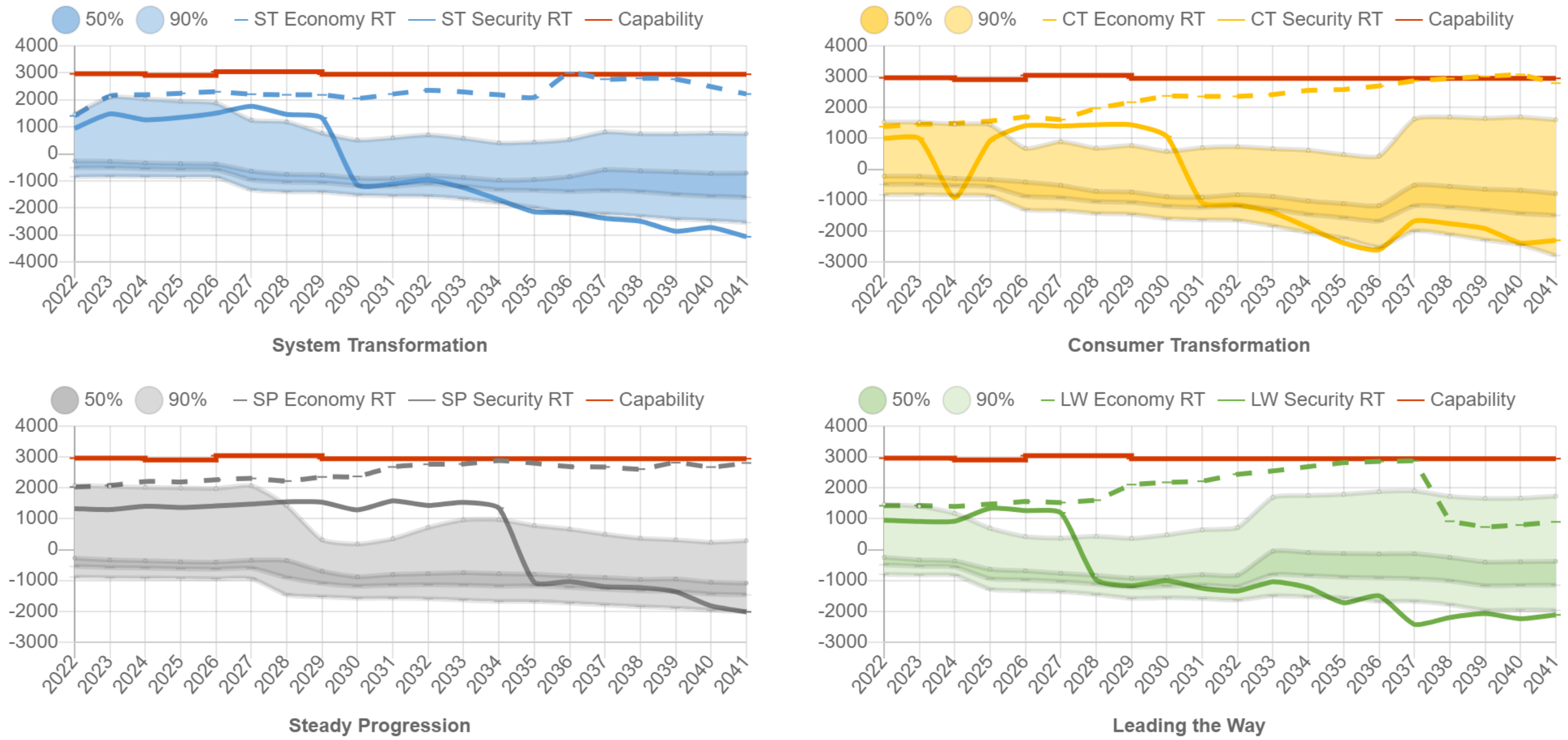
Boundary SW1 encloses South Wales is considered a wider boundary.



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 line (in red) is based on the recommendations from the NOA 2020/21 optimal path which uses the 2020/21 FES and ETYS data as inputs. The 50%, 90% Economy RT and Security RT lines are based on FES 2021/22.

Variations in background FES flows can result in both increase and decrease of the boundary capabilities. This is due to the way power flows distribute on the available circuits.

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

* ETYS Transfer capability calculated using the 2021/22 FES data

ETYS 2021 / South of England 55

Way Forward

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Way Forward

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

As operation of the NETS becomes increasingly complex, we need to find new ways of identifying weak points in the existing network planning process. This will involve the use of innovative analysis techniques, such as our work on year-round probabilistic analysis, and looking at the NOA pathfinders to see how we can better address both voltage and stability issues. This could lead to more informed network investment and operational planning decisions.

ETYS 2021 / Way Forward 57

Year-round probabilistic analysis

We continue to develop our probabilistic analysis tools to analyse year-round system conditions. This will allow us to assess more snapshots and identify system needs that could arise from a range of generation and demand conditions.

This year we committed in our ETYS consultation to present our probabilistic tool developments in a separate publication. This will allow us to focus more on the probabilistic methodology and its potential use outside of our license requirements for the ETYS publication and allow the ETYS to focus on communicating system needs.

We will look at year-round network performance and requirements and demonstrate the new functionality added to our tool during the past year. The report will give more detailed insight into our analysis and updates on related innovation projects. We will also present our findings alongside a clear vision for their use cases and potential integration within the ETYS and NOA processes.

We intend to publish this new document in the first quarter of 2022.

ETYS 2021 / Way Forward 58

NOA Pathfinder projects

The *ETYS* is looking to expand its view of system needs, this will be informed by the *NOA* Pathfinders. The road to determining the future network capability requirements and opportunities is one that needs to be refined and developed.

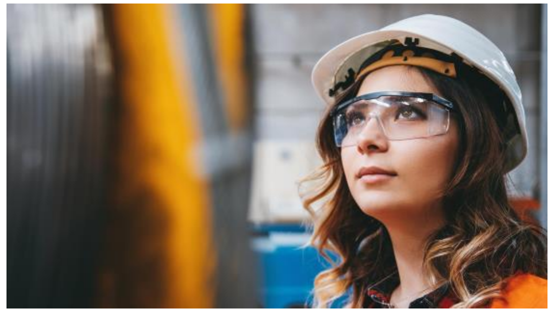
One of the ways we do this is through the NOA pathfinders.

These investigate specific network requirements and open the network development to a wider range of participants, both regionally and nationally.

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

In June we published our annual voltage screening report identifying areas that could have future high voltage system needs. We are now carrying out more detailed analysis to quantify the requirements.

Pathfinder projects already underway:



***NOA* High Voltage Pathfinder**

Finding solutions to regional high voltage issues

***NOA* Stability Pathfinder**

Addressing our immediate needs of national inertia, and local short circuit level needs in Scotland.

***NOA* Constraint Management Pathfinder**

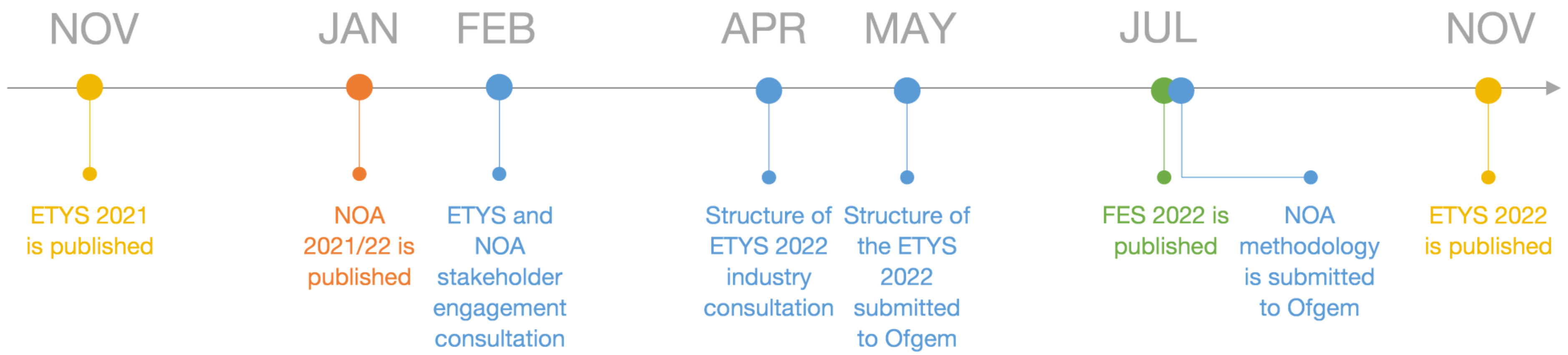
Resolving network constraint issues and lowering balancing costs.

ETYS 2021 / Way Forward 59

Stakeholder engagement

The ETYS and NOA documents are continually evolving to meet our ambitions set out in the ESO's RIIO-2 Business 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 2021 and our 2022 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
- 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 Form consultation (planned for April 2022)
- Consultation events as part of our customer seminars
- Industry engagement events e.g. operational forums, etc
- Emails direct to transmission.etys@nationalgrideso.com
- Stakeholder meetings

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Further Information

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Appendices overview

Appendix A - System schematics and geographic drawings

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

Appendix B - System technical data

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

Appendix C - Power flow diagrams

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

Appendix D – Fault levels Narrative

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

Appendix D Fault Levels Minimum

You can view the fault level data at minimum demand.

Appendix D Fault Levels Peak

You can view the fault level data at peak demand.

Appendix E – FES charts and workbook

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

Appendix H – Further information on inputs and methodologies

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

Appendix I – Transmission losses

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

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Meet the Team

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

Head of Networks
Julian Leslie

Network Development Manager
Nicholas Harvey

Network Operability Manager
Cheng Chen

Network Development

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

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

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

You can contact us to discuss:

Network requirements and the Electricity Ten Year Statement

Faith Natukunda
GB System Capability Manager
Faith.Natukunda@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.

You can contact us to discuss:

Network data used in ETYS

Lilian MacLeod
Data and Modelling Manager
Lilian.MacLeod@nationalgrideso.com

The System Operability Framework (SOF)

Cheng Chen
Network Risk and Performance Manager / Network Operability Manager (Interim)
Cheng.Chen@nationalgrideso.com

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Glossary – 1 / 6

Acronym	Phrase	Explanation
	Ancillary services	Services procured by a system operator to balance demand and supply and to ensure the security and quality of electricity supply across the transmission system. These services include reserve, frequency control and voltage control. In GB these are known as balancing services and each service has different parameters that a provider must meet.
ACS	Average cold spell	Average cold spell is defined as a particular combination of weather elements which gives rise to a level of winter peak demand which has a 50% chance of being exceeded as a result of weather variation alone. There are different definitions of ACS peak demand for different purposes.
	Boundary allowance	An allowance in MW to be added in whole or in part to transfers arising out of the NETS SQSS economy planned transfer condition to take some account of year-round variations in levels of generation and demand. This allowance is calculated by an empirical method described in Appendix F of the Security And Quality of Supply Standards (SQSS).
	Boundary transfer capacity	The maximum pre-fault power that the transmission system can carry from the region on one side of a boundary to the region on the other side of the boundary while ensuring acceptable transmission system operating conditions will exist following one of a range of different faults.
CBA	Cost-benefit analysis	A method of assessing the benefits of a given project in comparison to the costs. This tool can help to provide a comparative base for all projects to be considered.
CCS	Carbon capture and storage	Carbon capture and storage is a process by which the CO2 produced in the combustion of fossil fuels is captured, transported to a storage location and isolated from the atmosphere. Carbon capture and storage can be applied to large emission sources like power plants used for electricity generation and industrial processes. The CO2 is then compressed and transported for long-term storage in geological formations or for use in industrial processes.
	Climate change targets	Targets for share of energy use sourced from renewable sources. The 2020 UK targets are defined in the Directive 2009/28/EC of the European Parliament and of the Council of the European Union, see 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.

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Acronym	Phrase	Explanation
	Double-circuit overhead line	In the case of the onshore transmission system, this is a transmission line which consists of two circuits sharing the same towers for at least one span in SSEN Transmission's system or NGET's transmission system or for at least two miles in SP Transmission's system. In the case of an offshore transmission system, this is a transmission line which consists of two circuits sharing the same towers for at least one span.
DC	Direct current	An electric current flowing in one direction only.
DSR	Demand side response	A deliberate change to an industrial and commercial user's natural pattern of metered electricity or gas consumption, brought about by a signal from another party.
DNO	Distribution Network Operator	Distribution Network Operators own and operate electricity distribution networks.
	Embedded generation	Power generating stations/units that don't have a contractual agreement with the Electricity System Operator (ESO). They reduce electricity demand on the National Electricity Transmission System.
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 own the assets concerned. For example, National Grid ESO operates the electricity transmission system in Scotland, which is owned by Scottish Hydro Electricity Transmission and Scottish Power Transmission.
EU	European Union	A political and economic union of 28 member states that are located primarily in Europe.
FACTS	Flexible alternating current transmission system	FACTS devices are static power-electronic devices that utilise series and/or shunt compensation. They are installed in AC transmission networks to increase power transfer capability, stability, and controllability of the networks.
FES	Future energy scenarios	The FES is a range of credible futures which has been developed in conjunction with the energy industry. They are a set of scenarios covering the period from now to 2050, and are used to frame discussions and perform stress tests. They form the starting point for all transmission network and investment planning, and are used to identify future operability challenges and potential solutions.
GEP	Grid entry point	A point at which a generating unit directly connects to the National Electricity Transmission System. The default point of connection is taken to be the busbar clamp in the case of an air insulated substation, gas zone separator in the case of a gas insulated substation, or equivalent point as may be determined by the relevant transmission licensees for new types of substation. When offshore, the GEP is defined as the low voltage busbar on the platform substation.
GSP	Grid supply point	A point of supply from the GB transmission system to a distribution network or transmission-connected load. Typically only large industrial loads are directly connected to the transmission system.

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Acronym	Phrase	Explanation
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.
HVDC	High voltage direct current	The transmission of power using continuous voltage and current as opposed to alternating current. HVDC is commonly used for point to point long-distance and/or subsea connections. HVDC offers various advantages over HVAC transmission, but requires the use of costly power electronic converters at each end to change the voltage level and convert it to/from AC.
	Interconnector	Electricity interconnectors are transmission assets that connect the GB market to Europe and allow suppliers to trade electricity between markets.
LCPD	Large Combustion Plant Directive	The Large Combustion Plant Directive is a European Union directive which introduced measures to control the emissions of sulphur dioxide, oxides of nitrogen and dust from large combustion plant.
LW	Leading the Way	A scenario from the Future Energy Scenarios (FES) where net zero is achieved at the fast pace with a high level of societal change and a rapid speed of decarbonation
	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.

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Glossary – 4 / 6

Acronym	Phrase	Explanation
MITS	Main Interconnected Transmission System	This comprises all the 400kV and 275kV elements of the onshore transmission system and, in Scotland, the 132kV elements of the onshore transmission system operated in parallel with the supergrid, and any elements of an offshore transmission system operated in parallel with the supergrid, but excludes generation circuits, transformer connections to lower voltage systems, external interconnections between the onshore transmission system and external systems, and any offshore transmission systems radially connected to the onshore transmission system via single interface points.
NETS	National Electricity Transmission System	The National Electricity Transmission System comprises the onshore and offshore transmission systems of England, Wales and Scotland. It transmits high-voltage electricity from where it is produced to where it is needed throughout the country. The system is made up of high voltage electricity wires that extend across Britain and nearby offshore waters. It is owned and maintained by regional transmission companies, while the system as a whole is operated by a single Electricity System Operator (ESO).
NETS SQSS	National Electricity Transmission System Security and Quality of Supply Standards	A set of standards used in the planning and operation of the National Electricity Transmission System of Great Britain. For the avoidance of doubt, the National Electricity Transmission System is made up of both the onshore transmission system and the offshore transmission systems.
NGET	National Grid Electricity Transmission plc	National Grid Electricity Transmission plc (No. 2366977) whose registered office is 1-3 Strand, London, WC2N 5EH.
	Network access	Maintenance and system access is typically undertaken during the spring, summer and autumn seasons when the system is less heavily loaded and access is favourable. With circuits and equipment unavailable, the integrity of the system is reduced. The planning of system access is carefully controlled to ensure system security is maintained.
NOA	Network Options Assessment	The NOA is the process for assessing options for reinforcing the National Electricity Transmission System (NETS) to meet the requirements that the Electricity System Operator (ESO) finds from its analysis of the Future Energy Scenarios (FES).
OFGEM	Office of Gas and Electricity Markets	The UK's independent National Regulatory Authority, a non-ministerial government department. Their principal objective is to protect the interests of existing and future electricity and gas consumers.
	Offshore	This term means wholly or partly in offshore waters.
	Offshore transmission circuit	Part of an offshore transmission system between two or more circuit breakers which includes, for example, transformers, reactors, cables, overhead lines and DC converters but excludes busbars and onshore transmission circuits.
	Onshore	This term refers to assets that are wholly on land.
	Onshore transmission circuit	Part of the onshore transmission system between two or more circuit breakers which includes, for example, transformers, reactors, cables and overhead lines but excludes busbars, generation circuits and offshore transmission circuits.
OCGT	Open cycle gas turbine	Gas turbines in which air is first compressed in the compressor element before fuel is injected and burned in the combustor.

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Acronym	Phrase	Explanation
	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.
QB	Quadrature booster	A quadrature booster is a type of transformer also known as a phase shifting transformer and it is used to control the amount of real power flow between two parallel lines.
	Ranking order	A list of generators sorted in order of likelihood of operation at time of winter peak and used by the NETS SQSS.
	Reactive power	Reactive power is a concept used by engineers to describe the background energy movement in an alternating current (AC) system arising from the production of electric and magnetic fields. These fields store energy which changes through each AC cycle. Devices which store energy by virtue of a magnetic field produced by a flow of current are said to absorb reactive power; those which store energy by virtue of electric fields are said to generate reactive power.
	Real power	This term (sometimes referred to as "Active Power") provides the useful energy to a load. In an AC system, real power is accompanied by reactive power for any power factor other than 1.
	Seasonal circuit ratings	The current carrying capability of circuits. Typically, this reduces during the warmer seasons as the circuits' capability to dissipate heat is reduced. The rating of a typical 400kV overhead line may be 20% less in the summer than in winter.
	SSEN Transmission	Scottish Hydro-Electric Transmission (No.SC213461) whose registered office is situated at Inveralmond HS, 200 Dunkeld Road, Perth, Perthshire PH1 3AQ.
SP	Steady Progression	This scenario makes progress towards decarbonisation through a centralised pathway, but does not achieve the 2050 target.
	SP Transmission	Scottish Power Transmission Limited (No. SC189126) whose registered office is situated at Ochil House, 10 Technology Avenue, Blantyre G72 0HT.

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Acronym	Phrase	Explanation
	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.
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 electricity on a regional or national level, using fixed infrastructure.

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