ENSG 'Our Electricity Transmission Network: A Vision For 2020'

AN UPDATED FULL REPORT TO THE ELECTRICITY NETWORKS STRATEGY GROUP ON THE STRATEGIC REINFORCEMENTS REQUIRED TO FACILITATE CONNECTION OF THE GENERATION MIX TO THE GREAT BRITAIN TRANSMISSION NETWORKS BY 2020

Note: This report provides the full supporting data for the ENSG updated summary report *'Our Electricity Transmission Network: A Vision for 2020'* (URN11D/955). It is published to provide further information on how the conclusions in the summary report were reached

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Foreword

by the Joint Chairs of the Electricity Networks Strategy Group

We welcome this report ("2012 ENSG Report") as a valuable contribution to the ongoing discussions about how to develop our electricity infrastructure in order to address the challenges facing the sector, namely: the decarbonisation of electricity generation, including meeting the Governments' 2020 renewables targets; maintaining security of supply; and managing the costs of the network.

The 2012 ENSG Report sets out an updated view of how the electricity transmission system might need to be reinforced to facilitate the achievement of the Government's 2020 renewables targets. It presents, in one accessible resource, the updated views of the three onshore electricity Transmission Owners [1], as developed with input from the ENSG Working Group . It is accompanied by a summary document[2]. It updates a report published in July 2009 entitled "Our Electricity Transmission Network: A Vision for 2020 Full Report" ("2009 ENSG Report") which provided supporting data for a Summary report published in March 2009.

The 2012 ENSG Report is part of an ongoing process. In 2008, following the Transmission Access Review, the Government and Ofgem recognised that the potentially long lead times for expanding transmission capacity could impact upon meeting the 2020 renewables target. We therefore asked the Transmission Owners to set out the strategic transmission network investment that might be required to ensure that sufficient renewable and low carbon generation could be accommodated on the network. We also invited the ENSG to provide input to this work. The subsequent 2009 ENSG Report was welcomed by stakeholders in industry and the wider community as recognition of the urgency of network investment to help meet the UK's energy and climate change goals.

The 2009 ENSG Report contained a commitment to ensure that appropriate investment was taken forward in a timely manner. Since that time, the Transmission Owners have developed more detailed proposals for certain reinforcements, and have presented some of their proposals to the appropriate planning authorities. Similarly, proposals have been presented to Ofgem for decisions on whether each project is justified at the proposed time, and, if so, what the appropriate level of funding should be. Through the Transmission Investment Incentives framework, Ofgem has granted over £400million of funding since 2009. It is important to note, however, that neither the

[1] National Grid Electricity Transmission (NGET), SP Transmission (SPT) and Scottish Hydro Electric Transmission Ltd (SHETL)

[2] http://www.decc.gov.uk/en/content/cms/meeting_energy/network/ensg/ensg.aspx

2009 ENSG Report nor this updated report prejudge future decisions by the Transmission Owners about what projects to develop, or decisions by planning authorities about whether to grant consents Nor do the reports prejudge decisions by Ofgem about whether to grant funding or whether there could be benefits from a role for third parties in delivering certain projects.

The 2009 ENSG Report also contained a commitment to continue to monitor developments in generation and the network. At its meeting in February 2011 the ENSG asked the Transmission Owners to undertake updated studies in the light of developments in generation and the network since the 2009 ENSG Report was published. It also established a Working Group to provide input into this. The studies were also drawn upon by the Transmission Owners in preparing their Business Plans for the next transmission price control, (RIIO-T1), which includes mechanisms for funding reinforcements once the need has been established.

We thank all of those who contributed to producing the 2012 ENSG Report. It will serve as an important input into the future development of the electricity network, and a useful means of communicating potential network requirements to wider stakeholders. We would welcome feedback on the usefulness of this document and the summary document, including content and presentation. Please provide any comments to ensg@decc.gsi.gov.uk

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ofgem Promoting choice and value for all gas and electricity customers

Executive Summary

Overview

The Electricity Networks Strategy Group (ENSG) is a high level forum, which brings together key stakeholders in electricity networks that work together to support Government in meeting the long-term energy challenges of tackling climate change and ensuring secure, clean and affordable energy.

The Group is jointly chaired by the Department of Energy and Climate Change (DECC) and Office of Gas and Electricity Markets (Ofgem) and its broad aim is to identify, and co-ordinate strategy to help address key strategic issues that affect the electricity networks in the transition to a low-carbon future. The ENSG Terms of Reference and membership are at Appendix G.

This report ("2012 ENSG Report") has been prepared by the Transmission Owners (TOs) with input from the ENSG Working Group to discharge an action placed on them by the ENSG to provide:

- *An update of the ENSG 2020 vision report ["2009 ENSG Report"] incorporating network responses to changes to generation scenarios, technologies, policy developments, etc.*

The reinforcements identified by the TOs in this report are based on the Gone Green 2011 scenario. This scenario, developed by National Grid Electricity Transmission (NGET), and updated annually in consultation with stakeholders, represents a potential generation and demand background which meets the UK targets of 15% of energy demand being provided by renewable sources and a 34% reduction in Green House Gas emissions by 2020. It would also meet the Scottish and Welsh Governments' 2020 renewable energy targets i.e. the equivalent of 100% of Scotland's electricity demand should be met from renewables and 7 TWh per annum of Welsh electricity production by 2020. It takes a holistic approach to the meeting of the targets i.e. assumes that heat and transport will also contribute towards meeting the targets. It estimates that in order to meet this target, approximately 30% of UK's electricity will have to come from renewable sources by 2020, with a corresponding 12% from heat and 10% from transport. A previous scenario (Gone Green 2008) was utilised in The 2009 ENSG Report and the Gone Green 2011 scenario takes the same holistic approach to meeting the 2020 environmental targets.

Gone Green takes into account the significant changes anticipated in the generation mix between now and 2020. Sensitivities have also been applied to the Gone Green 2011 scenario to reflect possible faster or slower deployment of offshore wind on a regional basis. The scenario and sensitivities particularly examine the potential transmission investments associated with the connection of large volumes of onshore and offshore wind generation that are required to meet the 2020 renewables targets and new nuclear generation. The 2012 ENSG Report concludes that, provided the identified reinforcements are taken forward on time and the planning consents needed for network development works can be secured in a timely manner, then the reinforcements identified in this report can be delivered to required timescales.

In this report the TOs have identified and estimated the regional costs of the potential transmission reinforcements that may be required to accommodate the connection of a range of new generation needed to meet the UK's renewable energy targets whilst, at the same time, facilitating the connection of other essential new generation that will be needed to maintain continued security of supply. To ensure that the identified reinforcements are sufficiently robust, they have been tested against a range of background scenarios, which take account of likely developments up to the year 2020. The total estimated cost of the potential reinforcements contained in this report, based on the Gone Green 2011 scenario, is around £8.8bn. The resulting network would be able to accommodate a further 38.5GW of new generation (a little under half of current generation), of which 23GW could be a combination of onshore and offshore wind generation. Details of these potential reinforcements are included in Chapter 4 "Potential transmission network reinforcements". A summary table of significant changes to potential reinforcements since the last ENSG report is at Appendix E.

Feedback on the 2009 ENSG Report indicated that stakeholders would find the identification of possible alternative reinforcement helpful. In drafting this report, therefore, the TOs have undertaken analysis to identify possible alternative reinforcements. This is particularly relevant to the Scotland-England interface, North Wales, South West, East Coast/East Anglia, and London. Details are in Chapter 4.

Any new transmission infrastructure works would require regulatory and planning approval which would require a number of actions by TOs including comprehensive routeing and siting studies, consultations and detailed environmental impact assessment.

The increase in estimated costs compared to the 2009 ENSG Report (£4.7bn) is largely due to this updated report including the costs of possible provision of new subsea links from Scottish Islands[3] to the mainland, the inclusion of further options for reinforcements notably a possible HVDC subsea link from North to South Wales and a possible third HVDC link between Scotland and England; and the base price has also been updated. The Scottish Island links were considered as possibilities in

[3] Western Isles, Orkney Islands and Shetland Islands

the 2009 ENSG Report, but costs estimates were not available then. The subsea North to South Wales link has been raised as a possibility since the 2009 ENSG Report (with pre-construction funding approved by Ofgem).

Table 1 provides details of the cost difference totalling around £4bn between the 2009 ENSG Report and this updated report.

Regions	2009 ENSG Report Cost (£m)	2012 ENSG Report Cost (2008/09 Price Base) (£m)	Difference (£m)	Comments
Scotland + Scotland-England Interface	2715	5740	+3025	Inclusion of Scottish Island connections The cost of the Western HVDC link, NGET – SHETL East Coast HVDC link 1, Series Compensation are updated since the 2009 ENSG Report. NGET – SPT East Coast HVDC Link and Mersey Ring upgrade. These reinforcements were not considered in the 2009 ENSG Report
North Wales + Mid-Wales	575	1260	+685	New updated cost of Wylfa – Pentir double circuits Inclusion of Irish Sea – Pembroke HVDC Link
South West	340	430	+90	Updated cost of possible reinforcement
East Coast & Anglia	910	750	-160	In the 2009 ENSG Report, onshore HVDC reinforcements were considered in the Humber region. But The2012 ENSG Report considers onshore AC reinforcements in this region and the cost of the onshore AC reinforcements in less than the cost of the onshore HVDC reinforcements
London	190	190	0	
Base Price Difference			+450	The base price difference from 2008/09 to 2010/11
Totals	4730	8820	+4090	

Table 1: Cost difference between the 2009 and 20012 ENSG Reports

The decrease in new generation connected (38.5GW) compared to the 2009 ENSG Report (45GW) is due to updated assumptions in the Gone Green 2011 scenario in particular:

- The exclusion of energy used in the aviation sector from the overall target calculation which would reduce the amount of renewable capacity required to meet the 15% target. This would also result in a reduction in the overall renewable capacity requiring connection in the scenario.

- A greater number of extensions of the existing nuclear power plant are assumed than in the 2009 report. This means that more generation remains connected negating the need for some new generation to be connected by 2020.

Table 2 contains further details on generation accommodated and costs. Appendices A and B contain maps of GB showing the existing National Electricity Transmission System (NETS) and potential reinforcements respectively.

The Transmission Owners (TOs - National Grid Electricity Transmission (NGET), SP Transmission (SPT) and Scottish Hydro Electric Transmission Ltd (SHETL)) have identified the potential need for transmission investments to accommodate new generation and interconnection as well as optimising the existing infrastructure. Any transmission system reinforcement (including those identified in this report) would only be applied when all other possible network solutions have been explored and exhausted with the existing assets being fully utilised. Consideration has been given to employing the latest and possible future technologies[4], especially where additional economic and/or additional environmental benefits can be expected. Due account has been taken of the lead time required to develop robust engineering solutions and the need to obtain the necessary planning consents for each reinforcement. The TOs will keep these designs under review and consider suggestions to help ensure the right solution is developed.

The potential reinforcements are phased to be delivered in line with the prospective growth of renewable generation in each region. It is recognised that there will continue to be a degree of uncertainty about the volume and timing of generation growth in any given area. It is therefore proposed to continue to monitor the developments of the market and update the scenarios accordingly. Proposals for the potential transmission reinforcements would be developed in such a manner as to ensure that options for future development are maintained at minimum cost. Undertaking pre-construction engineering work, for example, means that for each project construction can be commenced when there is sufficient confidence that transmission system reinforcement will be required. This is a least regret solution, i.e. the minimum commitment to secure the ability to deliver to required timescales.

Scenario and Sensitivities

The 2012 ENSG Report takes a similar approach to the 2009 ENSG Report. A number of electricity generation and demand backgrounds have been developed. In their development, numerous

[4] See section 5

factors were taken into account; particularly in relation to ensuring that the UK, Scottish and Welsh Governments' 2020 targets for renewable energy and the UK target for Greenhouse Gas emissions[5] would be met. Such factors include the analysis of:

- closures of existing plants due to various legislation and age profile;
- contracted new connections for all types of plant;
- the potential for, and location of onshore and offshore wind generation; and
- the potential build rates for wind and new nuclear generating plant.

In developing a detailed background, issues such as: security of supply; the ability of the supply chain to deliver; and technological advances have been taken into consideration. The potential reinforcement requirements identified by the TOs in this report are based on a Gone Green 2011 scenario which has been developed from the Gone Green 2008 scenario originally used for the 2009 ENSG Report and has since been updated in the light of stakeholder feedback. As with the Gone Green 2008 scenario, the Gone Green 2011 scenario assumes that the main generation in 2020 would be from gas and wind, with a greater role for nuclear and a reduced role for coal. The generation mix in the Gone Green 2011 scenario for the year 2020 on which this report is based, is set out in Figure 1:

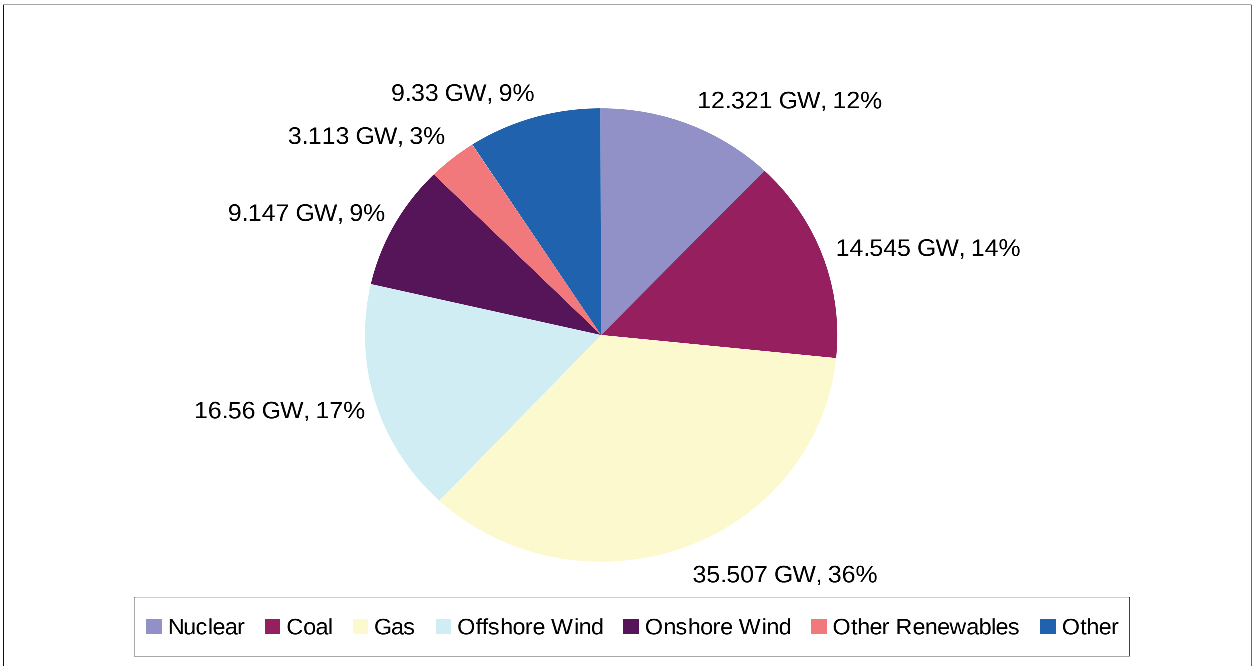

Figure 1: Generation mix in 2020 of the Gone Green 2011 Scenario Generation connected to Transmission network

In the 2009 ENSG Report sensitivities were applied to the Gone Green 2008 scenario to accommodate faster or slower development of onshore wind in Scotland. This was achieved by

[5] The UK target for 2020 is a reduction of at least 34% in greenhouse gas emissions compared to 1990.

increasing offshore wind generation in England and Wales to compensate for any volumes of onshore wind in Scotland less than 11.4GW. For this updated document sensitivities have also been applied to the Gone Green 2011 scenario to consider the possible effects of faster or slower development of offshore wind generation connecting in six GB regions. Under all sensitivities the 2020 renewable energy targets are still met.

The total offshore windfarm capacity connected is assumed to be in the region of 16.5GW by 2020. In considering how this offshore capacity could be achieved, it is assumed that around 8GW of projects in the The Crown Estate announcements on offshore wind Round 1, Round 2 and Round 2 extensions will proceed to completion, with the remainder being made up from The Crown Estate Round 3 and Scottish Territorial Waters (STW) development sites.

The Gone Green 2011 scenario also assumes 11.2GW of onshore wind generation; 12.3GW of nuclear generation (based on the existing nuclear Advanced Gas-Cooled Reactor (AGR) plants receiving 10-year life extensions from their original expected date of closure and two new nuclear installations connecting by 2020); and 41.7GW of gas generation.

The developments in the generation market and the progress that Developers have made in obtaining planning consent and the subsequent build rate will be continued to be monitored and the Gone Green scenario updated accordingly.

The generation assumptions made for the purpose of this report are entirely independent from, and in no way pre-suppose, the outcome of individual planning decisions about projects on particular sites.

Further details of the scenario and sensitivities, including how they differ from those used for the 2009 ENSG Report, are in Chapter 2.

Findings

As with the 2009 ENSG Report the predominant power flow on the GB transmission system is from North towards the South.

In the North of Scotland, generation is assumed to significantly increase with onshore, offshore wind and marine renewables. The level of demand is not anticipated to increase significantly over the next decade. Accordingly, there is a predominant net export of energy from the region to the Central Belt of Scotland. Additional power flows in the Central Belt of Scotland, within the SPT network, would place a severe strain on the 275 kV elements of the network and, in particular, the north to south and east to west power corridors.

The circuits between Scotland and England are already being used to their maximum capability. Under the Gone Green 2011 scenario and all sensitivities considered, the transfers from Scotland to England increase significantly requiring a number of reinforcements to relieve these boundary restrictions. The Upper North network of the England and Wales transmission system also experiences increased power flows which require reinforcements on the system.

Offshore wind generation connecting in England and Wales, together with the potential connection of new nuclear power stations raises a number of regional connection issues; particularly in North Wales, South West and along the English East Coast between the Humber and East Anglia. The increased power transfers across the North to Midlands boundary and/or the increased generation off the East Coast and/or Thames Estuary could result in severe overloading of the northern transmission circuits securing London especially when interconnectors around the South East area are assumed exporting to mainland Europe, hence the need for reinforcing London networks.

Analysis to determine transmission reinforcement requirements

The range of potential power flows on the NETS has been determined on the basis of the current NETS together with all the approved transmission system reinforcements assumed to be in place for the year 2015. Such authorised transmission reinforcements include:

- the proposed Beauly – Denny 400 kV line,
- the uprating of the transmission capacity between Scotland & England (TIRG); and,
- the additional transmission capacity around the North West and North East of England.

The 2009 ENSG Report used the existing NETS SQSS[6], but predominately focused on the application of the deterministic rules. A full-cost benefit analysis (CBA) was restricted to areas where the potential for high constraint cost had previously been identified, mainly the Scotland-England boundaries.

For the purpose of calculating Required Transfers (RT), the 2012 ENSG Report is based on the current NETS SQSS (version 2.1). This is consistent with the TOs' RIIO-T1 Business Plans submitted to Ofgem on 31 July 2011. However, the analysis is then further supplemented with the CBA analysis method (as set out in the GSR009 amendment to the NETS SQSS approved by the Gas and Electricity Markets Authority[7] on 1 November 2011) for the NETS SQSS under the economy criterion; whereas the RIIO-T1 Business Plans include a series of more detailed CBAs to

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[6] National Electricity Transmission System Security and Quality of Supply Standards

[7] http://www.ofgem.gov.uk/Pages/MoreInformation.aspx?docid=26&refer=Networks/Trans/ElecTransPolicy/SQSS

help determine the necessary level of transmission investment. The Security Model criterion is not used in the analysis for the 2012 ENSG Report.

Chapter 3 contains more details on the SQSS and network analysis methodology.

When a shortfall in network capacity is indentified, consideration has been given to traditional solutions such as reconductoring circuits, upgrading to a higher voltage and constructing new lines. However, it is recognised that traditional methods of enhancing system capacity, particularly those which involve new overhead line routes, can be difficult to achieve due to planning constraints and environmental concerns. The TOs have therefore investigated the potential for new or previously unused technologies on the NETS in order to either, enhance and maximise the use of existing assets, or to provide new infrastructure with reduced environmental impact and an acceptable level of technological risk.

When considering the use of new technologies or technology that has not previously been used on the NETS it is important to ensure that all issues associated with these systems (technical, commercial and environmental) are fully understood prior to commitment to construct. Discussions have already taken place with manufacturers to assess what technologies could be used in future network developments and what designs represent feasible options considering the required timescales. In many cases using new technologies appears to offer significant benefits over traditional design options. However, when comparing a new or unused technology with existing design options it will be necessary to quantify any benefits or drawbacks accurately to ensure that the optimum design is selected. There is also a need to look towards "smarter" ways of operating the transmission network to meet the increasing challenge of integrating large amounts of variable renewable generation and the advent of varying demand profiles. This could comprise a number of techniques such as the use of dynamic ratings to enhance the thermal rating of lines; the use of automated and co-ordinated systems such as Quadrature Booster (QB) control; and co-ordinated HVDC control systems which work in parallel with the existing HVAC networks.

Chapter 5 presents further details on new technologies and their potential use on the NETS.

Potential Reinforcements

Scotland

The volume of generation in SHETL's north of Scotland area is expected to increase over the coming years due to the growing capacity of renewable generation such as The Crown Estate Round 3 offshore wind farms, STW wind farms, marine generation in the Pentland Firth and Orkney waters and numerous onshore wind farms within Scotland. Under the Gone Green 2011 scenario about 6.3GW of new generation would be connected by the end of 2020 in SHETL's area. This includes 3.5GW of onshore wind, 2.2GW of offshore wind and 0.6GW of marine generation. At present there is about 0.9GW of onshore wind and no offshore and marine generation connected to the SHETL system.

The volume of generation in SPT's central and south of Scotland area is similarly expected to increase over the coming years due to the growing capacity of onshore wind farms across the south of Scotland, together with wind farms in STW and the Crown Estate Round 3 offshore wind farm in the Firth of Forth. Under the Gone Green 2011 scenario about 3.9GW of new generation would be connected in the SPT area by the end of 2020. This includes 2.3GW of onshore wind, 1GW offshore wind and 0.6GW of coal generation. Presently about 1.4GW onshore wind is connected to SPT's network.

A number of options for reinforcements have been identified by the TOs which would meet the requirements from the Gone Green 2011 generation scenario for this area. These reinforcements do not include projects which are currently under construction; Beauly-Denny, Beauly-Dounreay and Beauly-Kintore. A number of other reinforcements have been included which would address regional transmission issues including the links to the main islands of Western Isles, Orkney and Shetland.

- **Caithness-Moray-Shetland (CMS) 600MW HVDC Link** from Caithness to Moray Coast via Moray Firth Offshore hub and associated reinforcements to accommodate existing and planned onshore and offshore renewable generation in Caithness, in the Moray Firth, and on Orkney and Shetland.

- **East Coast AC 400kV Upgrade** to address capacity requirements on the east side of SHETL's area to enable the export of renewable energy from the north of Scotland to the demand centres in the south.

- **East Coast Subsea HVDC Link** from Peterhead in the north of Scotland to the north of England to provide a significant increase in north to south transfer capacity. Should there be more renewable generation connections in the north of Scotland, a second East Coast HVDC Link could be required to provide further capacity.

- **Kintyre to Hunterston AC Subsea Link** could provide the necessary capacity to accommodate the renewable generation in the Kintyre and Argyll area.

- **Orkney and Pentland Firth Subsea Link** An initial 132kV subsea link between the west Orkney mainland and Caithness would be required to accommodate the first tranches of marine sites, together with developing onshore renewables. As further marine generation deploys there is expected to be a requirement for an HVDC link of greater capacity around 2019-2021, with a delivery point on the Scottish mainland, linked to a main HVDC hub at Peterhead.

- **Western Isles 450MW HVDC Link** to accommodate potential increased wind generation in the Western Isles
- **Shetland Islands HVDC Link** to connect onshore wind from Shetland Islands to Moray Firth offshore hub
- further **Caithness reinforcement** to integrate the Caithness AC system with the Sinclairs Bay HVDC hub
- **Beauly to Blackhillock Reinforcement** it is possible that further high capacity reinforcement between Beauly and Blackhillock may be required in the future. There are a number of options being considered to provide this capacity.
- **Central 400kV Upgrade** (Denny – Wishaw) to meet increased transfer requirement from SHETL to SPT areas
- **SPT East Coast 400kV Upgrade** (Kincardine – Harburn) to meet increased transfer requirement from SHETL area

Cost

A number of possible reinforcements have been considered in the B0, B1, B4 and B5 boundary studies. The total estimated cost of the possible set of reinforcements considered for Scotland are between £2.14bn and £4.3bn for the slower and faster development sensitivities respectively with a cost of around £2.5bn estimated for the base Gone Green 2011 scenario. The base cost excludes possible reinforcements with dates marked as 2020+ in Table 13. These costs exclude the costs of reinforcements shared from Scotland to England and Wales. Estimated costs for individual projects in all regions cannot generally be provided in this report for commercial, procurement and legal reasons.

Scotland-England Interface

In addition to facilitating the transfer of flows from North Scotland this area (region between boundary B6 and B7a) would also have 1.1GW of new generation connected under the Gone Green 2011 scenario. This includes about 0.8GW of offshore wind and about 0.3GW of biomass generation. There is no offshore wind generation connected to the area at present. The existing capability of the Boundary B6 connecting the SPT and NGET networks is currently limited to 2.2GW by stability restrictions. Reinforcements to this boundary are due to complete in 2012/13, resulting in an export capability from Scotland to England and Wales of around 3.3GW. Further south Boundary B7 currently has a capability of around 3.6GW and Boundary B7a has a capability of 5.4GW. All of these other Scotland-England boundaries would become more constrained as power flows increase from Scotland, thus potentially requiring numerous reinforcements. In addition Boundary B7a also has potentially more generation to accommodate. The principal means of accommodating potentially significantly increased power flows would be through a Western HVDC link and East Coast HVDC Link.

Incremental Reinforcement

Upgrades to the onshore transmission system will maximise the capability of the Scotland-England interconnection and enable the firm 4.4GW thermal capability of the existing overhead line routes to be utilised. These works will involve the installation of series capacitors and Mechanically Switched Capacitors (MSC) at a number of sites in southern Scotland and the north of England, together with the uprating of some circuits from 275kV to 400kV operation and replacement of overhead line conductor systems.

Western HVDC Subsea Link

The project constructs a new HVDC link between Hunterston substation in central Scotland and Connah's Quay substation in North Wales. The connection would be via an undersea cable sited along the west coast of Great Britain. The project has already been allocated some funding by Ofgem for preconstruction works and further funding has been requested.

East Coast Subsea HVDC Link

The Western HVDC link option would provide sufficient transmission capacity until 2019 for Boundary B7 and until 2018 for Boundary B7a under the Gone Green 2011 scenario, after this point further reinforcement would be required. The NGET-SHETL East Coast HVDC link option would provide an additional 2.1GW of boundary capability to B6 boundary. Although the East Coast HVDC link would not cross the B7 and B7a boundaries, the improved load sharing that the link can provide would result in an increase in boundary capability, however this would not be the full 2.1GW as seen with the B4 and B6 boundaries.

Reconductor Harker-Hutton-Quernmore

This reinforcement would provide sufficient transmission capability until 2016 for Boundary B7. This reinforcement would increase the post-fault winter capability of existing Harker-Hutton-Quernmore circuits from 1390MVA to 3100MVA per circuit. Thus the improvement in boundary capability would be 1.4GW following this reinforcement.

Mersey Ring

These investments would provide for the voltage upgrade of the 275kV double circuit from Penwortham Substation through Washway Farm Substation to Kirkby Substation to 400kV operation and the associated substation works at Penwortham, Washway Farm and Kirkby. This Voltage Uprate would be required to restore compliance with the NETS SQSS following the potential connection of several offshore wind farm projects, Combined Cycle Gas Turbine (CCGT) Plant and also to allow increased electricity exports from Scotland.

Only the major reinforcement options have been explained. There are other reinforcement options which are included in Section 4.2 of this report.

Cost

The total estimated cost of the possible set of reinforcements considered for boundary B6, B7 and B7a in sections 4.2.5, 4.2.6 and 4.2.7 lies between £2.9bn and £3.9bn for the slower and faster development sensitivities respectively with a cost of around £3.5bn estimated for the base Gone Green 2011 scenario.

North to Midlands and Midlands to South

The capability of this region is sensitive to the changing generation backgrounds and is restricted by voltage limitations which vary throughout the year. The expected closure of existing CCGT generation plants under the Gone Green 2011 scenario on both sides of boundary B8 and B9 causes voltage depression around the boundaries. The Wylfa – Pembroke HVDC link indentified in the North Wales region would provide additional thermal and voltage capability to these boundaries. Alternatively voltage issues within Boundaries B8 and B9 can be solved by providing additional reactive power support.

Cost

The estimated cost of the possible set of reinforcements considered for boundary B8 and B9 has been covered in the sections on North Wales (NW2 and NW3) and East Coast (EC1) boundary.

North Wales

A net increase of 2.8GW of generation is forecast to connect under the Gone Green 2011 scenario in the North Wales area by 2020. This includes a new nuclear power station at Wylfa, offshore wind in the Irish Sea, and an interconnector link to Ireland which is expected to complete before 2012/13.

Under the Gone Green 2011 scenario when a significant contribution from the Round 3 Irish Sea windfarms and nuclear starts to impact on the boundary further reinforcement would be required in the form of:

- Two new transmission lines between Wylfa and Pentir
- Installation of a second circuit between Pentir and Trawsfynydd

A Wylfa - Pembroke HVDC link could also be required under the Gone Green 2011 Scenario as early as 2020. This reinforcement is further justified when all the units of Wylfa C nuclear are operating at full capacity

Other reinforcements which could be required:

- Reconductoring of the Trawsfynydd to Treuddyn Tee circuits

Cost

The estimated cost of the possible set of reinforcements considered in sections 4.4.7 to 4.4.9 is between £420m for the slower development sensitivity case and £1.12bn for the baseline Gone Green 2011 case. For this region, the cost to cover the faster development sensitivity is same as the Gone Green estimated cost.

Mid-Wales

Under the Gone Green 2011 scenario 360MW of onshore wind would connect to transmission system and 400MW to the Scottish Power Manweb distribution network. The capacity of the distribution network in the area is not sufficient to accommodate this generation unless transmission infrastructure is established in Mid-Wales. In order to provide a connection for the wind generation the following reinforcements have been considered. The earliest anticipated completion date of these reinforcements is 2016.

- Mid Wales Substation

- Construction of a new 400kV double circuit from Mid Wales to Legacy – Shrewsbury - Ironbridge circuits

- Establish a new single switch 400kV mesh substation at Shrewsbury and reconfigure the existing tee transformer arrangement such that it connects into the mesh substation.

The dates for the completion of these works are aligned with the generators' expected connection dates and are subject to the consenting process.

The first phase of public consultation of Mid-Wales was completed in June 2011, and the full set of need case, strategic optioneering and consultation reports can be found on the National Grid website[8]. The other projects noted will also be subject to the Infrastructure Planning Commission (IPC) process with need case and strategic option document being produced.

Cost

The cost of the reinforcements in the Gone Green 2011 scenario is estimated to be around £200m for this region.

South West

Under the Gone Green 2011 scenario 2.8GW of new generation is forecast to connect in the area over the next decade. The new generation comprises offshore wind in the Bristol Channel, nuclear at Hinkley, and a small amount of marine.

A number of reinforcement options could be applied to accommodate this new generation. Note that only one of these options would be required to achieve compliance with NETS SQSS and they are subject to the consenting process:

- Hinkley – Seabank 400kV two AC Transmission Circuits

- Hinkley-Alternative Destinations 400kV AC Transmission Circuit

- HVAC subsea cable Hinkley Point-Seabank

- HVAC subsea cable Hinkley Point-Aberthaw

- HVDC cable Hinkley Point -Seabank

- HVDC cable Hinkley Point –Aberthaw

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[8] http://www.nationalgrid.com/uk/Electricity/MajorProjects/MidWalesConnection/

NGET announced, on 29th September 2011 following two years of extensive public consultation, its preferred route corridor for the Hinkley Point C connection. The full set of need case, strategic optioneering and consultation reports can be found on the National Grid website[9]. The other projects noted will also be subject to the IPC process with need case and strategic option documents being produced.

Cost

The total estimated cost of the possible reinforcement considered for boundary B13 and B13E (SW-R01) is £450m.

English East Coast and East Anglia

The volume of generation off the East Coast is expected to increase significantly over the study period under the Gone Green 2011 scenario. The East Coast has been extremely active in terms of proposed generation connections, with the three largest potential offshore wind developments (Dogger Bank, Hornsea and East Anglia, potentially amounting to around 25GW) all seeking to connect (at least in part) into this area. By 2020 the Gone Green 2011 scenario shows just under 6GW of offshore wind connecting. In addition, there are a number of other, smaller, offshore wind developments, proposed new gas-fired generation and potential nuclear power stations. There is about 8.4GW generation currently connected within the region. This includes just over 7GW of gas and over 1GW of nuclear generation.

Given the high levels of potential generation and uncertainties about timing of connections and eventual scale of generation a large number (21) of possible reinforcement options (onshore and offshore) have been identified by NGET for the East Coast & East Anglia region that could enable the transmission system to meet the required power transfer levels. 17 of these possible reinforcement options did not appear in the 2009 ENSG Report.

Potential onshore reinforcements are:

- Norwich - Sizewell turn-in at Bramford & reconductoring
- Extend Bramford Substation
- Bramford – Twinstead two new circuits
- Braintree – Rayleigh reconductoring
- Rayleigh - Coryton – Tilbury reconductoring

[9] http://www.nationalgrid.com/uk/Electricity/MajorProjects/HinkleyConnection/

- Killingholme South Substation and new Double Circuit to West Burton
- Grimsby West - South Humber Bank new double circuit
- South Humber Bank – Killingholme new double circuit
- Humber circuits reconductoring
- Walpole QBs
- Elstree - Waltham Cross – Tilbury uprating, reconductoring and QBs
- Barking – Lakeside uprating
- Kemsley - Littlebrook – Rowdown reconductoring
- Rayleigh Reactor installing reactor
- Tilbury - Kingsnorth - Northfleet East reconductoring

4 potential offshore reinforcements would connect Hornsea, and Dogger Bank offshore wind farms to each other and to connection points on the East Coast and East Anglia (Killingholme South, Creyke Beck and Walpole). A further 2 potential offshore reinforcements would connect Norfolk offshore wind farm to Bramford and Norwich Main. All of these reinforcements have the potential to provide additional security to the onshore and offshore networks.

The Bramford – Twinstead two new circuits have been in public consultation since October 2009, and the full set of need case, strategic optioneering and consultation reports can be found on the National Grid website[10]. The other projects noted will also be subject to the IPC process with need case and strategic option documentation being produced.

Cost

The estimated cost of reinforcing this region ranges between £420m and £1.26bn for the slower development and faster development sensitivity scenarios respectively. The total cost of the possible set of reinforcements considered in the boundary EC1 and EC5 study for the Gone Green 2011 base scenario is estimated to be around £790m.

London, Thames Estuary and South Coast

London is the largest demand centre in the UK and a large proportion of electricity generated nationally flows into the city from the adjacent regions. Regionally the only significant generation is focused in the lower Thames Estuary where there is large coal, oil and gas-fired stations

[10] http://www.nationalgrid.com/uk/Electricity/MajorProjects/BramfordTwinstead/

Generation support is provided by units further away, such as the nuclear power stations to the East of London. Demand can also be met through the existing interconnectors to France and the Netherlands. Consequently, the demand in London is predominantly met by transmission connections from remote generation sources. The area is particularly sensitive to changes from the existing interconnectors to Europe which would become more significant (potential swing from 5GW import to 5GW export) with the commissioning of the Belgium-England interconnector (NEMO).

The potential reinforcement options to accommodate potential changes are:

- Uprate a 275 kV overhead line from Waltham Cross to Hackney via Brimsdown and Tottenham to 400 kV.
- Reconductor the Pelham – Rye House circuits.
- St. John's Wood – Elstree – Sundon reinforcement
- Uprating the transmission circuits between Tilbury-Warley-Waltham Cross and Elstree from 275kV to 400kV

The Waltham Cross to Hackney reinforcement is currently the subject of public consultation, and the full set of need case, strategic optioneering and consultation reports can be found on the National Grid website[11]. The other projects noted will also be subject to the IPC process with need case and strategic option document being produced.

This report has considered a wider range of potential alternative reinforcements. The final two options listed above did not appear in the 2009 ENSG report.

Cost

The total estimated cost of the possible reinforcement options (LN-R01&LN-R02) considered for boundary B14 is £200m under interconnector importing conditions and could rise up to £415m under exporting conditions.

Capex requirement

The estimated capex requirement to deliver the reinforcements to meet the Gone Green 2011 scenario identified by the TOs in this report and the amount of generation which can be accommodated is shown in Table 2. The estimated capex requirement to deliver the reinforcements will be subject to a rigorous review as part of the pre-construction engineering stage

[11] http://www.nationalgrid.com/uk/Electricity/MajorProjects/NorthLondonReinforcement/

and to the Ofgem investment approvals process of any investment proposals put forward by the TOs.

Region	Generation Accommodated	Estimated Cost
Scotland	10.2GW	£2.5bn
Scotland-England	1.1GW	£3.56bn
North to Midlands and Midlands to South	3.7GW	-
North and Central Wales	3.8GW	£1.12bn
Mid Wales	0.36GW	£200m
South West	6.0GW	£450m
English East Coast and East Anglia	10.8GW	£790m
London	3.3GW	£200m
Total	39.26GW	£8.82bn

Table 2: Regional summary of estimated cost of reinforcements and additional generation that can be accommodated

Taking Investment Proposals Forward

A wide range of potential reinforcements have been identified by the TOs to achieve the compliance against the generation background and sensitivities. The reinforcements listed in this Executive Summary and other parts of the report are only options identified by the TOs at this stage. Any network reinforcements at and above 132kV would be (or are being) consulted on would be/are required to undergo pre-application consultation and examination under the Planning Act 2008 in England & Wales (except for associated development, including substations in Wales which require local authority and Welsh Assembly approval) and under the Electricity Act 1989 for electricity networks and in Scotland under the Scottish Planning regime. Appendix F provides further details. The constrained areas of the network which may require reinforcing have been classified as very strong need case and strong need case. Appendix B presents this information on a map of GB.

Table of Contents

1 Introduction

This report sets out an updated view of strategic areas where the National Electricity System (NETS) might need reinforcement in order to facilitate the achievement of the UK's 2020 renewables targets. The studies in this report were conducted by the three onshore electricity TOs[12], and the work received input from the ENSG Working Group.

This report seeks to contribute to the ongoing discussions about how to develop our electricity infrastructure in order to address the challenges facing the sector:

The decarbonisation of electricity generation – action is being taken to transform the UK permanently into a low-carbon economy and meet our 15% renewable energy target by 2020. DECC estimates that the proportion of electricity supplied from renewable sources will need to increase to around 30% to enable the 2020 target to be met. The networks need to accommodate the flows from the increased levels of renewable and other generation that will be needed in order to meet the 2020 target.

Maintaining security of supply – over the next decade we will lose around a quarter (around 20GW) of our existing generation capacity as old or more polluting plant closes. As new generation is connected the electricity network will need to manage an electricity system containing more intermittent generation (such as wind) and more continuous generation (such as nuclear).

Costs of the network – The costs of network expansion and replacement must also be properly managed to reduce the impact on consumers.

The electricity market and network will require significant change to deliver the scale of the long-term investment needed, at the required pace, to meet these challenges. In July 2011 the Government published its Electricity Market Reform White Paper[13] which set out its commitment to transform the GB's electricity system to ensure that our future electricity supply is secure, low-carbon and affordable. This was accompanied by The UK Renewable Energy Roadmap[14] which outlined a plan of action to accelerate renewable energy deployment to meet the 2020 target while driving down costs. The transmission network will play a vital role in ensuring these wider energy market objectives are successfully met.

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[12] The three onshore Transmission Owners (TOs) are: National Gird Electricity Transmission, NGET; Scottish Power Transmission, SPT; and Scottish Hydro Electric Transmission Limited, SHETL. NGET also acts as the System Operator (SO).

[13] http://www.decc.gov.uk/en/content/cms/legislation/white_papers/emr_wp_2011/emr_wp_2011.aspx

[14] http://www.decc.gov.uk/en/content/cms/meeting_energy/renewable_ener/re_roadmap/re_roadmap.aspx

Alongside these initiatives, Ofgem is conducting an independent and open review of the transmission charging and associated connection arrangements through “Project TransmiT”. The aim of Project TransmiT is to ensure that arrangements are in place which will facilitate the timely move to a low carbon energy sector whilst continuing to provide safe, secure, high quality network services at value for money to existing and future consumers.

Electricity transmission charging is one of the immediate priorities for Project TransmiT with Ofgem announcing in July 2011 the launch of Significant Code Review (SCR). The SCR is focusing on options for potential changes to the existing Transmission Network Use of System (TNUoS) charging arrangements.

Potential options are being considered ranging from socialised charging under which part or all of the costs relating to shared transmission assets would be recovered through the same uniform tariff, through to potential improvements to the existing TNUoS methodology to improve the accuracy of cost targeting.

Economic assessment of the impacts of the potential charging options has been undertaken by Redpoint on behalf of Ofgem. Changes to transmission charging could accelerate or decelerate the rate of renewable and low carbon generation deployment and/or change the level of support required to achieve a certain level of deployment. The final stage of Redpoint’s modelling exercise, which aims to assess the overall cost to consumers of each potential charging option, adjusts low carbon support levels such that renewable and carbon intensity targets are met under all charging options by 2020 and 2030 respectively. As the Gone Green 2011 background utilised for the ENSG work is also based on the fundamental starting assumption that these aforementioned targets will be met, it is consistent with the TransmiT work in that respect. However, the geographical and technological disposition of generation capacity will vary from study to study.

ENSG 2020 Vision

In 2008, following the Transmission Access Review, the Government and Ofgem recognised that the potentially long lead times for expanding transmission capacity could prevent the UK meeting its share of the EU 2020 renewable energy target. The TOs were therefore asked to provide a robust, transparent and authoritative report on the potential network requirements to achieve the 2020 renewable energy target.

In March 2009 the ENSG published the "Our Electricity Transmission Network: A Vision for 2020" report[15]. The report set out the TOs' view,with ENSG input, of the potential strategic transmission network investment potentially required to ensure that new generation necessary to meet the UK's 2020 renewable energy targets could connect to the system in a timely manner. It was welcomed by stakeholders in industry and the wider community as a recognition of the urgency of network investment to help meet the UK's energy and climate change goals. A full report providing supporting data was published in July 2009[16].

In January 2010, Ofgem confirmed the interim funding arrangements (the Transmission Investment Incentives (TII) framework), to apply to critical investments undertaken prior to the next full transmission price control review (RIIO-T1)[17].

Updated ENSG 2020 Vision Report

The 2009 ENSG Report contained a commitment to continue to monitor developments in generation and the network and ensure appropriate investment was taken forward in a timely manner. At its meeting in February 2011 the ENSG asked the TOs to undertake updated studies in the light of developments in generation and the network since the 2009 ENSG Report was published. It also established a Working Group[18] to provide input into this. These developments included:

- the implementation of a new connect and manage approach resulting in new generation connecting to the transmission network more quickly;
- more ambitious industry plans for offshore wind generation which have a potentially significant impact on the onshore transmission network;
- further progress towards nuclear investment; and
- extensive (and ongoing) stakeholder engagement by TOs as they developed their Business Plans for the next transmission price control, RIIO-T1[19].

The TOs conducted comprehensive network studies during 2011 as part of their RIIO-T1 business plan submissions. The study results have been used to draft this report with input from the ENSG Working Group. As with the 2009 ENSG Report, this updated report is a high-level technical and

15 http://www.decc.gov.uk/en/content/cms/meeting_energy/network/ensg/ensg.aspx

16 http://www.decc.gov.uk/en/content/cms/meeting_energy/network/ensg/ensg.aspx

17 RIIO-T1 is the transmission price control that will run from 1 April 2013 to 31 March 2021. For more information, see: http://www.ofgem.gov.uk/Networks/Trans/PriceControls/RIIO-T1/Pages/RIIO-T1.aspx

18 The Terms of Reference and membership of the ENSG Working Group are at Appendix G of this report.

19 http://www.ofgem.gov.uk/Pages/MoreInformation.aspx?docid=120&refer=Networks/Trans/PriceControls/RIIO-T1/ConRes

economic analysis. It presents updated views of where network reinforcement might be required in one accessible resource, against a common set of assumptions, and with certain sensitivities applied

The report focuses on the Main Interconnected Transmission System (MITS) and Scottish island connections. It does not propose developments in either interconnection or offshore transmission, which are covered by separate regimes with their own workstreams. For example, the offshore transmission coordination project, which is led by DECC and Ofgem, is considering:

- the potential costs, risks and benefits that may arise from the development of a co-ordinated offshore and onshore electricity transmission network; and
- whether additional measures are required to enable different grid configurations should the analysis support such development.

This updated ENSG report does however consider potential interactions between interconnectors, offshore transmission, and the MITS, and has made certain assumptions about interconnection and offshore transmission. For example there are three regions (Scotland, North Wales, and the East Coast of England) where offshore wind connections may impact significantly on the MITS before 2020. For the purposes of this report, therefore, illustrative offshore network designs have been incorporated to assess the potential impact on the MITS in these regions. The illustrative offshore transmission system designs used in this report do not prejudge the outcome of the offshore transmission coordination project, nor do they represent any investment decisions and/or contracted arrangements or programme of the TOs, Offshore Transmission Owners (OFTOs) or third parties; nor do they imply the actual connection routes for new electricity transmission infrastructure. All relevant assumptions would need to be reviewed were the TOs to develop more detailed plans for reinforcing any particular area of the MITS.

Roles and Responsibilities

As set out earlier, this report presents updated TO views of areas where the onshore NETS might need to be reinforced in order to facilitate the achievement of the Government's 2020 renewables targets. It is important to recognise that this report is not a Government plan for developing the networks, nor does this report prejudge future decisions by the TOs, planning authorities or Ofgem. It is the responsibility of the TOs to judge when (and if) there is justification to develop these high-level views into detailed plans for specific reinforcements or if other options should be developed. Any such plans would be subject to the planning applications with the relevant authorities which would decide whether or not to grant planning consents. A statement from the TOs on their approaches to the planning process is at Appendix F. Any such reinforcement plans would also be subject to scrutiny by Ofgem, which would decide whether or not a given investment would be in the interests of consumers, and, if so, what level of funding would be appropriate and what outputs should be delivered. Ofgem would also decide whether there would be benefits from a role for third parties in delivering certain projects. In these decision-making processes as the TOs develop their reinforcement plans in more detail they are required to engage with stakeholders and to take their views into account.

The TOs’ initial Business Plans for the RIIO-T1 price control were submitted to Ofgem in July 2011. The RIIO framework has been designed such that the network companies can play their full part in meeting the challenges facing the sector, while providing long term value for money. The TOs’ performance in RIIO-T1 will be judged against a comprehensive series of outputs, including those related to connections and network reinforcements, with strong incentives for delivering appropriate and timely solutions that meet the needs of network users and that provide value for money for electricity consumers.

2 Scenarios and Sensitivities

2.1 Approach to developing scenarios

2.1.1 Overview

The 2009 ENSG Report utilised an energy scenario developed by NGET - Gone Green 2008 - that presented one way the UK could meet its 2020 target of 15% of energy demand being provided by renewable sources. Following internal and external stakeholder engagement the Gone Green scenario has been updated annually to reflect changes in the energy market in the intervening period while maintaining the original aim of meeting the 2020 environmental targets. The Gone Green scenario is a stakeholder supported scenario which has received wide energy industry support as a credible scenario to meet these targets. In addition to the engagement process forming part of TOs' price control processes, the Gone Green scenario has formed part of NGET's Transporting Britain's Energy (TBE) consultation process[20] and the Offshore Development Information Statement (ODIS) energy scenarios consultation (Future Scenario consultation[21]). This section outlines the key aspects of the Gone Green 2011 scenario. Sensitivities to the scenario have been developed by assessing higher and lower levels of renewable generation (offshore wind) connecting in six regions of the network. The approach to this sensitivity analysis is outlined in section 2.2

2.1.2 Gone Green 2011 Scenario

The Gone Green 2011 energy scenario takes an holistic approach to meeting the 2020 environmental targets. It focuses on the strategic priorities of conserving energy and decarbonising electricity generation, but also assumes a contribution from the heat and transport sectors. It also ensures that the UK meets the unilateral 2020 carbon emissions reduction target and remains on the 'flightpath' to the long-term 2050 carbon emissions reductions target. In developing the scenario consideration has been given to issues such as security of supply, the ability of the supply chain to deliver, technological advances and grid connection.

[20] http://www.nationalgrid.com/uk/Gas/OperationalInfo/TBE/

[21] http://www.nationalgrid.com/NR/rdonlyres/99312A31-9D0A-42B6-8098-39D6CCC83A78/45576/Scenario_Paper.pdf

2.1.3 Generation

There is likely to be an unprecedented amount of change in the generation mix in the period to 2020 if the renewable targets are to be met. Renewable generation is likely to play a major role in delivering the volumes of energy needed to decarbonise electricity generation and provide the volumes of energy the UK requires. In the Gone Green 2011 scenario 31% of electricity generation would come from renewable sources in 2020, predominantly wind. With existing nuclear power stations coming to the end of their planned lifespan and coal and oil capacity limited by the Large Combustion Plant Directive (LCPD), the majority of new power generation is likely to come from new CCGT plant and renewable generation, with new nuclear also being delivered towards the end of the decade. Figure 2 details the volumes of openings and closures in the Gone Green 2011 scenario and also highlights the net capacity increase over the period. This capacity increase is driven by the changing generation mix, principally the variable nature of wind generation resulting in back-up capacity requirements for security of supply purposes. The chart highlights the need, under the Gone Green 2011 scenario, to enable some 38.5GW of new generation connections across Great Britain by 2020, which is a little under half of the current installed generation total. This includes 23GW of new wind generation, 12GW of gas-fired generation and 3GW of new nuclear generation. The closure of 25GW of existing generation capacity is assumed over the same period[22].

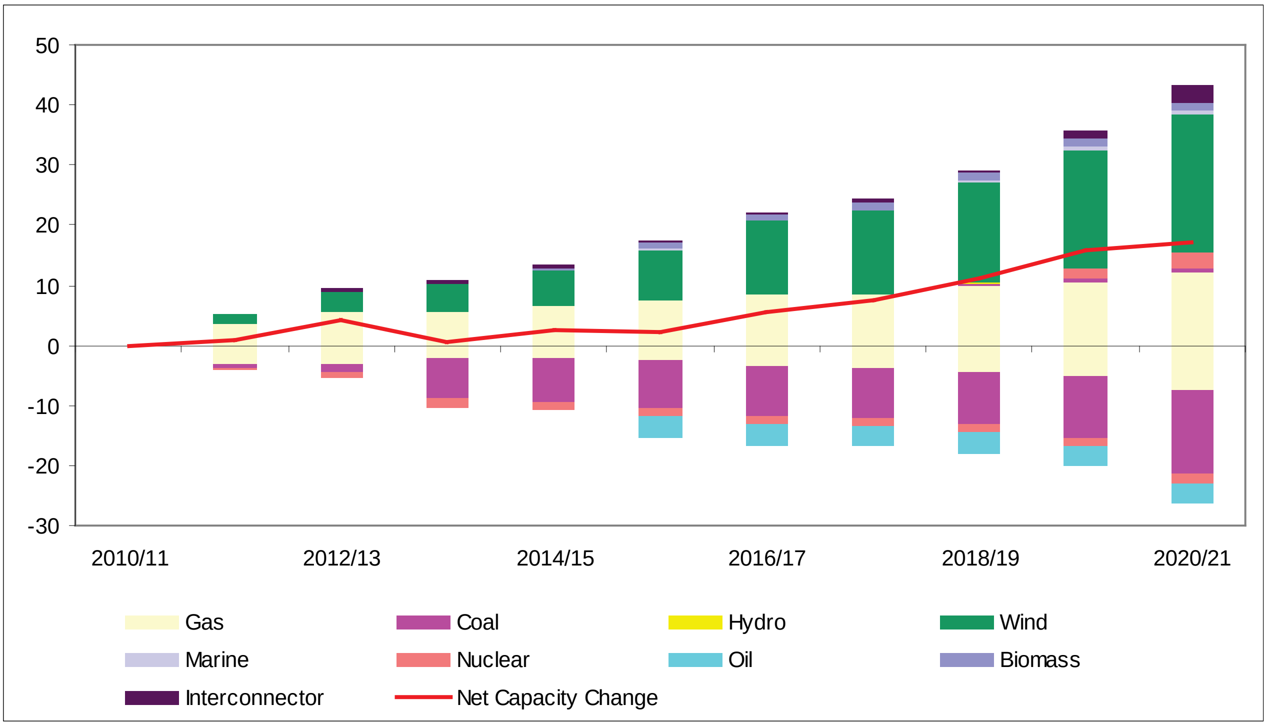

Figure 2: Capacity changes on the Transmission system in Gone Green 2011

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[22] Due to confidentiality agreements and commercial sensitivity of such information, specific generation changes within the background are not presented.

In addition to the significant volumes of new connections, one of the key aspects of the Gone Green 2011 scenario is that it assumes the existing nuclear Advanced Gas-Cooled Reactor (AGR) plants receive ten-year life extensions from their original expected date of closure. In some cases five–year extensions have already been granted therefore an additional five years is assumed in these instances. This maintains the level of nuclear capacity until the advent of new nuclear plant and assists in lowering the level of carbon emissions from the generation sector. It should be noted that life extensions are commercial decisions for operators and are subject to approval from the Office for Nuclear Regulation (ONR) and the Nuclear Decommissioning Authority (NDA).

Another key aspect of the Gone Green 2011 scenario is the treatment of wind generation when assessing the required plant margin. In order to account for the intermittent nature of wind and the fact that wind generation may be limited at the time of peak demand, wind generation is de-rated to 5% of the nameplate capacity for security of supply purposes. This enables an assessment of the required level of capacity that would be necessary to maintain an adequate long-term plant margin. This 5% figure is based on recent experience during the previous two winters. This methodology is applied to both transmission connected wind and to embedded wind connected to the distribution networks.

Figure 3 shows the breakdown of installed transmission connected capacity in 2020 in the Gone Green 2011 scenario. Other renewables are hydro, wave, tidal and biomass. ‘Other’ generation capacity is oil, interconnectors and pumped storage.

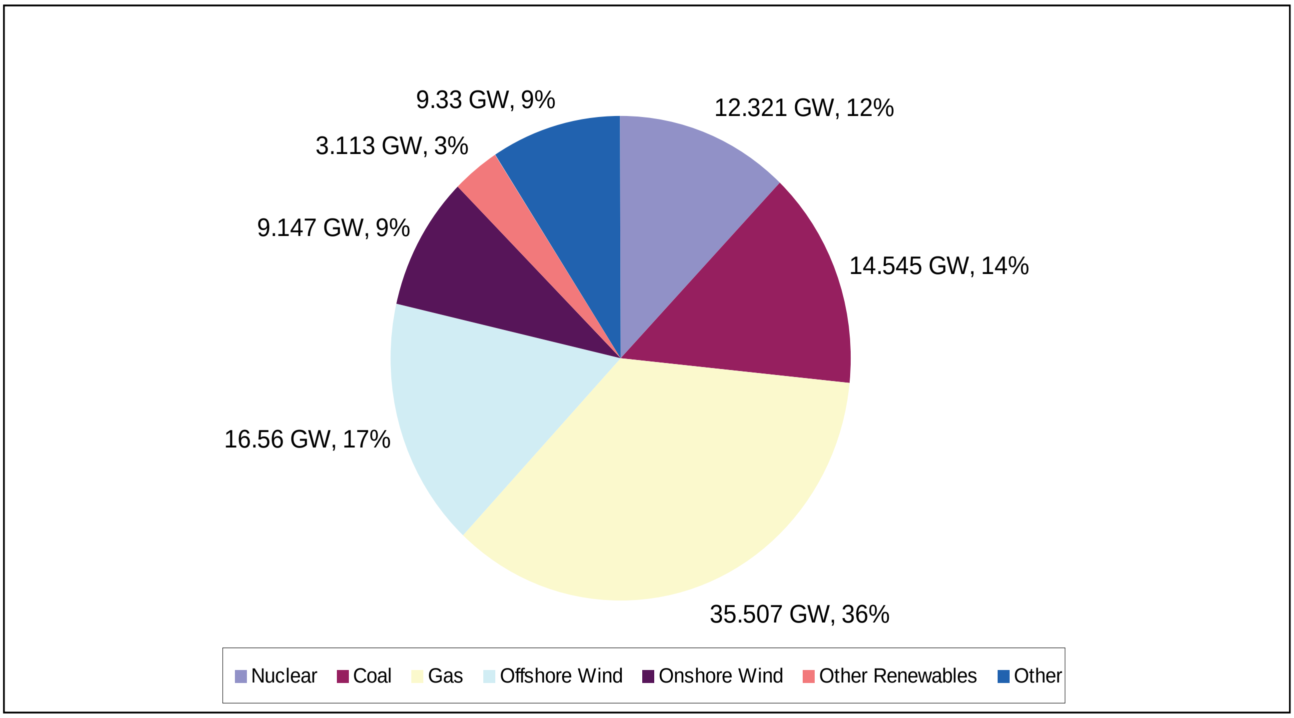

Figure 3: Installed Transmission capacity in Gone Green 2011 scenario in 2020

The following points are some of the key features of the Gone Green 2011 Scenario.

- AGR nuclear plant receives 10 year life extension from original expected date of closure.
- First new nuclear plant connects in 2019/20.
- Coal plant closes due to environmental directives and age.
- Existing gas-fired plant assumed to close at around 25 years of age.
- 12GW of new conventional CCGT capacity:
- 26GW of total Transmission connected wind capacity in 2020 with 17GW offshore
- 5% of wind nameplate capacity used for plant margin calculation.[23]

2.1.3.1 Interconnector Capacity

The treatment of interconnector capacity is another key aspect of the Gone Green 2011 scenario. Interconnectors can impact on the capacity margin depending on the direction of flow. For the purposes of system peak analysis in the Gone Green 2011 scenario, interconnectors between the NETS and mainland Europe are assumed to operate at 'float' as a central assumption i.e. neither importing nor exporting. Interconnectors connecting to Northern Ireland and the Republic of Ireland are assumed to be exporting from the NETS at full capacity. In some regions such as in the London, Thames Estuary and South Coast region, the capabilities with the links exporting have been considered. For CBA purposes, variation of flows across interconnectors within the year has been accounted for to improve the accuracy of the analysis.

Table 3 lists the existing and future interconnectors which have been considered in the Gone Green 2011 Scenario with their capacity and status. The future interconnectors which have been considered have been included on the basis that they have formal contracts/signed agreements with National Grid as the System Operator for the NETS. Interconnectors in general can create flow swings on the network that can significantly impact the operation of the transmission network. More information on these interconnectors can be found on the Transmission Entry Capacity (TEC)[24] register. Due to confidentiality agreements and commercial sensitivity, other potential future interconnectors which are in very early stages of development at this moment have not been considered in this report.

[23] This figure has been specifically used for determining plant margin. The figure used for transmission planning differs from this and has been set in accordance with existing NETS SQSS standards (http://www.nationalgrid.com/uk/Electricity/Codes/gbsqsscode/DocLibrary/).
[24] http://www.nationalgrid.com/uk/Electricity/Codes/systemcode/tectrading/

Link	Capacity (MW)	Status
IFA (France-England)	1988	Existing
Britned (Netherlands-England)	1200	Existing
Moyle (Northern Ireland-Scotland)	500	Existing
East-West (Ireland-Wales)	500	Expected 2012
NEMO (Belgium-England)	1000	Expected 2019
Norwegian (Norway-England)	1400	Expected 2018

Table 3: List of existing and future interconnectors

2.1.4 Demand

The level of electricity demand on the NETS is assumed to be broadly unchanged in the period to 2020 with economic growth and new connections being broadly offset by energy efficiency improvements. The impact of new demand sectors has been considered, namely heat pumps and electric vehicles, but these are assumed to have little overall effect on demand on the NETS in the period to 2020.

In addition to the transmission connected generation in Figure 3, embedded generation (generation connected to the distribution network) has an important role to play and is assumed to grow from around 9GW today to around 14GW by 2020. The impact of such an increase in embedded generation would be to reduce transmission demand over the period as the underlying demand growth would be 'netted off' at a transmission level by increasing embedded generation. The majority of the embedded demand growth is assumed to be in England and Wales as the cut-off between Transmission and embedded generation is much lower in Scotland than England and Wales. Figure 4 shows the overall transmission generation capacity mix to 2020 under the Gone Green 2011 scenario with peak transmission demand (around 60GW) also shown.

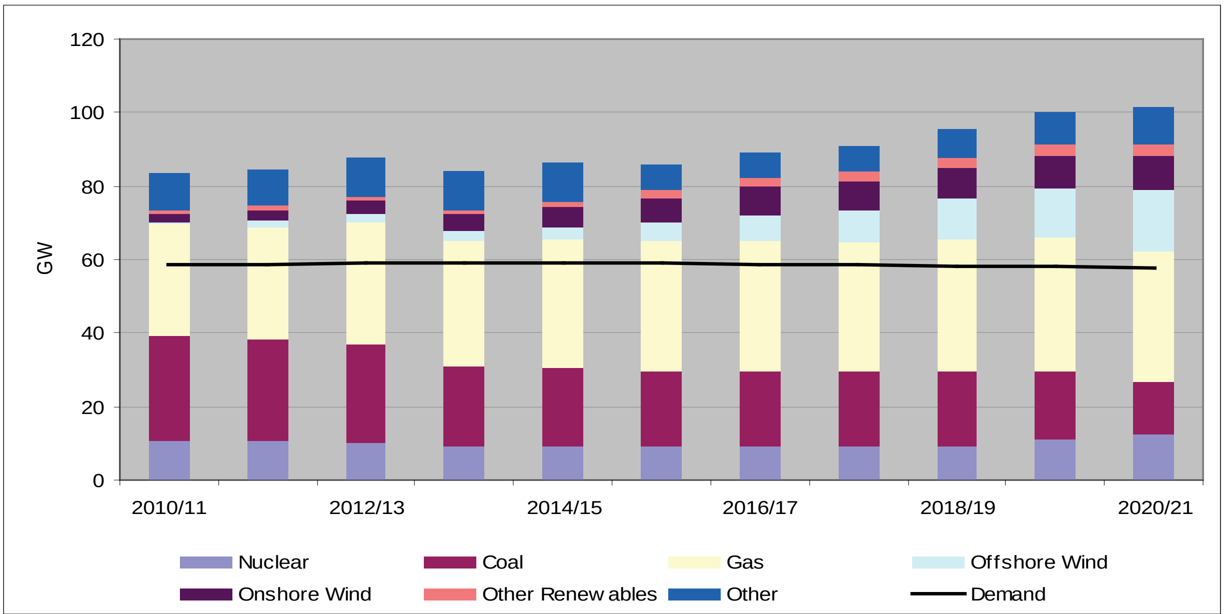

Figure 4: Gone Green 2011 Transmission connected generation and demand

2.1.5 Changes in Gone Green Scenario from the 2009 ENSG Report

Table 4 outlines the changes in all generation capacity (not just that connected to the NETS) in 2020 between the Gone Green 2008 scenario used in The 2009 ENSG report and the Gone Green 2011 scenario. The key differences in assumptions are:

- Increase in nuclear capacity to reflect the existing AGR stations being assumed to receive ten-year life extensions. This allows for a corresponding decrease in coal-fired generation and a subsequent decrease in carbon emissions.
- The Gone Green 2011 scenario also meets the UK's 2020 carbon reduction targets which have become more stringent since 2009. The carbon emission reduction target for 2020 in the Gone Green 2011 scenario is 34% on 1990 levels where as it was previously 29% for the Gone Green 2008 scenario.
- The exclusion of energy used in the aviation sector from the overall target calculation which would reduce the amount of renewable capacity required to meet the 15% target. This would also result in a reduction in the overall renewable capacity in the scenario. This reduction has been applied to wind generation capacity required as it is the main source of renewable energy.

Generation type	Gone Green 2008 for 2020 (GW)	Gone Green 2011 for 2020 (GW)
Coal	19.8	14.5
Gas	41.0	41.7
Nuclear	6.9	12.3
Wind	32.3	28.5[25]
Other Renewable	8.2	7.2
Other	3.8	3.4
Total	**112.0**	**107.6**
of which embedded	14.6	13.6
of which renewable embedded	7.7	6.7

Table 4: comparison of generation capacity in Gone Green 2008 (used for 2009 ENSG Report) and Gone Green 2011

The generation capacity shown in the Table 4 excludes Interconnectors capacity to enable proper comparison with Gone Green 2008. The total amount of Interconnector capacity is in Table 3.

2.1.6 Scenario Comparison

In addition to the wide stakeholder engagement outlined in section 2.1, the Gone Green 2011 scenario has also been validated against the UK Renewable Energy Roadmap to 2020 document[26].

[25] Includes embedded wind

The Renewable Energy Roadmap analysis of potential deployment of renewable energy to 2020 considered factors such as technology cost, build rates, and the policy framework. These variables were modelled to produce illustrative 'central ranges' for deployment. The central ranges do not represent technology specific targets or the level of the Government's ambition. They are based on current understanding of deployment, costs and non-financial barriers and could change significantly as the market evolves to 2020. However, they provide a useful sense check for Gone Green 2011. Table 5 compares both the renewable capacity and generation output in the Gone Green 2011 scenario and the Renewable Energy Roadmap to 2020 analysis. As the comparison shows, Gone Green 2011 is at the upper end of the Renewable Energy Roadmap central ranges.

	Gone Green 2011	DECC Renewable Energy Roadmap
Capacity (GW):		
Total renewable	35.6GW	25.2-37.3GW*
Onshore wind	11.2GW	10-13GW
Offshore wind	17.3GW	11-18GW
Output (TWh):		
Onshore wind	30 TWh	24-32 TWh
Offshore wind	50 TWh	33-58 TWh
Biomass	30 TWh	32-50 TWh
Marine	3 TWh	1 TWh

Table 5: A comparison of 2020 generation mix between Gone Green 2011 and DECC Renewable Energy Roadmap document

** Total renewable figure was not included in Renewable Roadmap. Range calculated from ranges of wind, biomass and marine, but total renewable range would vary dependent on how co-firing capacity is incorporated*

2.2 Approach to developing scenario sensitivities

The 2012 ENSG Report takes a similar approach to scenarios as the 2009 ENSG Report. This involves the use of the Gone Green 2011 base scenario. This scenario was originally developed for ODIS 2011 following stakeholder engagement as described in Section 2.1. The only difference between the Gone Green 2011 scenario used for this report and that for the ODIS is the treatment of interconnectors. For the Gone Green 2011 in ODIS an aggregate figure was used for interconnection. For this report individual projects have been referenced which, due to confidentiality agreements and commercial sensitivity, means only those interconnectors with a signed connection agreement have been considered.

[26] http://www.decc.gov.uk/assets/decc/11/meeting-energy-demand/renewable-energy/2167-uk-renewable-energy-roadmap.pdf

To determine the robustness of the potential reinforcements, an appropriate range of sensitivity scenarios has been considered. The sensitivities analyse the possibility of slower or faster development of offshore renewable generation[27] in a region and how the deficit or surplus of power can be balanced by slower or faster deployment of new offshore renewable generation in the other regions such that the 2020 renewable targets are still met.

In this approach, Gone Green 2011 is used as the base scenario and is consistent with the TO business plans, submitted under RIIO-T1 in July 2011. Six regions of the NETS where the majority of the offshore renewable generation is or will be connected have been selected. These regions are North Wales, East Coast, East Anglia, South West, SPT area and SHETL area. In all the sensitivity scenarios the plant margin is kept the same. For each sensitivity scenario, one region exhibits either slower or faster development of offshore renewable generation and the deficit or surplus of the generation from that region (compared to the Gone Green 2011 scenario for the years between 2016-2021) is balanced uniformly by increasing or decreasing the generation in the other regions. By using this approach the 2020 renewable targets can be achieved and the robustness of the reinforcements can be assessed.

Only Round 3 and STW windfarms and marine (wave/tidal) generation have been modified for the sensitivity scenarios as they have the greatest potential 'flex' of all generation types. For simplicity the contribution from other renewables, conventional fossil fuel plants and nuclear remains unchanged from the Gone Green 2011 scenario.

2.2.1 Regions and Sensitivity

Table 6 shows the total offshore wind and Scottish Marine Renewable (wave and tidal) generation for each sensitivity in 2020.

Generation (MW)	Gone Green	Slower Development Sensitivity	Faster Development Sensitivity
R1 Wind	584	584	584
R2 Wind	5981	4961	6731
R2.5 Wind	500	500	1484
R3 Wind	8185	5001	21325
Scottish Territorial Waters	1310	460	2750
Scottish Marine Renewable	570	10	1170

Table 6: Offshore wind generation in 2020 for each sensitivity

[27] Slower and Faster Development of generation scenarios are consistent with the proposed Slow Progression and Accelerated Growth scenarios for ODIS 2011.

Table 7 shows the total amount of Round 3 and STW wind and marine generation for each region and under the different sensitivities in 2020.

Region	Total R3 Wind, STW and Scottish Marine Generation (MW)		
	Gone Green	Slower Development Sensitivity	Faster Development Sensitivity
North Wales	2000	2000	3000
East Coast	2000	1500	6500
East Anglia	1200	250	4000
South West	1110	706	2750
SPT	950	450	4250
SHETL	2805	565	4745

Table 7: Six regions with total generation in 2020 under each sensitivity

2.2.2 Slower Development of Generation Sensitivity

There are six sensitivities under this scenario. For each region and sensitivity the Gone Green 2011 generation is replaced by the Slower Development of generation in one region at a time and the deficit is smeared equally to the other regions. Table 8 shows the Slower Development of Generation sensitivity applied to each of the six regions.

Sensitivity	Region	Gone Green	Slower Development	Deficit	Generation Added To Each Of The Other Regions	Region	New For Each Region
Sensitivity 1	North Wales	2000	2000	0	0	North Wales	2000
						East Coast	2000
						East Anglia	1200
						South West	1110
						SPT	950
						SHETL	2805
						Total	10065
Sensitivity 2	East Coast	2000	1500	500	100	North Wales	2100
						East Coast	1500
						East Anglia	1300
						South West	1210
						SPT	1050
						SHETL	2905
						Total	10065
Sensitivity 3	East Anglia	1200	250	950	190	North Wales	2190
						East Coast	2190
						East Anglia	250
						South West	1300
						SPT	1140
						SHETL	2995
						Total	10065

Sensitivity	Region	Gone Green	Slower Development	Deficit	Generation Added To Each Of The Other Regions	Region	New For Each Region
Sensitivity 4	South West	1110	706	404	80.8	North Wales	2080.8
						East Coast	2080.8
						East Anglia	1280.8
						South West	706
						SPT	1030.8
						SHETL	2885.8
						Total	10065
Sensitivity 5	SPT	950	450	500	100	North Wales	2100
						East Coast	2100
						East Anglia	1300
						South West	1210
						SPT	450
						SHETL	2905
						Total	10065
Sensitivity 6	SHETL	2805	565	2240	448	North Wales	2448
						East Coast	2448
						East Anglia	1648
						South West	1558
						SPT	1398
						SHETL	565
						Total	10065

Table 8: Slower development sensitivities for each region

For example in 'Sensitivity 2' the East Coast Gone Green 2011 generation is replaced by Slower Development of generation and the 500MW of deficit is equally divided to the other five regions which means each other region has to increase its generation by 100MW to balance the deficit and to keep the overall 2020 renewable energy level in line with the Gone Green 2011 scenario. The 'Sensitivity 1' is exactly the same as the base case i.e. the Gone Green 2011 scenario.

2.2.3 Faster Development of Generation Sensitivity

In this sensitivity the Gone Green 2011 generation in each region is replaced by the Faster Development of generation and the surplus is balanced by reducing other regions generation equally from their original Gone Green 2011 level. Table 9 shows the six sensitivities for the Faster Development of Generation.

Sensitivity	Region	Gone Green	Faster Development	Surplus	Generation Reduced From Each Other Region	Region	New Level For Each Region
Sensitivity 1	North Wales	2000	3000	1000	200	North Wales	3000
						East Coast	1800
						East Anglia	1000
						South West	910
						SPT	750
						SHETL	2605
						Total	10065
Sensitivity 2	East Coast	2000	6500	4500	900	North Wales	1100
						East Coast	6500
						East Anglia	300
						South West	210
						SPT	50
						SHETL	1905
						Total	10065
Sensitivity 3	East Anglia	1200	4000	2800	560	North Wales	1440
						East Coast	1440
						East Anglia	4000
						South West	550
						SPT	390
						SHETL	2245
						Total	10065
Sensitivity 4	South West	1110	2750	1640	328	North Wales	1672
						East Coast	1672
						East Anglia	872
						South West	2750
						SPT	622
						SHETL	2477
						Total	10065
Sensitivity 5	SPT	950	4250	3300	660	North Wales	1340
						East Coast	1340
						East Anglia	540
						South West	450
						SPT	4250
						SHETL	2145
						Total	10065
Sensitivity 6	SHETL	2805	4745	1940	388	North Wales	1612
						East Coast	1612
						East Anglia	812
						South West	722
						SPT	562
						SHETL	4745
						Total	10065

Table 9: Faster development sensitivities for each region

For example in Table 9 ‘Sensitivity 1’ shows that the North Wales Gone Green 2011 generation is replaced by the Faster Development of generation and each other region sees its generation reduced by 200MW to balance the 1000MW surplus.

2.2.4 Slower and Faster Development of Generation in Scotland

In this section the sensitivity calculation is done assuming Scotland as a single region to better reflect the range of sensitivity for the Scotland-England boundaries. That means, Slower and Faster Development generation is applied to the SPT and SHETL region at the same time to achieve the appropriate range of sensitivities for the Scotland-England boundaries.

Sensitivity	Region	Gone Green 2011	Faster Development	Slower Development	Deficit	Surplus	Generation Added/Reduced From Each Other Region	Region	New Level For Each Region
Slower Development	Scotland	3755	-	1015	2740	-	685	North Wales	2685
								East Coast	2685
								East Anglia	1885
								South West	1795
								Scotland	1015
								Total	10065
Faster Development	Scotland	3755	8995	-	-	5240	1310	North Wales	535
								East Coast	535
								East Anglia	0
								South West	0
								Scotland	8995
								Total	10065

Table 10: Slower and Faster Development generation in Scotland

Each of these fourteen sensitivities is used to calculate required transfers for the boundaries. Therefore there are fourteen required transfers for each boundary in 2020. Among the fourteen required transfers only highest and lowest values are used to show the band of the sensitivity. The same process has also been done from 2016 to 2019 to provide a band of sensitivities for all boundaries throughout those years. In some boundaries the highest and lowest boundary transfers obtained following the sensitivity analysis have a straight correlation to the Faster and Slower Development of generation within the region. In other boundaries, the highest and lowest boundary transfers for the sensitivity studies can be a result of changes in generation to other regions.

3 Approach to Determining Network Reinforcement

3.1 NETS SQSS standards

The NETS Security and Quality of Supply Standards (NETS SQSS) set out a coordinated set of criteria and methodologies that TOs (both onshore and offshore) shall use in the planning and operation of the NETS.

The criteria presented in the NETS SQSS represent the minimum requirements for the planning and operation of the NETS. Section 4 of the NETS SQSS sets the standards for the design of the MITS and the minimum required transmission capacity. This minimum transmission capacity is determined by the application of set deterministic rules. Further, the NETS SQSS also stipulates that additional transmission capacity should be provided when it can be demonstrated that the saving in operational cost exceeds the cost of providing this additional capacity - such requirements can be determined by undertaking cost-benefit analysis.

Traditionally the deterministic rules set out in the NETS SQSS for minimum transmission capacity requirements have been determined with an implicit assumption that all connected generation provided an equal contribution to winter peak security. However, with the connection of large volumes of intermittent generation (which is considered as an energy source rather than a security source), the NETS SQSS Review Group felt it appropriate to review[28] this assumption, and consequently a proposed amendment report (known as GSR009) was submitted to Ofgem on the 1st April 2011.

The proposals recommended a 'dual criteria' approach which incorporates both demand security and economic criteria to be considered in the development of the transmission network. Each of these criteria would include specific assumptions about different types of generation, including intermittent generation.

- The Demand Security Criterion requires sufficient transmission system capacity such that peak demand can be met without intermittent generation.

- The Economy Criterion requires sufficient transmission system capacity to accommodate all types of generation in order to meet varying levels of demand efficiently. The proposed approach involves a set of deterministic parameters which have been derived from a Cost

[28] The review was led by the SQSS review team, which has representatives from all the TOs and chaired by NGET.

Benefit Analysis (CBA) seeking to identify an appropriate balance between the constraint costs with the costs of transmission reinforcements.

An Impact Assessment (IA) was published on 12th August 2011. The IA set out Ofgem's assessment of the effect the proposals would have on consumers, competition and sustainable development. The IA invited comments for consultation until 23rd September 2011. The Ofgem IA recognised that the proposed changes could drive additional investment, but in assessing the proposals, noted that investment decisions today are based on more than the application of the NETS SQSS rules alone. Significant investments are normally subject to a more detailed cost benefit analysis taking account system-wide requirements such as interactive boundaries, multiple-year conditions, as was the case with the Western HVDC link. Therefore the actual investment could depart from the results from applying either the rules set out in the economy criterion, or as set out in version 2.1 of the SQSS.

The Gas and Electricity Markets Authority (GEMA) has since considered the issues raised by the modifications to version 2.1 of the NETS SQSS and taking into account the views and arguments put forward in response to the impact assessment on GSR009, approved the changes proposed by GSR009 on the 1st November 2011[29].

The changes put increased emphasis on ensuring appropriate balance between the constraint costs with the costs of the transmission reinforcements. For areas where there are high volumes of renewable generation, this will drive the requirement for more transmission capacity than the application of the deterministic rules as set out in version 2.1 of the NETS SQSS.

The changes are expected to provide a better overall view of what the optimum investment is likely to be and give an assessment likely to be closer to the right minimum cost solution. By providing a better 'first estimate' of the optimal capacity requirements it brings efficiency to the planning process as it provides a better starting point before a more detailed assessment is carried out and this will simplify and streamline the design process.

The 2009 ENSG Report only used the deterministic NETS SQSS (version 2.1) criteria. A full-CBA was restricted to areas where the potential for high constraint cost had previously been identified, mainly the Scotland-England boundaries.

In this updated report, the TOs have developed network reinforcements against the requirements of the Economy criterion. For the exporting boundaries being considered, this tends to give greater

[29] A licence change is required to give effect to any change to the NETS SQSS. Following a statutory consultation on the proposal to modify the electricity transmission licences (designed to give effect to the GSR009 proposals) the Authority issued a decision on 9 January 2012 to modify the licences. This decision will take effect from 5 March 2012.

transmission requirements; however the requirements align with the deterministic SQSS criteria (version 2.1) supplemented by CBA and are therefore consistent with the TOs' RIIO-T1 Business Plans submitted to Ofgem.

3.2 Network Analysis Methodology

3.2.1 Planned and Required Transfer and Transfer Capabilities

The planned transfers, required transfers and boundary capabilities presented are based on an application of the NETS SQSS to generation, demand and system developments. The planned transfer is obtained by scaling the registered capacity of generation, and calculating the difference between generation and the Average Cold Spell (ACS) Winter Peak demand which gives rise to the net power flow from one region of the network to another. The required transfer which is a planning requisite under an N-1 or N-2/N-D contingency can be calculated by applying interconnection allowance (in the case of N-1) or half interconnection allowance (in the case of N-2/N-D) to the planned transfer. Boundary transfers (transfers between selected regions of the network) must meet the required transfer to achieve compliance.

The analysis starting point is the planned transfer condition for a specific year and this is obtained by scaling all contributory generation to meet demand. A load flow study is performed for this planned transfer condition based upon generation/demand scenario against the planned network. The planned network consists of the current transmission system, all current sanctioned reinforcements by that year plus all reinforcements identified, during studies for previous years, required to meet compliance. The level at which voltage, thermal or stability limits are encountered, following the security analysis as specified in the NETS SQSS, determines the actual capability of the boundary circuits.

3.2.2 Boundaries

For the purpose of this analysis the NETS has been split into a number of regions specified by boundaries crossing critical circuits. The boundaries in the NETS consist of both 'local' and 'wider' system boundaries. The planning of transmission capacity reflects the differing levels of access requirements for various generation technologies and the ability to accommodate a high level of sharing. This is achieved through the scaling of generation in a different manner depending on its fuel type.

3.2.2.1 Wider Boundary

When analysing wider system boundaries[30], the installed capacities of both conventional and wind generation are scaled down by different amounts to take into account factors such as wind availability and the fact that not all generation will be running at a given time and a high degree of sharing of transmission capacity can be assumed in planning timescales.

The required capabilities of a wider boundary are calculated using the criteria defined in the NETS SQSS for planning the MITS. MITS 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 400kV and 275kV network, as well as any elements of an offshore transmission system operated in parallel with the 400 and 275 kV system 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.

The wider boundary capabilities presented were obtained by increasing transfers in incremental steps of 5, 10, 20, 40%, etc. of the planned transfer condition for N-2 outage conditions (N-D conditions in Scotland) until the limiting boundary transfer is reached. This can be limited by voltage, thermal or stability conditions. The boundary transfer increase was achieved by scaling demand and generation proportionately on both sides of the relevant transmission system boundary. Consistent with the N-2 / N-D contingency criterion, the required transfer levels presented are based on planned transfer plus half interconnection allowance.

3.2.2.2 Local Boundary

The analysis of local boundaries[31] assumes that limited sharing of capacity will take place to avoid high local constraints. The treatment of wind and conventional plant is therefore the same in these areas. Local boundaries are assumed, for the purpose of the power flow studies in this document, as regions with demand lower than 1500MW. All the generators connected behind a local boundary are assumed at their registered capacity. Boundaries NW1, NW2, NW3, EC1 and EC5 have been studied as local boundaries.

For local boundaries, the analysis is carried out with the following assumptions:

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[30] Chapter 4; NETS SQSS; http://www.nationalgrid.com/NR/rdonlyres/784F2DFC-133A-41CD-A624-952EF4CCD29B/45776/NETSSQSS_v21_March2011.pdf

[31] Chapter 4; NETS SQSS; http://www.nationalgrid.com/NR/rdonlyres/784F2DFC-133A-41CD-A624-952EF4CCD29B/45776/NETSSQSS_v21_March2011.pdf

- Year-round minimum demands in the local group
- Generation is set to that reasonably expected to occur i.e. at the register capacity
- Year-round ratings are applied to transmission lines defining the boundaries for thermal assessment
- Year-round N-2 assessment of critical contingencies

For local boundary studies boundary transfers are taken as 100% generation – (demand + losses), and the load flow analysis is run under N-2 conditions to determine the boundary capability.

4 Potential transmission network reinforcements

The NETS has developed around the location of existing power stations which were built in areas close to their source of fuel. This has resulted in a clustering of generation which is supported by good electrical access to the large demand centres. With the advent of renewable generation and the potential for new nuclear power station construction, more generation is connecting at the periphery of the NETS.

NETS reinforcements are predominantly driven by changes to existing contracted[32] generation background and new connections. In order to assess the impact of connecting new generation the TOs have divided the NETS into specific regions which facilitates boundary assessments.

As previously mentioned, a wide range of sensitivity analyses has been undertaken on faster and slower renewable generation progression scenarios in order to develop a range of required transfers across each boundary. The graphs in the following sections show boundary capabilities, required transfers and reinforcements capable of accommodating the required transfers (for wider and local boundaries respectively). These are for the Gone Green 2011 scenario as well as a range of required transfer sensitivities from 2016 to the end of the study period and they reflect the slower and faster generation development scenarios.

A range of potential reinforcements can resolve each boundary constraint. However, where network reinforcements at and above 132kV [33] are required within England and Wales, these undergo more detailed analysis as part of NGET's pre-application consultation strategy. Applications for development consents in England and Wales are made and assessed in accordance with the Planning Act 2008 (except for associated development, including substations in England which require local authority and in Wales which require Welsh Assembly approval). Applications for electricity transmission network development consents in Scotland are made and assessed in accordance with the Electricity Act 1989 and the Scottish Planning regime.

The constrained areas of the network which may require reinforcement have been classified as "Very Strong Need Case" and "Strong Need Case" as shown in Appendix B.

Very Strong Need Case areas are defined as existing or possible areas in the near future (up to 2015) of the transmission network where there is significant and uneconomical constraints, or

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[32] Transmission Entry Capacity Register: represents a schedule of generation that has contracted to connect to the transmission system; http://www.nationalgrid.com/uk/Electricity/Codes/systemcode/tectrading/tecregister/tecregister.htm

[33] Requirement for IPC consent will in the future be only for transmission circuits greater than132kV i.e. relieves DNOs of the obligation

where the likelihood of these constraints (or technical limitation) in the earlier years are high. It is also characterised by conditions affecting the area such as generation background or new reinforcements that are fairly certain. One example of such an area is the Scotland-England circuits which currently have derogations against the NETS SQSS in place.

Strong Need Case areas are defined as areas where the need for significant network constraint is not as certain and depend more on assumptions about the generation and network conditions which are longer term (beyond 2015) than for the Very Strong Need Case.

This report uses illustrative offshore network designs where relevant and seeks to demonstrate the additional benefit of such a design to the boundary capability where applicable but does not:

- represent any investment decisions and/or contractual arrangements or programme of the TOs, OFTOs or Third Parties; nor
- imply the actual connection routes for new electricity transmission infrastructure.

There is currently a DECC/Ofgem led offshore transmission co-ordination project which is considering the potential costs, risks and benefits that may arise from the development of a co-ordinated offshore and onshore electricity transmission network, and whether additional measures are required to enable different grid configurations should the analysis support such development.

4.1 Scotland – Boundaries B0, B1, B4 and B5

4.1.1 Existing transmission system

The existing transmission network in the north of Scotland operates at 132kV and 275kV. This network, which is owned by SHETL, forms part of the NETS. Figure 5 shows the north of Scotland map with the main transmission system boundaries B0, B1 and B4 marked. Transmission boundary B4 forms the interface between the SHETL transmission system and the SPT network in central and south of Scotland.

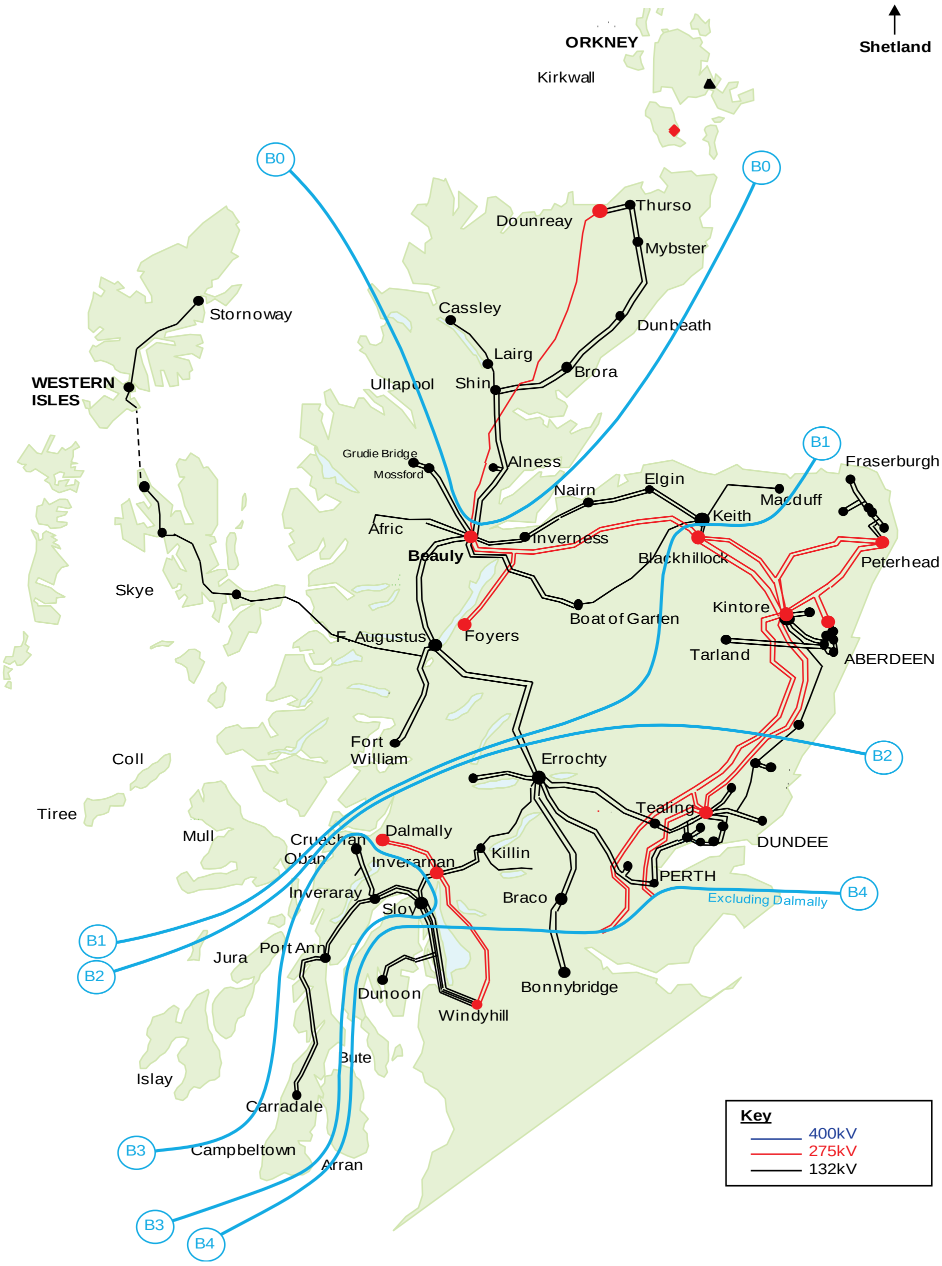


Figure 5. Existing north of Scotland Transmission system showing the main boundaries

The existing transmission network in central and the south of Scotland operates at 132kV, 275kV and 400kV. This network is owned by SPT. Figure 6 shows the south of Scotland map with the main transmission system boundaries B4, B5 and B6 marked. Transmission boundary B6 forms the interface between the SPT network and the NGET network in the north of England.

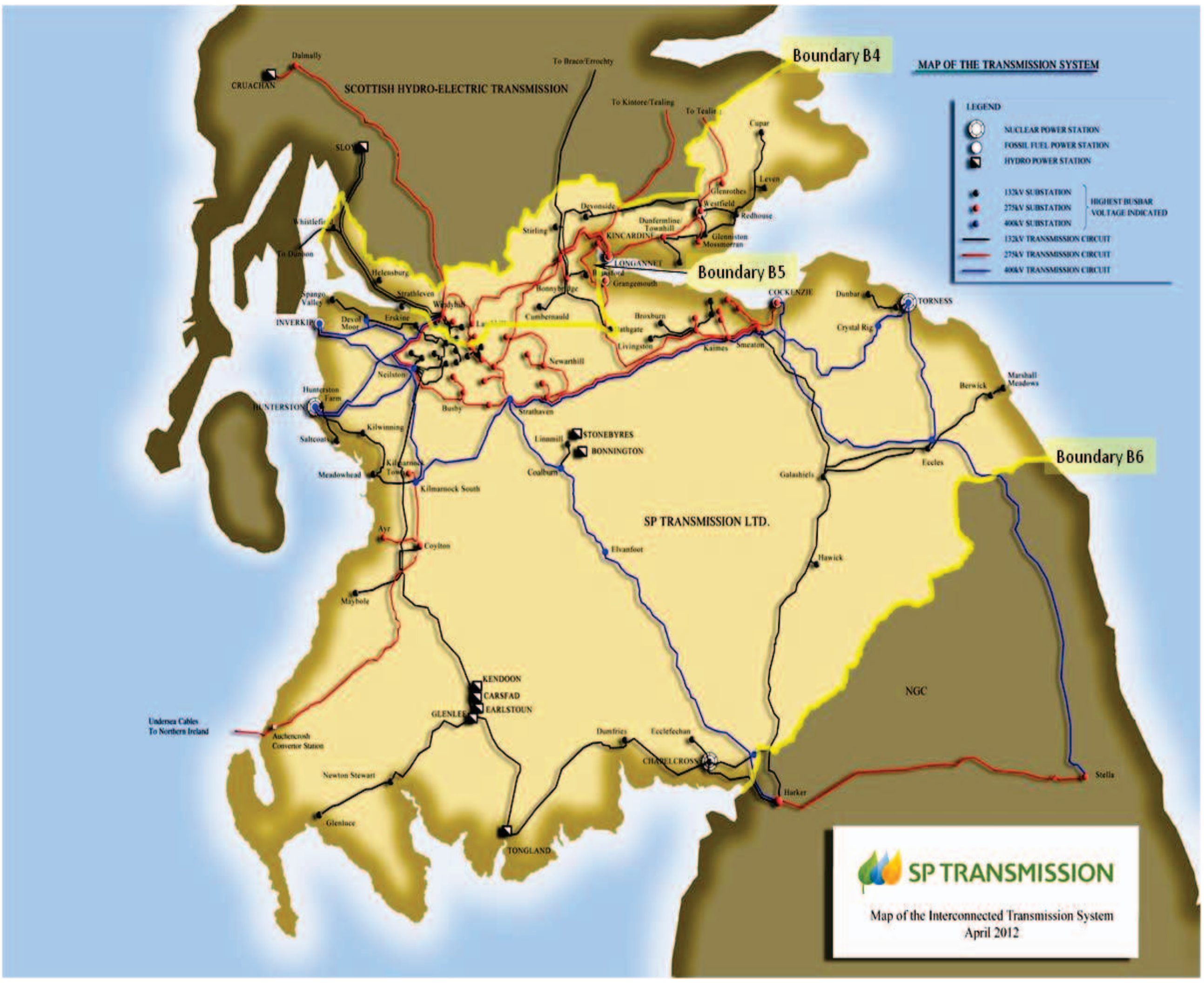


Figure 6: Existing south of Scotland Transmission system showing the main boundaries

4.1.2 Generation background

The volume of generation in SHETL's north of Scotland area is expected to increase over the coming years due to the growing capacity of renewable generation such as The Crown Estate Round 3 offshore wind farms, STW wind farms, marine generation in the Pentland Firth and Orkney waters and numerous onshore wind farms across the north of Scotland. Table 11 shows the overall generation breakdown in the baseline Gone Green 2011 scenario compared to the Gone Green 2008 scenario.

Ref	Scenario	Capacity at end of 2020 (MW)								Total (MW)
		Thermal	Nuclear	Hydro	Pump Storage	Marine	Biomass	Offshore Wind	Onshore Wind	
2009 ENSG Report	**GG2008**	1546	-	1095	300	510	-	240	6660	10351
2012 ENSG Report	**GG2011**	1202	-	1099	300	560	-	2235	4463	9858

Table 11: Generation background comparison between 2009 ENSG Report and 2012 ENSG Report in the SHETL area

The volume of generation in SPT's central and south of Scotland area is similarly expected to increase over the coming years due to the growing capacity of onshore wind farms across the south of Scotland, together with STW wind farms and The Crown Estate Round 3 offshore wind farm in the Firth of Forth. Table 12 shows the overall generation breakdown in the baseline Gone Green 2011 scenario compared to the Gone Green 2008 scenario.

Ref	Scenario	Capacity at end of 2020 (MW)								Total (MW)
		Thermal	Nuclear	Hydro	Pump Storage	Marine	Biomass	Offshore Wind	Onshore Wind	
2009 ENSG Report	**GG2008**	2547	1200	33	440	100	90	500	4000	8910
2012 ENSG Report	**GG2011**	2404	2289	33	440	10	97	950	4026	10249

Table 12: Generation background comparison between 2009 and 2012 ENSG Reports in the SPT area

4.1.3 Demand

The level of demand in Scotland is not forecast to increase significantly over the next decade. Reinforcements to the transmission system will be mainly driven by increasing flows due to high levels of the generation outlined in Table 12.

4.1.4 Potential Reinforcements

A number of reinforcements have been identified by the TOs which have the ability to increase the boundary capability to meet the increasing transfers across the B0, B1, B4 and B5 boundaries. The reinforcements are identified in Table 10 and do not include projects which are already under construction, i.e. Beauly-Denny rebuild, Beauly-Dounreay upgrade and Beauly - Kintore reconductoring. The table also shows the capability increases from these reinforcements for the relevant boundaries.

The measure being used in the table is boundary transfer capability, but transmission reinforcements are not only concerned with enhancing that capability. For example, reinforcement may be required to establish physical connection of a region or specific generators without crossing a boundary or to maintain power quality or secure demand. Similarly, an increase in boundary transfer capability may not be the sole reason or even the primary justification for a reinforcement which, from a power system performance perspective may be meeting several requirements simultaneously. It is also the case that reinforcements to enhance boundary transfer capability are not restricted only to circuits that straddle the boundary.

The reinforcements included in Tables 10 and 13 do not represent an exhaustive list of all planned and potential reinforcements (beyond those already under construction). For example, taking into account the focus in boundary transfer capability and relative materiality of the works, some projects have not been included. Also, although not directly enhancing transfer capability of the boundaries considered, other projects that facilitate the connection of renewable generation and secure demand have been included on grounds of their cost materiality and consistency with enabling the connection of generation included in the scenarios. Such projects include the links to the Western Isles, Orkney Islands and Shetland Islands, as well as the tie between Kintyre and Hunterston.

Ref.	Name	Scope	Capability increase (GW)				Earliest Possible Completion Date
			B0	B1	B4	B5	
SC-R01	Caithness- Moray	New substation at Spittall in Caithness and 600MW HVDC to Moray Firth offshore hub. 1200 MW HVDC link from Moray Firth hub to redeveloped Blackhillock substation in MorayNew AC substations required at Loch Buidhe and Fyrish. Conductor replacement between Beauly and Loch Buidhe. Dounreay to Mybster overhead line rebuild to 275kV.	0.6	0.4	-	-	2016
SC-R02	East Coast AC 400kV Upgrade	Re-insulation of existing towers between Blackhillock, Peterhead and Kincardine in SPT's area to allow operation at 400kV. Substation works at Blackhillock, Rothienorman, Peterhead, Kintore, Alyth and Kincardine. Blackhillock QBs and Errochty Works.	-	0.3	0.5	-	2016
SC-R03*	NGET – SHETL East Coast HVDC Link 1	~2GW HVDC link from Peterhead to Hawthorn Pit. Associated AC network reinforcement works on the Peterhead network. Possible Offshore HVDC integration in the Firth of Forth area	-	-	1.8	1.8	2018

Ref.	Name	Scope	Capability increase (GW)				Earliest Possible Completion Date
			B0	B1	B4	B5	
SC-R04	Kintyre – Hunterston AC Subsea Link	2*240MVA AC subsea link from Crossaig in Kintyre to Hunterston.	-	-	-	-	2015
SC-R05	Western Isles HVDC link	450MW HVDC Link between Gabhair on Lewis and Beauly near Inverness.	-	-	-	-	2015
SC-R06	Orkney Islands AC link	1*180MVA 132kV AC Link between Dounreay and West of Orkney.	-	-	-	-	2015
SC-R07	Orkney Islands HVDC link	600MW HVDC Link between West of Orkney and Sinclairs Bay HVDC hub. 1200MW link between Sinclairs Bay HVDC hub and Peterhead	-	-	-	-	2020+
SC-R08	Shetland Islands HVDC link	600MW HVDC Link between Kergord on Shetland and the Moray Firth Offshore hub.	-	0.6	-	-	2017
SC-R09	Possible further Caithness reinforcement	Integration of the Caithness AC system with the Sinclairs Bay HVDC hub	0.6	-	-		2020+
SC-R10	Possible further B1 reinforcement	AC reinforcement between Beauly and Blackhillock	-	1.0	-		2020+
SC-R11*	Possible NGET – SHETL East Coast HVDC Link 2	~2GW of second HVDC link from Peterhead to England with associated AC network reinforcement works on the Peterhead network. Possible Offshore HVDC integration in the Firth of Forth area	-	-	2.0	2.0	2020+
SC-R12	Central 400kV Upgrade (Denny – Wishaw)	Install 1 new bay at Denny 400kV Establish 17km 400kV OHL Uprate Bonnybridge to 400/132kV Install 1 new bay at Wishaw 400kV Modify associated connections.	-	-	0.4	1.7	2017
SC-R13	SPT East Coast 400kV Upgrade (Kincardine – Harburn)	Establish Kincardine 400kV Substation Establish Grangemouth 400kV Substation Establish Harburn 400kV Substation Uprate 40km of overhead line to double circuit 400kV operation	-	-	-	0.6	2017

The cost of potential reinforcements with completion dates of 2020+ have not been included in the base case costs (see § 4.1.9)
* These reinforcements form part of the Scotland-England reinforcements reported in § 4.2

Table 13: List of possible reinforcements in Scotland

Figure 7 shows how the 2020 SHETL transmission system might look with the potential reinforcements.

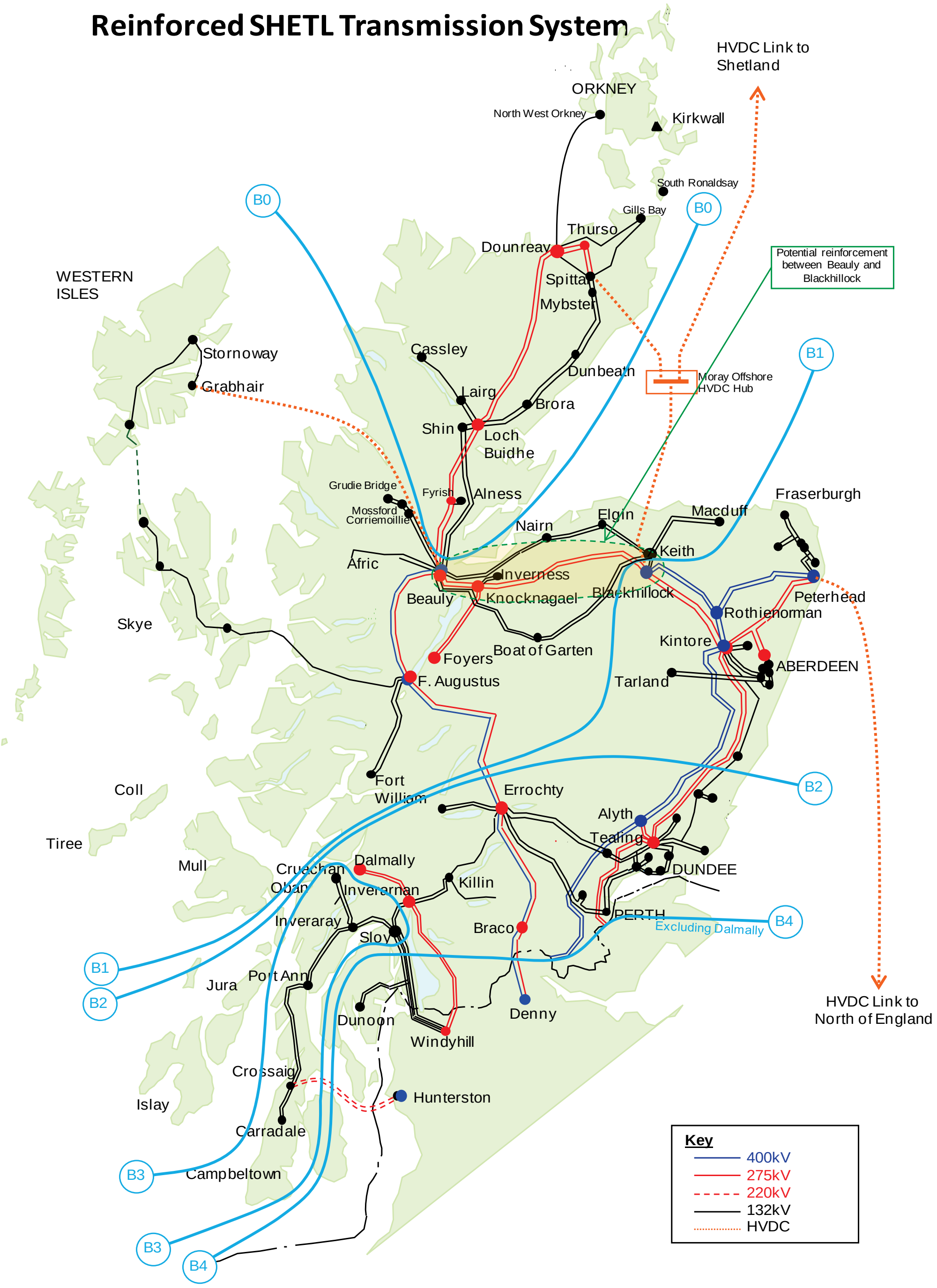


Figure 7. The north of Scotland transmission system showing potential reinforcements in 2020

Figure 8 shows how the SPT transmission system might look with the potential reinforcements.

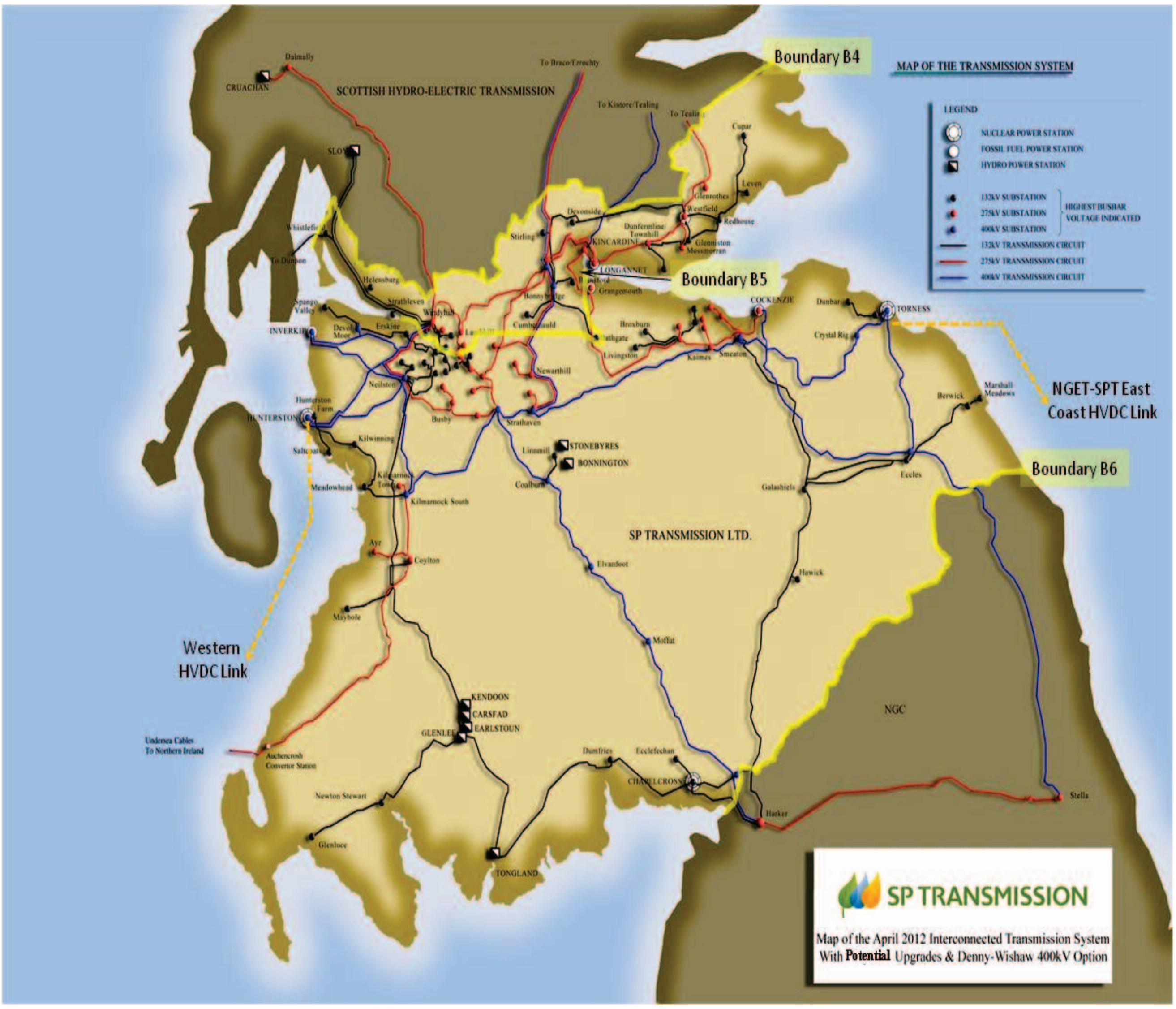


Figure 8: The SPT transmission system showing potential reinforcements

4.1.4.1 Caithness-Moray-Shetland (CMS)

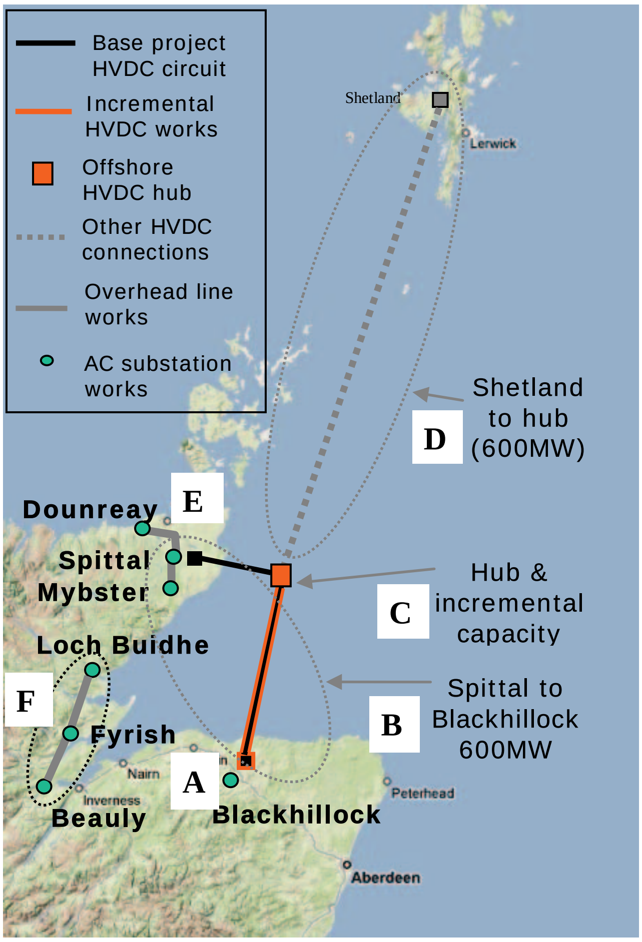
This transmission network reinforcement option in the far north of Scotland would provide required capacity to accommodate existing and planned onshore and offshore renewable generation in Caithness, in the Moray Firth, and on the Orkney and Shetland Islands. The reinforcements are shown in Figure 9 and include both HVDC and AC elements. The 2009 ENSG Report noted a direct connection for renewable generation on the Shetland Islands to Blackhillock in Moray, and summarised high level options for relief of Caithness as either:

- full re-build of AC circuits around "two sides of a triangle" from Caithness to Beauly, and from Beauly to Blackhillock, or,

- "cutting the corner" with an HVDC circuit from Spittal In Caithness to Blackhillock.

Since early 2009, offshore windfarm developers in the Moray Firth have also continued to progress their planned projects.

The reinforcements shown in Figure 9 represent a possible transmission reinforcement solution that provides the potential for the most economic and flexible approach to accommodating many potential permutations of renewable development in the region. It includes an innovative offshore HVDC hub in the Moray Firth and the inclusion of incremental capacity in the HVDC link between Caithness and Blackhillock. Those elements would benefit from a capital grant of €74m allocated to SHETL under the European Commission's European Energy Programme for Recovery (EEPR) subject to the conditions being met. The hub arrangement would provide a basis for future extension and additional export cables to accommodate any Shetland renewable generation and offshore wind in the Moray Firth as required.



The main elements of the Caithness Moray Shetland reinforcement are defined below:

A. Blackhillock substation redevelopment

B. Spittal – Blackhillock HVDC link

C. Offshore HVDC Hub and incremental subsea cable capacity

D. Shetland to Hub subsea cable link

E. Dounreay – Mybster overhead line rebuild

F. Loch Buidhe – Fyrish – Beauly substation and reconductoring works.

Figure 9. Caithness – Moray – Shetland region potential reinforcements

4.1.4.2 East Coast AC 400kV Upgrade

There are several possible reinforcements to address capacity requirements on the east side of SHETL's area. The East Coast 400kV upgrade consists of the uprating of one of the 275kV east coast tower routes which runs from the central belt, past Dundee and Aberdeen, to Blackhillock, to 400kV operation to increase capacity to export renewable energy from the north of Scotland to the demand centres in the south.

An associated reinforcement would extend the proposed 400kV east coast system to Peterhead using existing tower structures to provide the necessary capacity increase and system security in the north east. These reinforcements are illustrated in Figure 7.

4.1.4.3 East Coast Subsea HVDC Link

Further capacity on the east could be provided by the NGET – SHETL East Coast HVDC Link 1. This comprises the installation of a subsea HVDC link from Peterhead in the north of Scotland to north of England to provide a significant increase in north to south transfer capacity. This reinforcement is discussed in more detail under Section 4.2.4.3.

With more renewable generation connections in the north of Scotland, a second HVDC link (NGET – SHETL East Coast HVDC Link 2) could be required to provide further capacity.

4.1.4.4 Kintyre to Hunterston

This proposal consists of the installation two AC subsea cables between a new substation at Crossaig, on Kintyre peninsula and Hunterston substation in Ayrshire, as illustrated in Figure 7. The reinforcement could provide the necessary capacity to accommodate the renewable generation in the Kintyre and Argyll area.

4.1.4.5 Orkney and Pentland Firth

The Orkney Islands and the Pentland Firth are rich in renewable resource. Onshore wind has been developed on the islands for many years, with the potential for further schemes. For marine generation, Orkney has the EMEC test facilities for both tidal and wave technologies, and the aspirations to develop up to 1.6GW of marine generation in the Crown Estate leased waters. The Gone Green 2011 scenario includes for 560MW of marine generation in this area, developed by 2020.

SHETL anticipates a requirement for an initial 132kV subsea link between the west Orkney mainland and Caithness to accommodate the first tranches of marine sites, together with developing onshore renewables. As further marine generation deploys there is expected to be a requirement for an HVDC link of greater capacity towards the end of the eight year period, around 2019-2021, with a delivery point on the Scottish mainland, linked to a main HVDC hub at Peterhead.

Further development of marine renewable is anticipated in the southern area of the Orkney Islands, on the north side of the Pentland Firth, which may also require subsea links to the Scottish mainland from this location.

4.1.4.6 Western Isles Link

As illustrated in Figure 5, the proposed Western Isles link comprises a 450MW HVDC link between Grabhair on the Isle of Lewis and Beauly on the Scottish mainland. The link would include converter stations at each end, a subsea cable route of 80km and an underground cable route on the Scottish mainland of 76km. On Lewis, a new AC subsea link would run from Grabhair back to Stornoway would tie the link into the existing AC system on the island.

4.1.4.7 Beauly to Blackhillock Reinforcement

Beyond the work already underway it is possible that further high capacity reinforcement across the B1 boundary between Beauly and Blackhillock may be required in the future. There are a number of options being considered to provide this capacity.

4.1.4.8 Central 400kV Upgrade (Denny – Wishaw)

As part of the East Coast 400kV Upgrade (Section 4.1.4.2) the circuits on the Kintore (SHETL) to Kincardine (SPT) overhead line route will be uprated from 275kV to 400kV operation, utilising the existing towers. This will require new 400kV equipment at Kincardine and suitable 400kV links to the available network in central Scotland. To the south of Kincardine, two options are being considered: the Central 400kV Upgrade and the East Coast 400kV Upgrade. SPT is evaluating both reinforcement options.

The first option utilises existing infrastructure between Denny and Bonnybridge, Wishaw and Newarthill and a portion of an existing double circuit overhead line between Newarthill and Easterhouse. A new section of double circuit overhead line would be required from the Bonnybridge area to the existing Newarthill / Easterhouse route.

Together with modifications to substation sites, this option would create two new north to south circuits through the central belt: a 275kV Denny / Wishaw circuit and a 400kV Denny / Wishaw circuit, thereby increasing B5 capability. By redistributing the power flow across B4, this option would also enhance the capability of Boundary B4.

4.1.4.9 SPT East Coast 400kV Upgrade (Kincardine – Harburn)

As part of the second option, the circuits on the overhead line route south from Kincardine towards Edinburgh via Grangemouth would be uprated from 275kV to 400kV operation, together with the installation of a higher capacity conductor system, while continuing to make use of the existing towers. This would require new 400kV substations at Kincardine and Grangemouth and a new 400kV substation in West Lothian to facilitate a connection to the East-West 400kV circuits.

4.1.5 North of Beauly Boundary B0

Boundary B0 covers the area to the north of Beauly where there are currently two double circuit overhead line routes connecting Beauly to Dounreay in Caithness, one at 275kV and the other at 132kV. The 275kV overhead line is strung with conductors on one side only. Work is already underway to increase the capacity of this part of the system by adding a second 275kV conductor on the existing overhead line route and upgrading the 275/132kV substation at Dounreay and is due for completion by the end of 2012. Significant further reinforcement is required north of Beauly due to the growth in wind and marine generation.

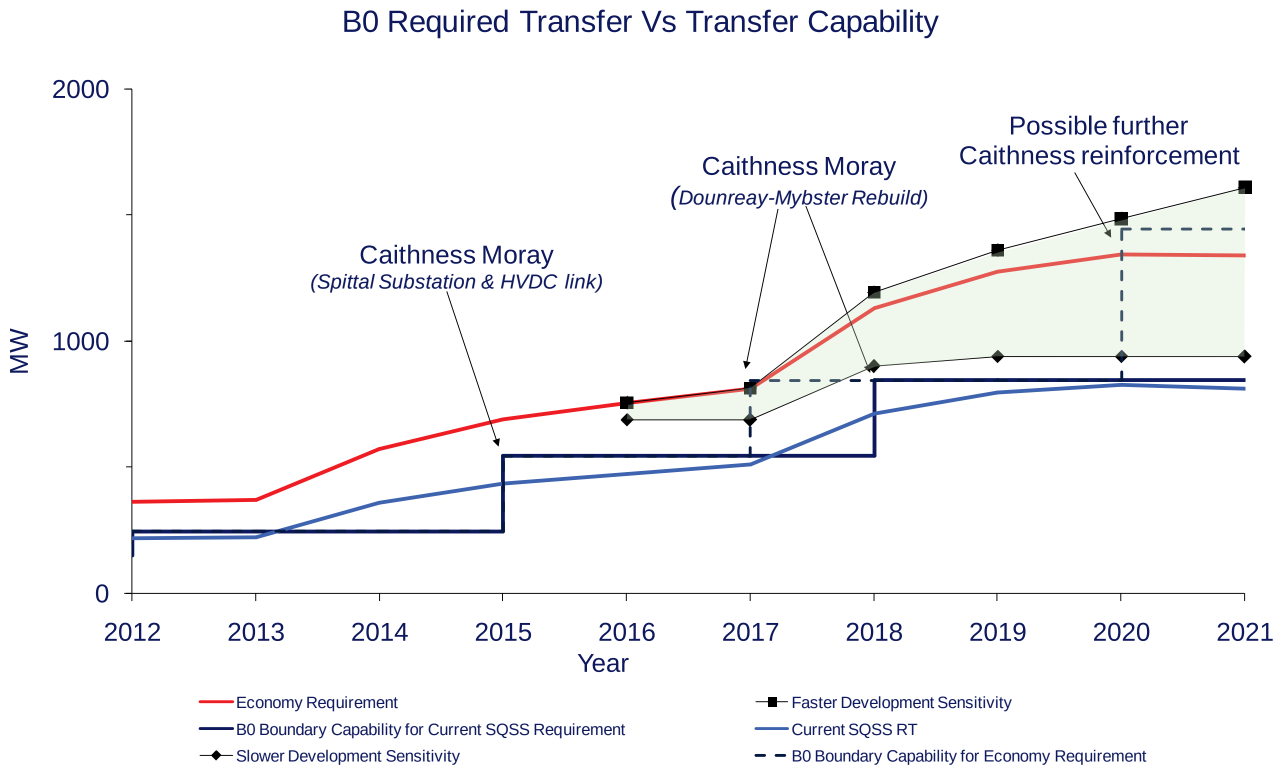


Figure 10: Required Transfer versus Transfer Capability for Boundary B0

Figure 10 shows the variation in required transfer for the B0 boundary under both the current NETS SQSS criteria and the Economy criteria for cost benefit analysis. The boundary capability is also shown with capability increases corresponding to a selection of possible boundary reinforcements. A range of required transfers is also provided in 2020 covering the faster and slower development sensitivities.

The boundary capability lags behind the required transfer. This is because the recently adopted Economy methodology has a significant impact on boundary B0 since the generation is mainly wind and marine which have higher scaling factors compared with the previous methodology. Reinforcement plans are in the process of being reviewed in this area, taking account of the uncertainty in marine generation which is not a mature technology as well as realistic build rates for large transmission projects.

Subject to delivery practicalities, it may be possible to advance the Dounreay – Mybster overhead line rebuild by one year to 2017. It is possible that further capacity will be required beyond that currently planned for the B0 boundary. One option to realise additional capacity could be the integration of the Caithness AC network with the Sinclairs Bay HVDC hub when the latter is completed, possibly by 2020.

4.1.6 SHETL North West Boundary B1

Boundary B1 covers the area north of Errochty and Blackhillock as shown in Figure 7. The Beauly to Denny project, comprising the rebuild of the 132kV overhead line route between Beauly and Denny, was granted consent in early 2010 and construction is already underway with an expected completion date of 2014. The Beauly-Denny upgrade is an important step in developing a transmission system in the north of Scotland of sufficient capacity to accommodate the renewable generation proposals. With this upgrade in place, further reinforcement can be achieved by the strengthening of other elements of the existing system. A new 275/132kV substation at Knocknagael at Inverness and the replacement of the 275kV conductors on the existing overhead line route between Beauly, Blackhillock and Kintore are also under construction to further increase the capacity across the B1 Boundary.

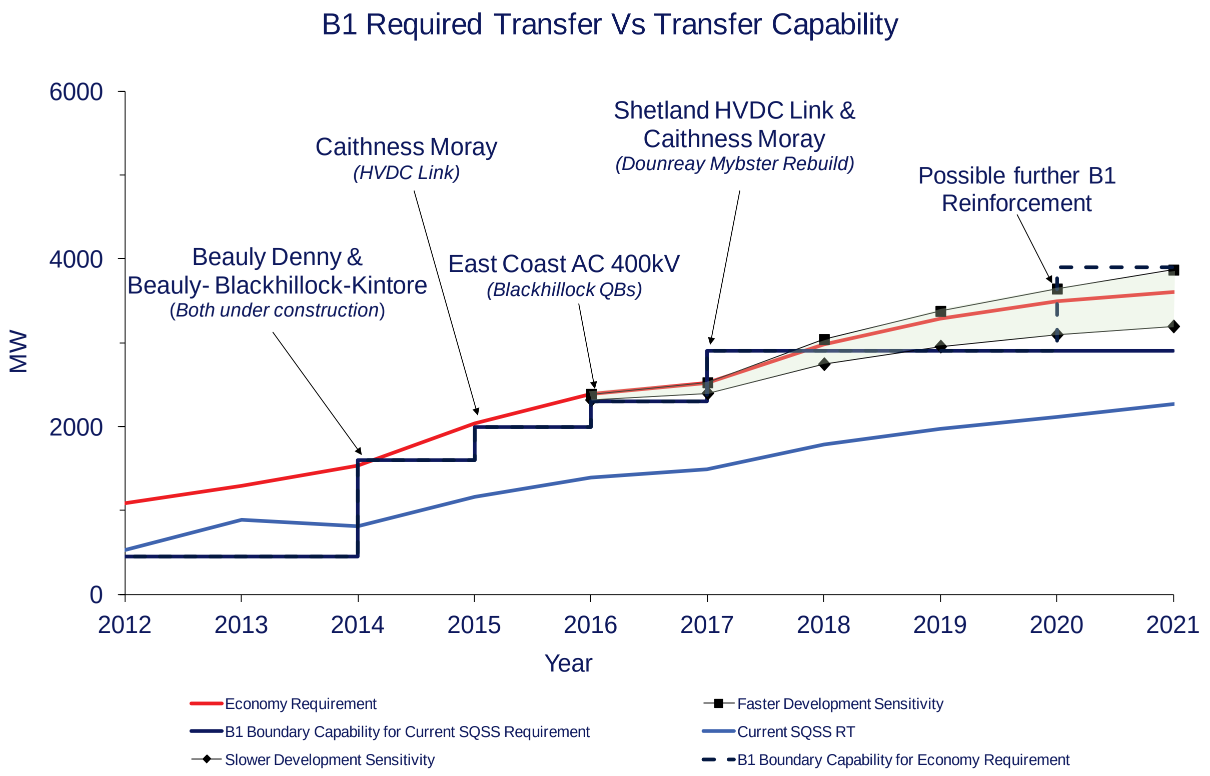


Figure 11: Required Transfer versus Transfer Capability for Boundary B1

Figure 11 shows the variation in required transfer for the B1 boundary under both the current NETS SQSS criteria and the Economy requirement. The boundary capability is also shown with capability increases corresponding to a possible selection of boundary reinforcements. A range of required transfers is also provided in 2020 covering the faster and slower development sensitivities.

The Caithness-Moray HVDC reinforcement covers boundaries B0 and B1 while Blackhillock QBs and the Errochty works are suggested for boundaries B2 and B4. The Shetland HVDC is suggested to connect generation in Shetland and, when integrated with the Caithness – Moray HVDC link via the Moray Offshore Hub, would increase the B1 capability. In order to accommodate the NETS SQSS Economy boundary requirement, post 2018 it may become necessary to further reinforce the network section between Beauly and Blackhillock.

4.1.7 SHETL – SPT Boundary B4

Boundary B4 is the interfacing boundary between the SHETL and the SPT transmission networks. The transfer requirement south towards the central belt of Scotland steadily increases over the period considered. Figure 12 shows the variation in required transfer for the B4 boundary under both the current NETS SQSS criteria and the Economy criteria for cost benefit analysis. The Beauly-Denny project which is due for completion in 2014 provides a significant increase in the B4 capability. However, further reinforcement will be required across boundary B4. The boundary capability in Figure 12 is shown with capability increases corresponding to additional boundary reinforcements. A range of required transfers is also provided in 2020 covering the faster and slower development sensitivities.

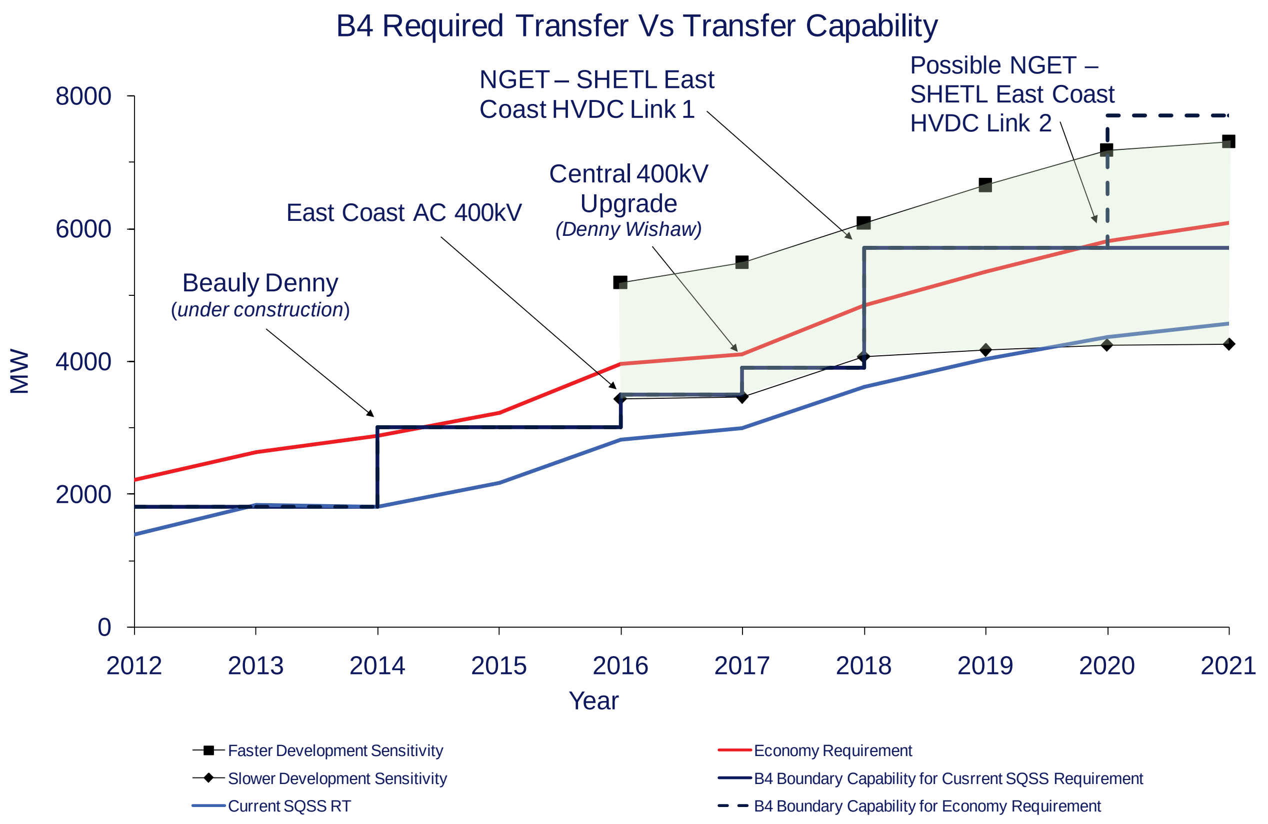


Figure 12: Required Transfer versus Transfer Capability for Boundary B4

4.1.8 SPT North – South Boundary B5

Boundary B5 is a boundary internal to the SPT area, between the SHETL-SPT and SPT-NGET interface boundaries. The Generating Stations at Longannet and Cruachan are located to the north of B5. The transfer requirement south across this boundary in the central belt of Scotland steadily increases over the period considered.

Figure 13 shows the variation in required transfer for the B5 boundary under both the current NETS SQSS criteria and the Economy requirement. The boundary capability in Figure 13 is shown with capability increases corresponding to additional boundary reinforcements. A range of required transfers is also provided in 2020 covering the faster and slower development sensitivities.

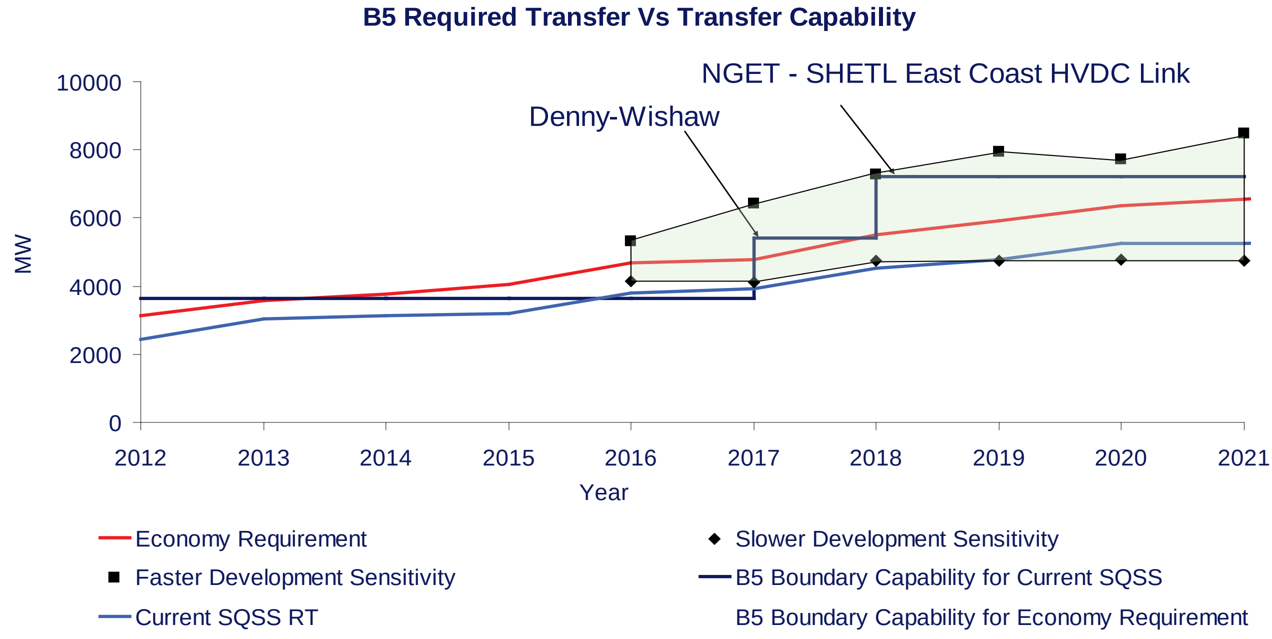


Figure 13: Required Transfer versus Transfer Capability for Boundary B5

4.1.9 Changes in the Potential Reinforcement since the 2009 ENSG Report

The 275kV East Coast reconductoring upgrade has been removed and four further potential reinforcements have been identified to cater for the high sensitivity scenario. These are the Orkney HVDC reinforcement, possible second East Coast HVDC from Peterhead and possible further reinforcements in the Caithness and boundary B1 areas.

4.1.10 Cost

A number of possible reinforcements have been considered in the B0, B1, B4 and B5 boundary studies. The total cost of the possible set of reinforcements considered for Scotland are between £2.14bn and £4.3bn for the slower and faster development sensitivities respectively with a cost of around £2.5bn estimated for the base Gone Green 2011 scenario. The base cost excludes possible reinforcements with dates marked as 2020+ in Table 13. The costs of reinforcements shared from Scotland to England and Wales are also excluded. Estimated costs for individual projects cannot generally be provided in this report for commercial, procurement and legal reasons. This applies to equivalent 'Cost' sections for all of the regions in this report.

4.2 Scotland-England interface – Boundaries B6, B7, B7a

4.2.1 Existing transmission system

The existing transmission network connecting the SPT and NGET systems comprises mainly of two double circuit 400kV routes, one on the western side of the country and the other on the east. There are three main boundaries that provide the capacity for generation in Scotland and the North of England to supply the major demand centres in the South; Boundaries B6, B7 and B7a. The circuits defining these boundaries will constrain generation with increasing flows from Scotland.

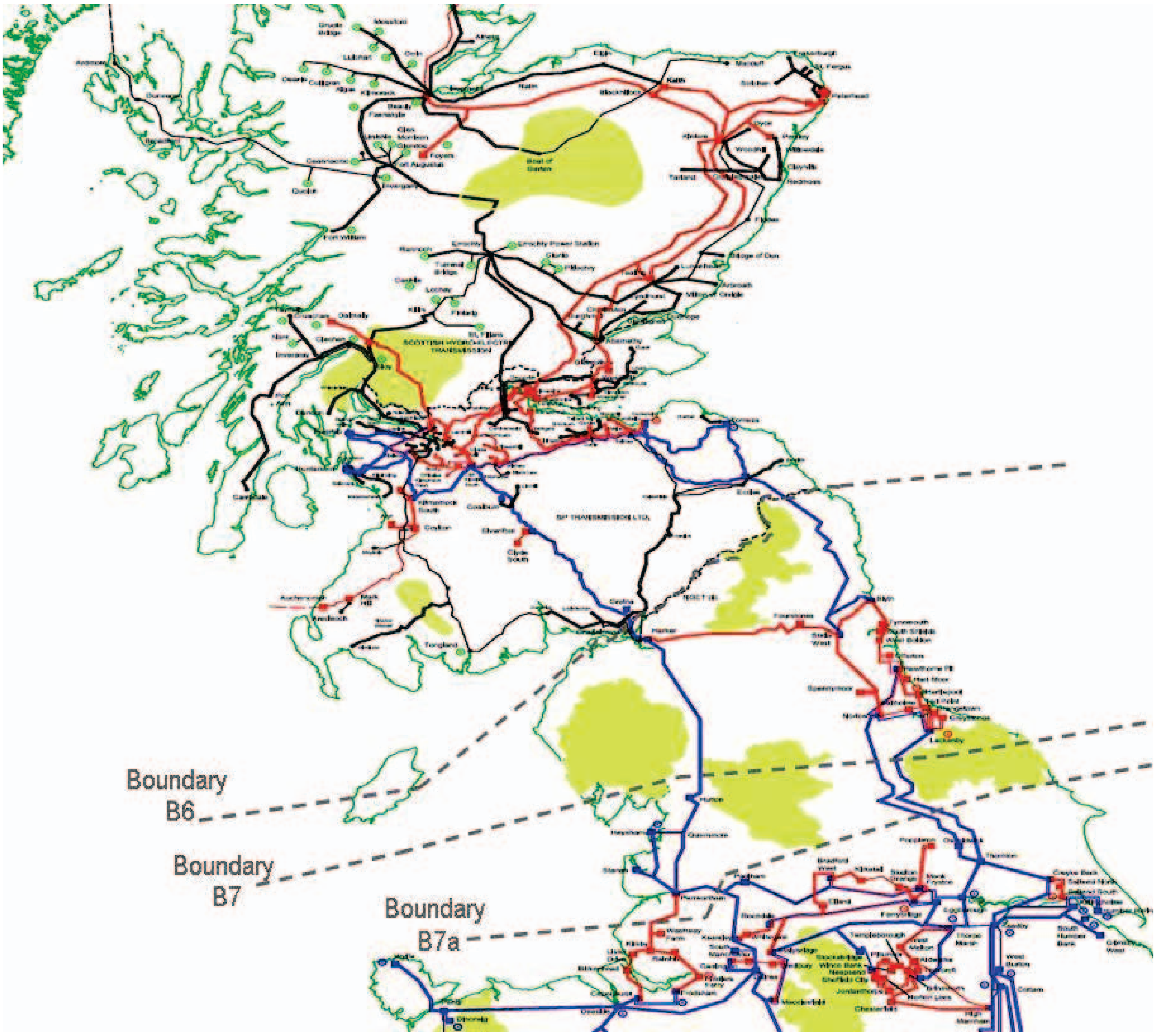


Figure 14 – Existing Scotland-England transmission circuits

4.2.2 Generation background

The volume of generation connecting in Scotland is expected to increase over the coming years due to the growing capacity of renewable generation such as the Crown Estate Round 3 offshore wind farms, STW wind farms and onshore wind farms in Scotland. Table 14 shows the overall generation including conventional generation breakdown in the baseline Gone Green 2011 scenario along with the changes from Gone Green 2008.

Ref	Scenario	Capacity at end of 2020 (MW)				Total (MW)
		Thermal	Nuclear	Biomass	Offshore Wind	
2009 ENSG Report	**GG**2008	2155	1203	100	950	4408
2012 ENSG Report	**GG2011**	374	3613	299	1117	5133

Table 14: Generation background comparison between 2009 and 2012 ENSG Reports in the Scotland–England region (North of England only)

4.2.3 Demand

The level of demand is not forecast to increase significantly over the next decade. Reinforcements to the transmission system will be mainly driven by increasing flows due to high levels of the generation outlined in Table 14.

4.2.4 Potential Reinforcement

A number of potential reinforcements have been identified which have the ability to increase the boundary capability to meet the increasing transfers from Scotland to England. These are summarised in Table 15. The table also shows the capability increase from these reinforcements for the different Scotland-England boundaries. Figure 15 shows the potential reinforcements.

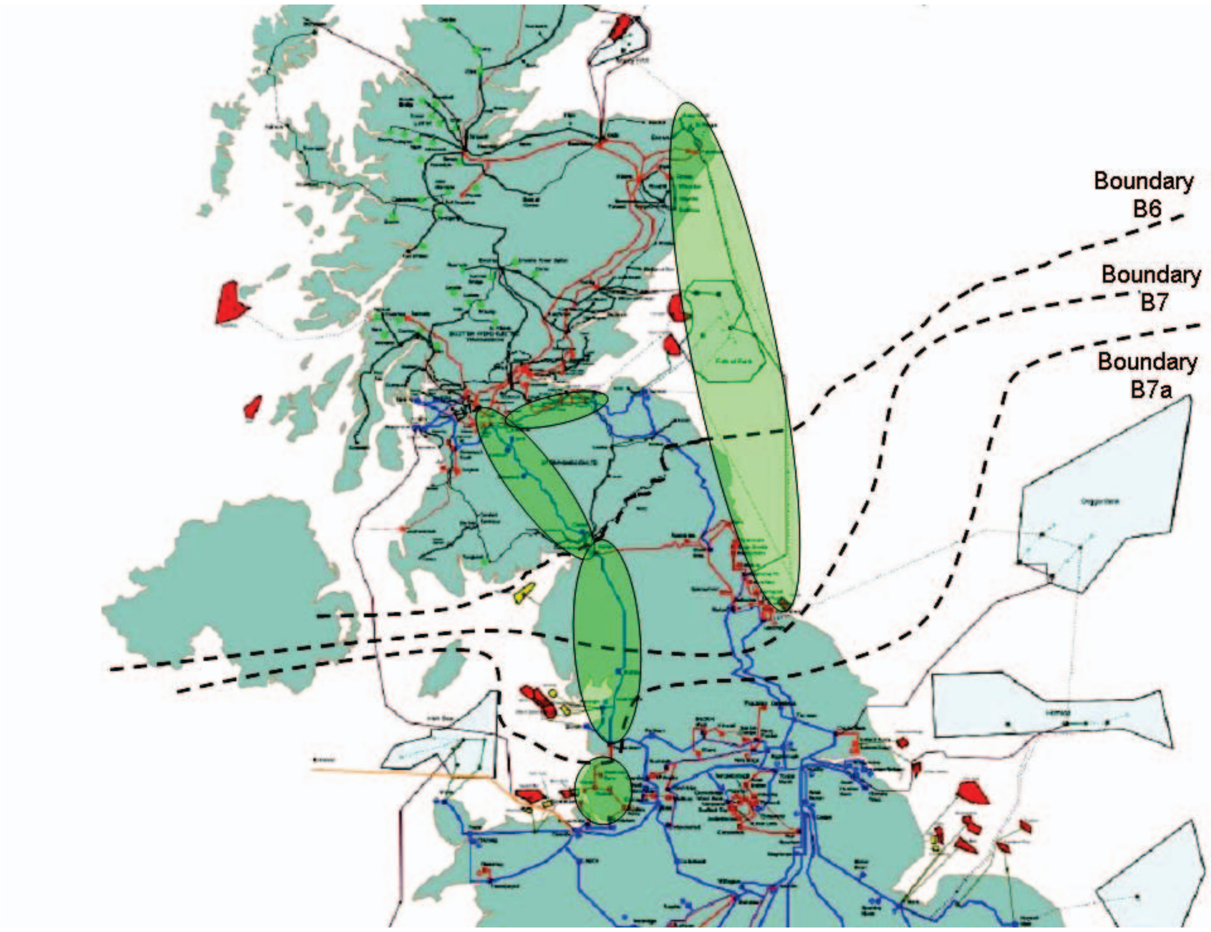


Figure 15 – Map of Scotland-England transmission circuits with possible location of reinforcements

Ref.	Name	Scope	Capability increase (GW)			Earliest Possible Completion Date
			B6	B7	B7a	
AS-R01	Reconductor Harker-Hutton-Quernmore	Reconductor the Harker-Hutton-Quernmore double circuit	-	+3.5	-	2014
AS-R02	Western HVDC link	Deeside: New 400kV GIS HVDC cable connection from Deeside to Hunterston, 400 km, submarine and land sections. DC converter ~2.1GW[34] capacity installation at Deeside and Hunterston.	+2.1		+2.1	2015
AS-R03	Series & Shunt Compensation	Compensation of Harker-Hutton route. Compensation of Eccles-Stella West route. Compensation of Strathaven-Harker route. *Shunt Compensation:* 2X225MVar MSCs at Harker. 1X225MVar MSCs at Hutton 2X225MVar MSCs at Stella West.	+1.0	-	-	2015

[34] The range of the rating of the HVDC links is between 1.8GW and 2.1GW

Ref.	Name	Scope	Capability increase (GW)			Earliest Possible Completion Date
			B6	B7	B7a	
		1X225MVar MSCs at Cockenzie. East-West 400kV Upgrade: Uprate Strathaven-Smeaton to 400kV double circuit operation. Uprate 400kV cables at Torness.				
SC-R03	NGET-SHETL East Coast HVDC Link 1	~2.1GW HVDC link from Peterhead to Hawthorn Pit. Associated AC network reinforcement works on both Peterhead and Hawthorn Pit networks. Possible Offshore HVDC integration in the Firth of Forth area	+2.1	+1.0	+0.7	2018
AS-R06	Penwortham QBs	Additional Quadrature Booster at Penwortham	-	-	+0.4	2014
AS-R07	NGET-SPT East Coast HVDC Link	2.1GW HVDC link between Lackenby and Torness	+2.1	+1.0	+0.7	2018
AS-R08	Mersey Ring Stage 1	Voltage uprate of the 275kV double circuit overhead line from Penwortham to Kirkby to 400kV operation. Substation Works: Construct new Washway Farm 400/132kV substation with 2X400/132kV 240MVA SGTs adjacent to the existing site. Construct new Kirkby 400kV substation Complete the necessary substation works at Penwortham substation Associated protection, control and metering.	-	-	+1.0	2018
AS-R09	Series Compensation	Compensation at Harker-Stella West circuits.	-	+0.6	-	2015
AS-R10	Reconductor Harker-Strathaven and series compensation	Reconductoring the existing 400kV Harker-Strathaven double circuit and additional series compensation in Scotland-England circuits	+0.6	-	-	2020
SC-R11	NGET-SHETL East Coast HVDC Link 2	~2.1GW of second HVDC link from Peterhead to England with associated AC network reinforcement works on both ends. Possible Offshore HVDC integration in the Firth of Forth area	+2.1	+1.0	+0.7	2020+

Table 15: Potential reinforcements on the Scotland-England boundaries

Table 16 shows potential offshore HVDC links to connect Round 3 offshore windfarms from Dogger Bank to the main AC transmission system under a co-ordinated offshore strategy approach. This approach could also provide an increase in boundary capability to the B7 and B7a boundary. The links in this table do not prejudge the outcome of the offshore transmission coordination project, nor do they represent any investment decisions and/or contracted arrangements or programme of the TOs, OFTOs or third parties; nor do they imply the actual connection routes for new electricity transmission infrastructure.

<table>
<tr><th rowspan="2">Ref.</th><th rowspan="2">Name</th><th rowspan="2">Scope</th><th colspan="3">Capability increase (GW)</th></tr>
<tr><th>B6</th><th>B7</th><th>B7a</th></tr>
<tr><td>AS-R14</td><td>Offshore HVDC Link from Offshore hub to main AC transmission System</td><td>2GW HVDC link from Dogger Bank to Lackenby substation</td><td>-</td><td rowspan="3">+1.0</td><td rowspan="3">+1.0</td></tr>
<tr><td>EC-16</td><td>Offshore HVDC Link between Offshore hubs</td><td>1GW HVDC link to Hornsea from Dogger Bank</td><td>-</td></tr>
<tr><td>EC-17</td><td>Offshore HVDC Link from Offshore hub to main AC transmission System</td><td>2GW HVDC link from Hornsea to Walpole substation</td><td>-</td></tr>
</table>

Table 16: Potential Offshore HVDC link under Co-ordinated Offshore Strategy Approach

4.2.4.1 Incremental Reinforcement

Upgrades to the onshore transmission system will maximise the capability of the Scotland-England interconnection and enable the firm 4.4GW thermal capability of the existing overhead line routes to be utilised. These works will involve the installation of series and Mechanically Switched Capacitors (MSC) at a number of sites in southern Scotland and the north of England, together with the uprating of some circuits from 275kV to 400kV operation and replacement of overhead line conductor systems.

4.2.4.2 Western HVDC link

Scope of Works

The project constructs a new HVDC link between Hunterston substation in central Scotland and Connah's Quay substation in North Wales. The connection will be via an undersea cable sited along the west coast of Great Britain. The project has already been allocated some funding through the TII framework for preconstruction works and further funding has been requested, with Ofgem issuing a 'minded to' approve decision.

Main Drivers

The main driver for the Western HVDC Link project is the large volume of renewable generation that is expected to connect in Scotland and Northern England over the next ten years.

This new generation creates a need to carry out network reinforcement against two main criteria.

(a) NETS SQSS Compliance

(b) Cost Benefit Analysis

NETS SQSS Compliance – There are three system boundaries that provide Scottish generation exports to the load centres in England; B6, B7 and B7a.

The B6 boundary has a maximum thermal capacity of 4.4GW. However, this is currently limited by system stability issues to approximately 2.8GW, increasing to 3.3GW in October 2013. The installation of series and shunt compensation, together with the East-West 400kV Upgrade in the SPT area will allow the B6 boundary capability to increase 4.4GW, consistent with the thermal capability of the existing overhead lines.

The current boundary transfer requirement exceeds the maximum capability of the existing network resulting in the transmission system being non-compliant with the requirements of the NETS SQSS. In order to restore compliance the boundary capability must be increased through network reinforcement. Boundaries B7 and B7a (located in the North of England) would also become non-compliant by 2014 under the Gone Green 2011 scenario.

The Western HVDC link will extend across all three boundaries and will provide an increase in capacity of around 2.1GW[35] to each of the boundaries. This reinforcement will support compliance against NETS SQSS requirements until 2018 (B6 and B7a) and 2019 (B7) under the Gone Green 2011 scenario.

Cost Benefit Analysis

An alternative option to reinforcing a system boundary is to pay constraint costs to generators located behind the relevant boundary to ensure transfers do not exceed the boundary capability. Due to the high total cost of the Western HVDC link project a comprehensive CBA was carried out to assess the benefits of the project against the “do nothing” option.

Without the addition of the Western HVDC link, constraint costs would rise steadily from 2015 onwards. Under the Gone Green 2011 scenario it was calculated that in 2015 annual constraint costs in the order of £185m could be incurred. Applying these calculations across the lifetime of the Western HVDC link showed that constraint costs are significantly higher than the total capital cost for the Western HVDC link which is estimated to be around £1bn as indicted in Ofgem’s update on TII funding for the Western HVDC link[36]. Therefore it was concluded that carrying out the system reinforcement would represent a significant saving over the life of the link.

Alternatives

[35] Dependent on the exact rating of the finished project.

[36] http://www.ofgem.gov.uk/Pages/MoreInformation.aspx?docid=20&refer=Networks/Trans/ElecTransPolicy/CriticalInvestments/InvestmentIncentives

A number of alternative onshore solutions were considered to increase the boundary capability of the B6, B7 and B7a boundaries. These included:

A number of projects have already been planned to ensure that the maximum capability (4.4GW) of the existing circuits can be realised. Further reinforcement would be required in the form of either two new 400kV transmission circuits: one from the West of Scotland to Lancashire and one from the East of Scotland to North East England or reconductoring existing 400KV double circuit between Harker and Strathaven and additional series compensation in these circuits to provide the necessary boundary capacity. These options were discounted for three main reasons:

(a) They did not represent the most economic solution. The total length of the new circuits would be in excess of 600km; this resulted in a total project cost that was higher than the undersea HVDC option.
(b) The construction of new onshore overhead line routes would have a greater disruption to land and higher visual impact.
(c) The timescales required to progress a project through the planning and consents process as prescribed in Appendix F would result in higher constraint costs.

For these reasons it was decided not to progress with onshore AC reinforcements.

Outputs Delivered

The main outputs that are anticipated from the Western HVDC link project are:

(a) Boundary capability - Increasing the boundary capability of the B6, B7 and B7a boundaries by 2.1GW.
(b) Reliability and Availability - Maintaining the security of supply and reducing expected constraint costs against an increasing volume of wind generation in Scotland.
(c) Environmental - Facilitating the connection of approximately 10GW of renewable generation in Scotland and progressing towards the Government’s 2020 targets. The project also does not require additional onshore overhead line construction with the associated impact on visual amenity.

4.2.4.3 NGET – SHETL East Coast HVDC Link 1

Scope of Works

The project would construct a new 2.1GW HVDC link between the North East of Scotland and the North East of England. The connection would be via an undersea cable sited along the east coast of the UK. A number of potential landing sites are being considered but it is currently assumed that the optimum landing point in England is at Hawthorn Pit.

The project has already been allocated some funding through the TII framework for preconstruction works which are progressing well.

Main Drivers

The main driver for the NGET-SHETL East Coast HVDC link project is the large volumes of new renewable generation (mainly onshore wind and some offshore tidal and wind) that is expected to connect in the North of Scotland out to 2021.

This would require additional transmission capacity from the North of Scotland to the North of England, driven by:

a. NETS SQSS Compliance
b. Cost Benefit Analysis

NETS SQSS Compliance – The transmission system in Northern Scotland can be defined with the B4 boundary and in the Scotland-England region with three system boundaries (B6, B7 and B7a).

The B4 boundary separates the Northern and Southern areas of the Scottish transmission system. The existing capability of this boundary is approximately 1.8GW. Under the Gone Green 2011 scenario, the new renewable generation that is planned to connect in the North of Scotland would result in the required boundary transfer exceeding this limit by 2018. Additional boundary capability of around 2.1GW can be provided by the NGET-SHETL East Coast HVDC link to ensure the continued compliance with the NETS SQSS.

The Western HVDC link raises the B6 boundary capability to approximately 6.4GW. This would provide sufficient transmission capacity to ensure compliance against the NETS SQSS requirements until 2018 under the Gone Green scenario, after this point further reinforcement would be required. The NGET-SHETL East Coast HVDC link option is expected to provide an additional 2.1GW of boundary capability and ensure NETS SQSS compliance under the Gone Green scenario to beyond 2025.

Although the NGET-SHETL East Coast HVDC link does not cross the B7 and B7a boundaries, the improved load sharing that the link can provide would result in an increase in boundary capability, however this would not be the full capacity of the link as seen with the B4 and B6 boundaries. If the suggested onshore reinforcements and the Western HVDC link are completed, the B7 and B7a boundaries are expected to be compliant until 2019 and 2018 respectively. The addition of the NGET-SHETL East Coast HVDC link would ensure compliance beyond 2025.

Cost Benefit Analysis

An alternative option to reinforcing a system boundary is to pay constraint costs to generators located behind the relevant boundary to ensure transfers do not exceed the boundary capability. Due to the high cost of the NGET-SHETL East Coast HVDC link a CBA was carried out to assess the benefits of the project against the “do nothing” option.

Without the addition of the NGET-SHETL East Coast HVDC link constraint costs would rise steadily from 2018 onwards. Under the Gone Green scenario it was calculated that over the lifetime of the NGET-SHETL East Coast HVDC link constraint costs in the region of £3bn could be incurred if no reinforcement was progressed. This cost is significantly higher than the capital cost of the NGET-SHETL East Coast HVDC link which is estimated to be circa £1.2bn[37]. The payback period is expected to be within the asset lifetime.

Whilst the NGET-SHETL East Coast HVDC link would resolve the potential non-compliance issues associated with increased transfers across B4, B6, B7 and B7a and the economic appraisal demonstrated an economic benefit for progressing the link for commissioning in 2018, it is also recognised that given future generation connections in the Firth of Forth area and the need to provide additional transmission capacity from Torness, it is appropriate to consider a number of potential variants of the HVDC link. These include:

(a) An HVDC link from Peterhead to Torness and a further HVDC link between Torness and Hawthorn Pit.
(b) A multi-ended HVDC link between Peterhead, Torness and Hawthorn Pit.

These options will continue to be developed and consulted on to ensure that the optimum solution is taken forward.

Alternatives

A number of alternative options are under consideration to increase the capability of the B4, B5, B6, B7 and B7a boundaries. These include onshore system reinforcement.

Outputs Delivered

The main outputs that are expected to be delivered by the NGET-SHETL East Coast HVDC link project would be:

(a) Boundary capability - Increasing the boundary capability of the B4 and B6 boundaries by 1.8GW and 2.1GW respectively, and B7 and B7a by 1.0GW and 0.7GW respectively
(b) Reliability and Availability - Maintaining security of supply and reducing expected constraint costs against an increasing volume of wind generation in Scotland

[37] The cost is for indicative purpose only as the project is in its early stages of development. The uncertainty surrounding this project is high covering a number of aspects such as final routing, technology, commodity prices, and markets.

(c) Environmental - Facilitating the connection of approximately 10GW of renewable generation in Scotland and progressing towards the government 2020 targets. The project would also not require additional onshore overhead line construction with the associated impact on visual amenity.

4.2.5 Scotland-England Boundary B6

Boundary B6 is the interfacing boundary which divides the SPT and the NGET networks. The boundary is characterised by two 400 kV double circuits with a number of 132 kV circuits providing a limited contribution to capability.

The existing capability of these circuits is currently limited to 2.8GW by stability restrictions. Reinforcements to this boundary are currently underway. On completion of these works in 2013/14, the boundary will have an export capability from Scotland to England and Wales in the order of 3.3GW.

The transfer requirement from Scotland to England steadily increases over the period considered. The existing boundary capability is insufficient for current generators requirements north of the boundary and the transfer requirement is expected to increase. There are currently derogations against the NETS SQSS in place reflecting the lack of transmission capacity and the need for these derogations is expected to remain in place until the reinforcement options identified in Table 15 are delivered.

Figure 16 shows the variation in required transfer for boundary B6 under the Economy criteria. The existing boundary capability which is 2.8GW is shown with the increase in capability corresponding to a possible set of reinforcements within the boundary for illustrative purposes. This set of reinforcements is a possible combination of the reinforcements listed in Table 15. A range of required transfers is also provided in the 2016-2020 period covering the faster and slower development sensitivities as explained in chapter 2.2.1.

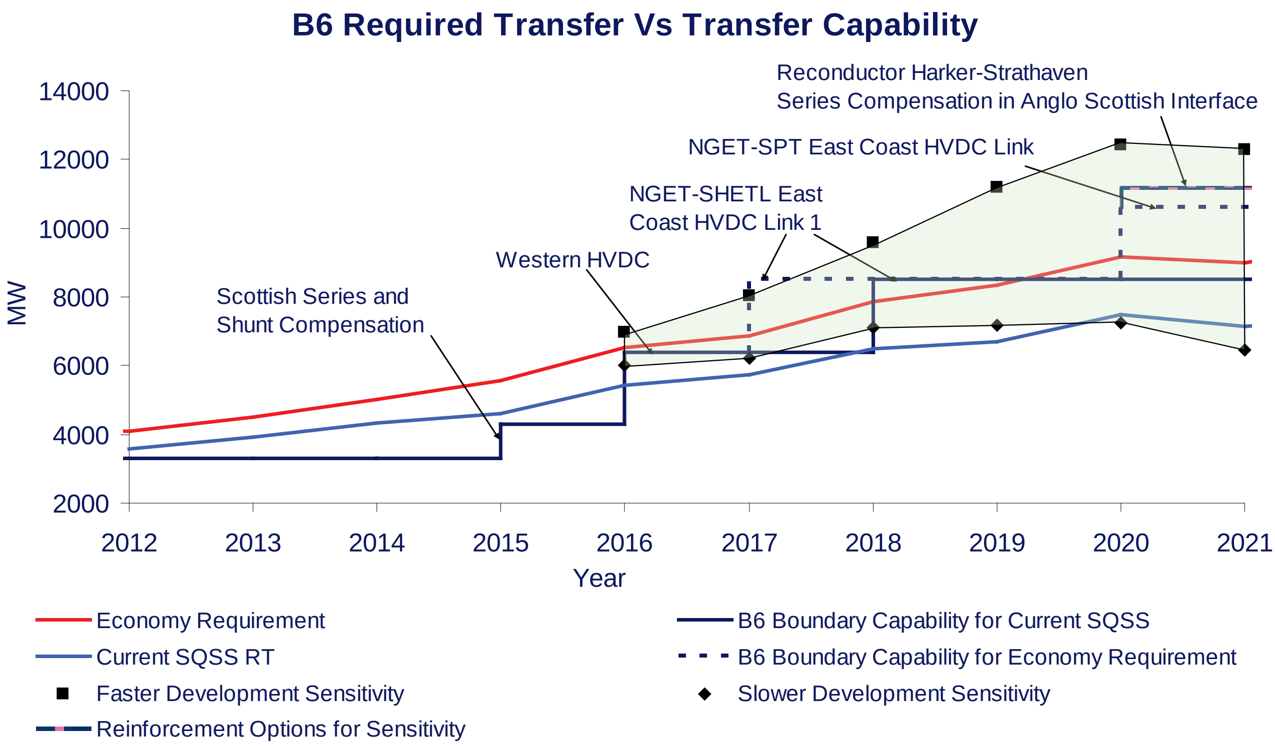


Figure 16: Boundary B6 Required Transfer and the Transfer Capability

4.2.6 Scotland-England Boundary B7

Boundary B7 is characterised by six 400kV primary circuits. These are the Lackenby-Thornton, Harker-Hutton and Norton-Osbaldwick double circuits. Boundary B7 is predominantly affected by power flows from Scotland to demand centres in the south of England. The existing boundary capability is around 3.6GW, limited by thermal capability of the circuits under an N-2 fault condition.

As with all the other Scotland-England boundaries, B7 becomes more constrained as power flows increase from Scotland, thus requiring numerous reinforcements. In the early years the boundary is limited by the thermal capability of the Harker-Hutton circuits. Reinforcement AS-R01 is an option that could be used to increase the post-fault winter capability of these circuits from 1390MVA to 3100MVA per circuit. The boundary capability is improved by 1.4GW following this reinforcement. The Western HVDC link could also provide an additional capability of 2.1GW with the Harker to Hutton reconductoring completed. However without reconductoring the Harker to Hutton circuits, the Western HVDC link only provides a capability of around 0.4GW across boundary B7. Additionally the NGET-SHETL East Coast HVDC link which could be an option for increasing boundary B6 capability would add a further 1GW to the boundary capability of B7.

Figure 17 shows the variation in required transfer for the B7 boundary under both the current Deterministic Criteria and the Economy requirement. The existing boundary capability which is 3.6GW is also shown with the increase in capability corresponding to the set of reinforcements. A range of required transfers is also provided in the 2016-2020 period covering the faster and slower development sensitivities as explained in chapter 2.2.1.

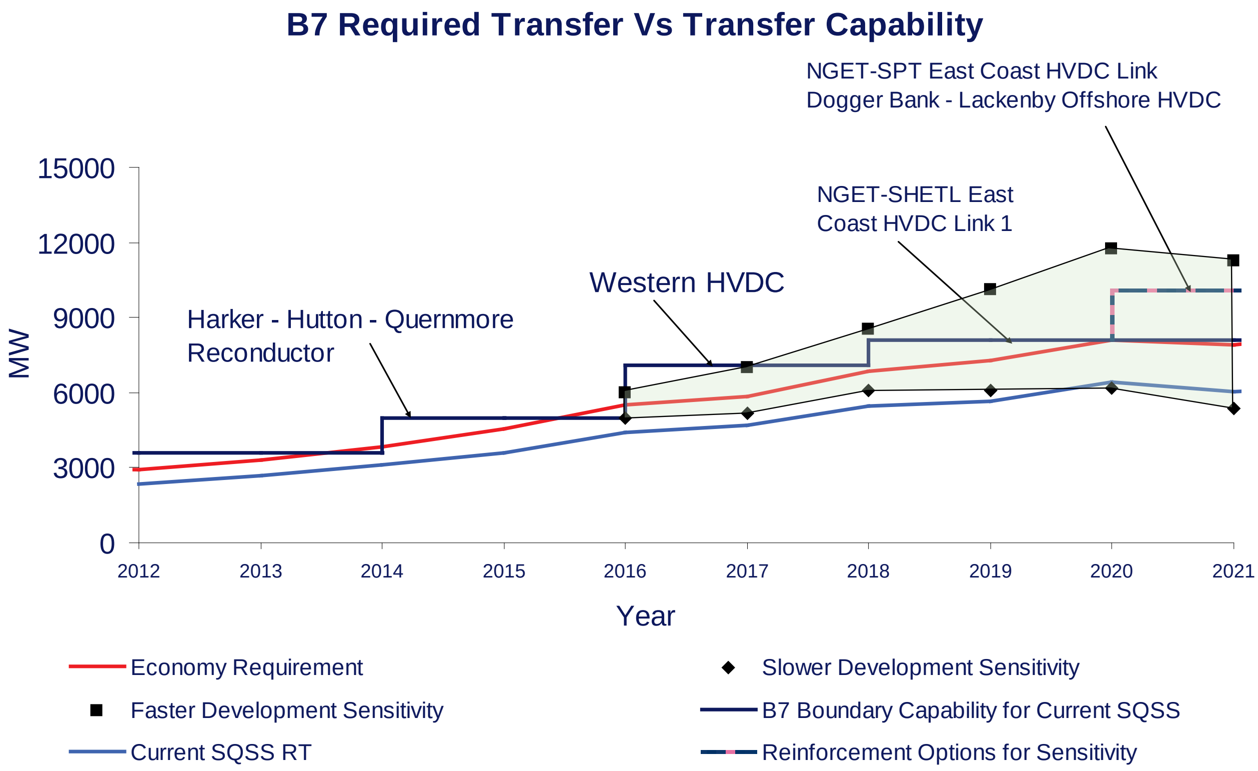


Figure 17: Boundary B7 Required Transfer and the Transfer Capability

4.2.7 Scotland-England Boundary B7a

Boundary B7a runs in parallel with B7, but encompasses Heysham, Hutton and Penwortham. The boundary is characterised by four 400 kV circuits running from Norton and Lackenby in Teeside into Osbaldwick and Thornton respectively in North Yorkshire and two single 400kV circuits from Penwortham to Padiham and Kearsley. Boundary B7a also crosses through one 275kV double circuit from Penwortham to Washway Farm. The existing boundary capability is around 5.4GW.

The boundary encompasses an additional zone compared to boundary B7. The boundary transfers from North to South are therefore affected by the Scottish generation as well as generation increase within this additional zone.

Figure 18 shows the variation in required transfer for the B7a boundary under both the Deterministic criteria and the Economy criteria for CBA. The existing boundary of the B7a boundary is 5.4GW. Figure 18 shows the increase in capability corresponding to a possible set of reinforcements from the options listed in Table 15. It should be noted that some of these reinforcements have been suggested for other Scotland-England boundaries but have additional benefits in this boundary. The options considered are reinforcements AS-R02 (Western HVDC link) which add 2.1GW to the boundary capability with the NGET-SHETL East Coast HVDC link 1 (AS-R04) and Mersey Ring uprate (As-R08) increasing the boundary capability by 0.7GW and 1GW respectively. A range of required transfers is also provided in 2020 covering the faster and slower development sensitivities.

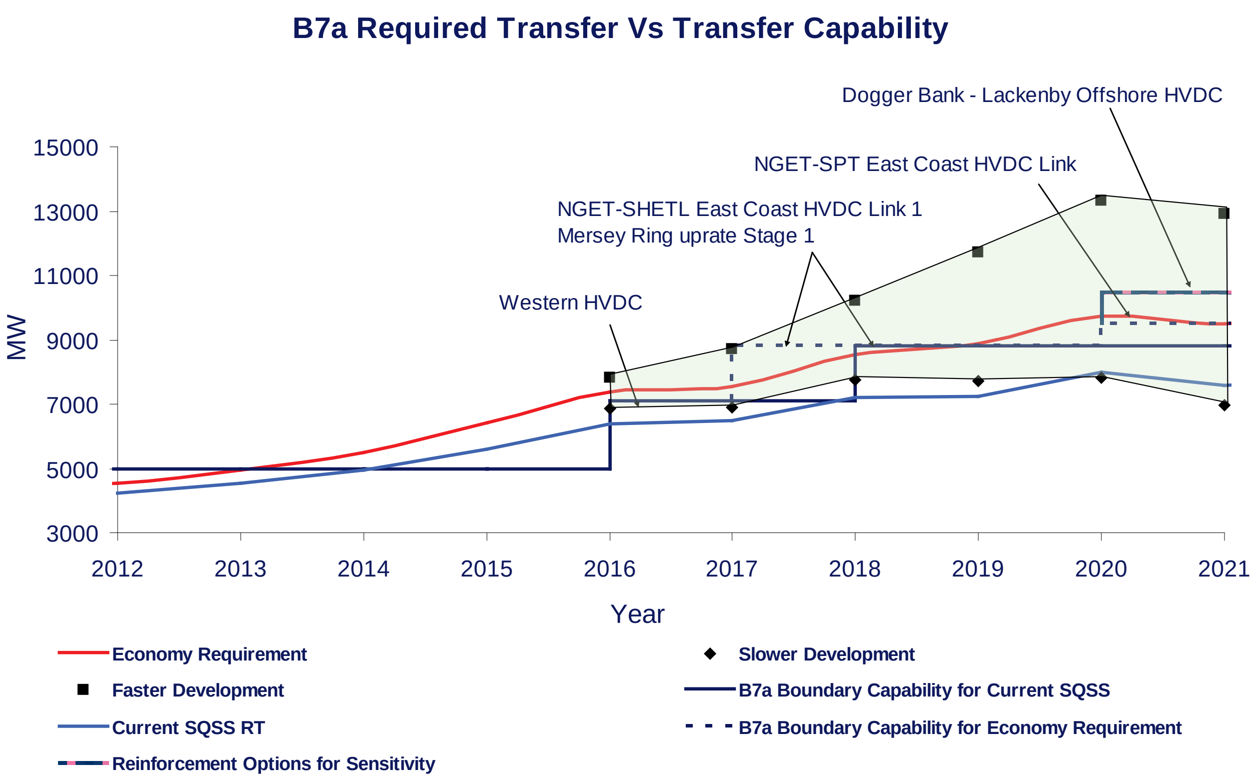


Figure 18: Boundary B7a Required Transfer and the Transfer Capability

A full range of potential reinforcements to cover sensitivities has not been provided for the boundary B6, B7 and B7a. Instead, it is more economical to explore options such as inter tripping arrangements and the use of advanced control techniques to cater for this large uncertainty.

4.2.8 Changes in the Potential Reinforcement since the 2009 ENSG Report

There has been a re-optimisation of the location of the series compensation and this resulted in the series compensation between the Norton – Spennymoor 400kV double circuit, being removed. However, there are a few further reinforcements that have been considered in the 2012 ENSG Report such as NGET-SPT East Coast HVDC link, Mersey Ring uprate and potential use of offshore connections

.

4.2.9 Cost

The total estimated cost of the possible set of reinforcements considered for boundary B6, B7 and B7a in sections 4.2.5, 4.2.6 and 4.2.7 lie between £2.9bn and £3.9bn for the slower and faster development sensitivities respectively; with a cost of around £3.5bn estimated for the base Gone Green 2011 scenario.

4.3 North to Midlands and Midlands to South

4.3.1 Existing transmission system

The North to Midlands and Midlands to South boundaries (B8 and B9) intersect the centre of Great Britain, separating the northern generation zones including Scotland, Northern England and Northern Wales from the Southern demand centres. Both boundaries are therefore characterised as wider boundaries, and transfer a high level of power as a result of the volume of generation supplying the major demand centres in the South of England.

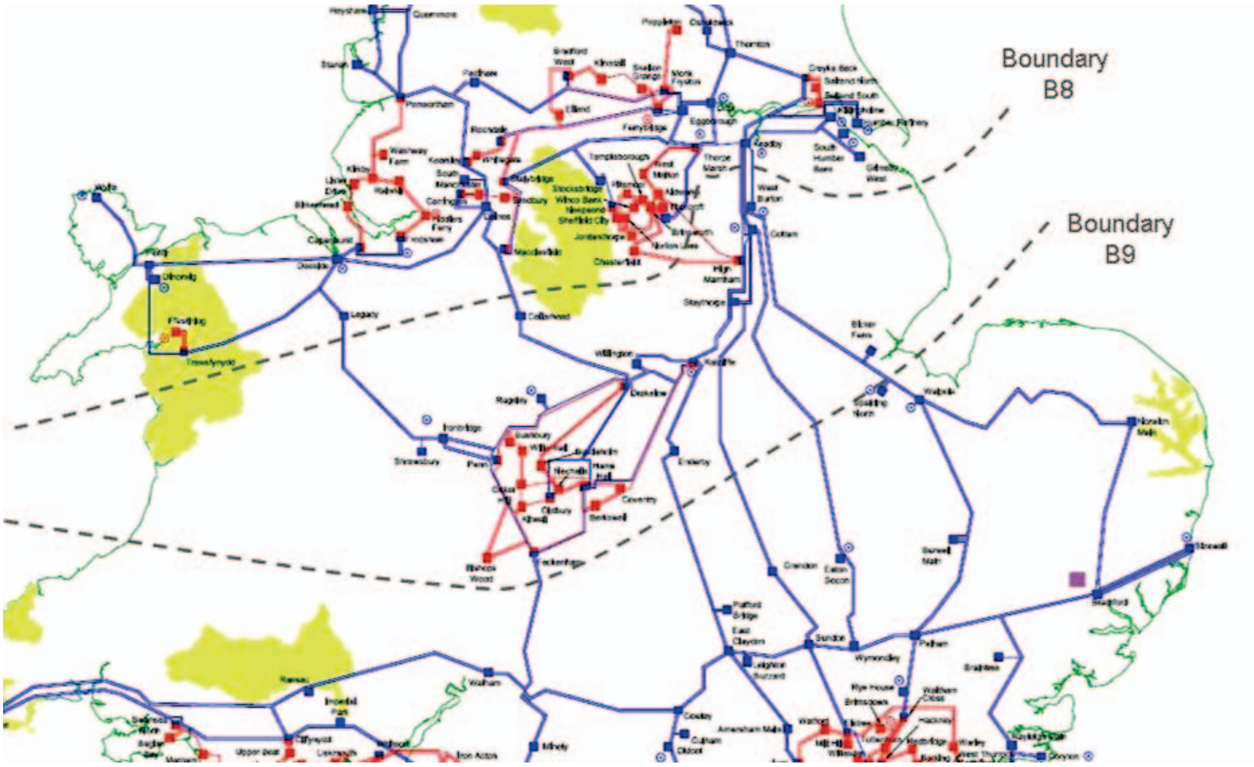


Figure 19 – Existing North to Midlands and Midlands to South circuits

4.3.2 Potential Reinforcement

The expected closures of existing CCGT generation plants within the Gone Green 2011 scenario on either side of boundaries B8 and B9 causes voltage depression within these boundaries. The Wylfa – Pembroke HVDC link indentified in the North Wales region would provide additional thermal and voltage capability to these boundaries. Alternatively voltage issues within Boundaries B8 and B9 can be solved by providing additional reactive power support. Potential reinforcement options are shown in Figure 20 and described in Table 17.

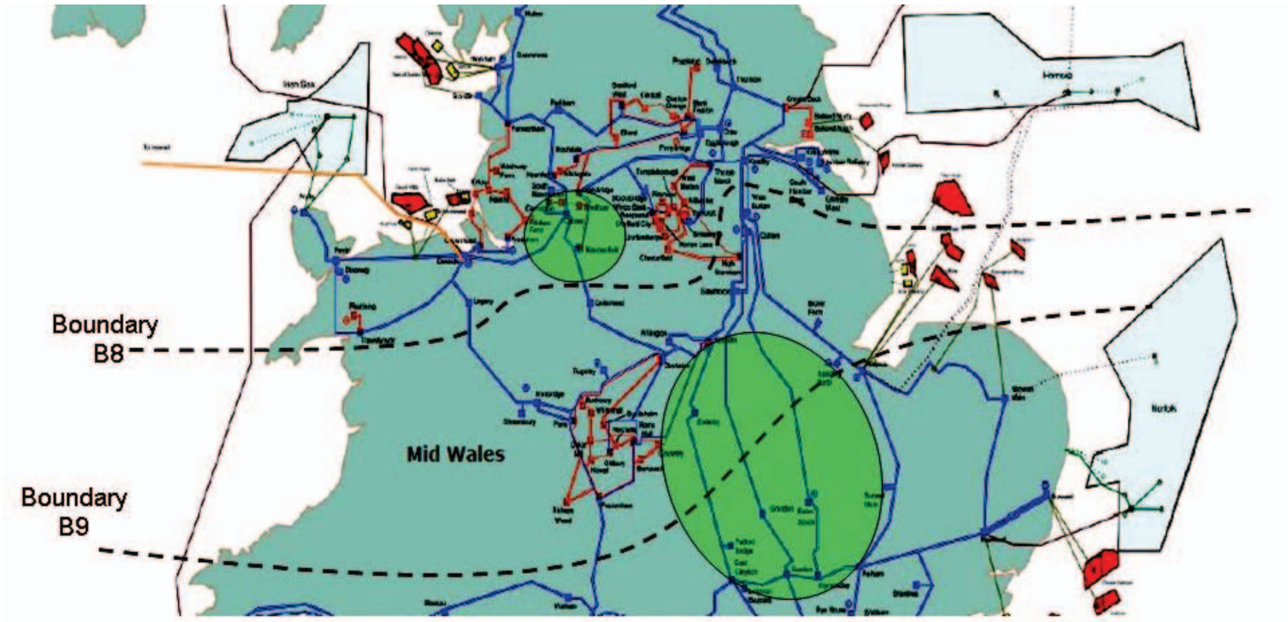


Figure 20 –Map of North to Midlands and Midlands to South boundaries with possible location of reinforcements

Table 17 lists the possible reinforcements for boundary B8 and B9. The table also includes the brief scope of work and additional boundary capability provided by the reinforcements.

Reference	Reinforcement	Works Description	Additional Boundary Capability (GW)		Earliest Possible Completion Date
			B8	B9	
NW-R07	WYLF-PEMB HVDC LINK	2GW HVDC link from Wylfa/Irish Sea to Pembroke Substation extension at Wylfa and Pembroke	+1.5	+1.3	2017
WB-R01	Reconductor Cellarhead - Drakelow	Reconductoring of Cellarhead – Drakelow double circuit	+1.6	+1.4	2016
WB-R02	Reactive compensation Support	A number of MSC's either sides of the B8 and B9 boundary			

Table 17: Potential reinforcements in North to Midlands and Midlands to South boundaries

4.3.3 Boundary Overview

The changing generation background influences the base capability of the B8 and B9 boundaries. These boundaries have always been heavily loaded with local generation critical in regulating voltage support.

Boundary B8 is a wider system boundary with five major 400kV double circuits and a limited 275kV connection to South Yorkshire. The current network capacity of boundary B8 is 11.3GW.

Boundary B9 is also a wider system boundary with five major double circuits across it and the current network capacity is 12.6GW.

4.3.3.1 Boundary B8

Figure 21 shows the required transfers across boundary B8 under the Deterministic and Economy Requirement. For the purpose of this discussion a number of possible reinforcements from those listed in Table 17 have been selected and the boundary capability shown in Figure 21 reflects the combined effect of these reinforcements.

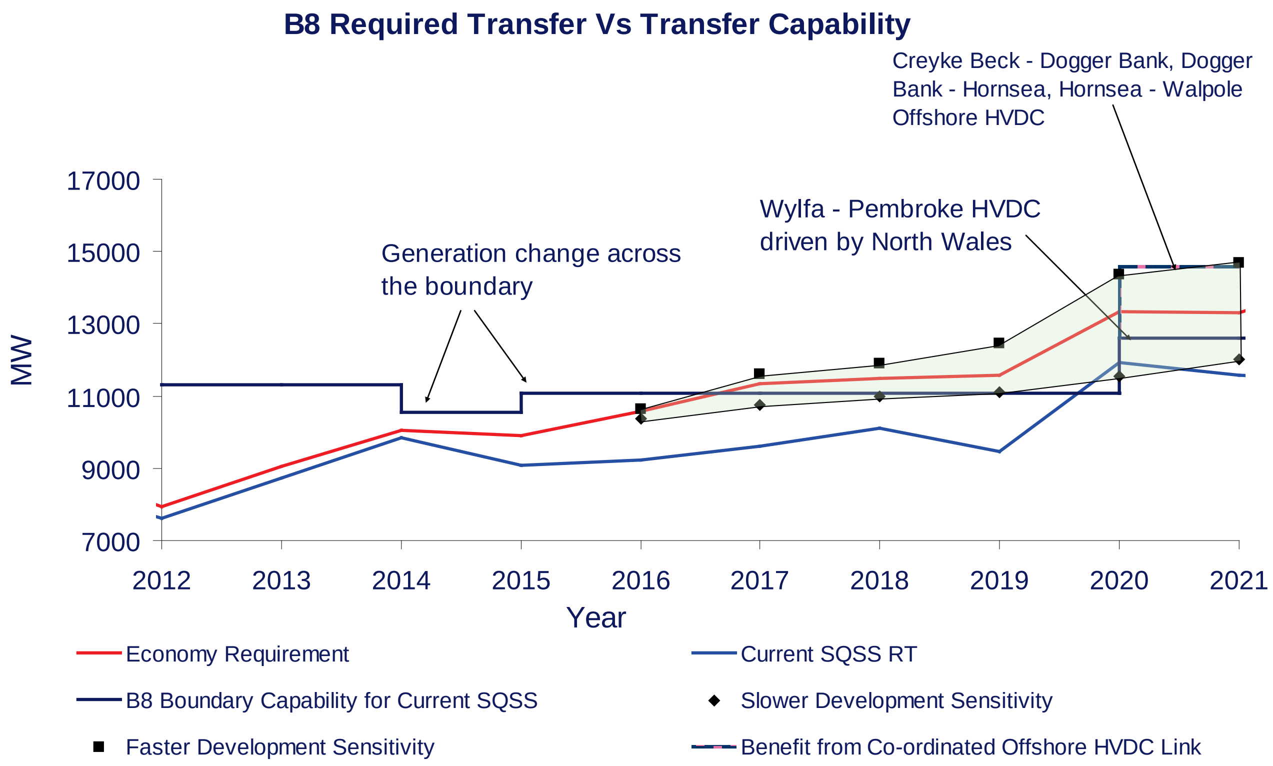


Figure 21: Boundary B8 Required Transfer and the Transfer Capability

The existing boundary capability of B8 boundary is 11.3GW. The capability of this boundary is sensitive to the changing generation backgrounds and is restricted by voltage limitations which vary throughout the year.

The reduction in boundary capability in 2014 and 2017 is caused by changes to the generation backgrounds and changes to the reactive demands. The Wylfa – Pembroke HVDC reinforcement option (identified as an option for increasing capability of the North Wales boundaries) and the coordinated offshore HVDC connection identified in Figure 21 (as discussed in the East Coast and East Anglia boundaries) could be used to increase the capability for boundary B8 with the resulting boundary capability satisfying both the economy requirement and faster development sensitivity. Under the economy requirement and the faster development sensitivity there may be a need to carry out further reinforcements (WB-R01 and WB-R02) or bring forward the reinforcements shown in Figure 21 but this will be subject to further evaluation.

4.3.3.2 Boundary B9

Figure 22 shows the required transfers across boundary B9 under the current Deterministic and Economy Requirement. For the purpose of this discussion a number of potential reinforcements from those listed in Table 17 have been selected and the boundary capability shown in Figure 22 reflects these reinforcements.

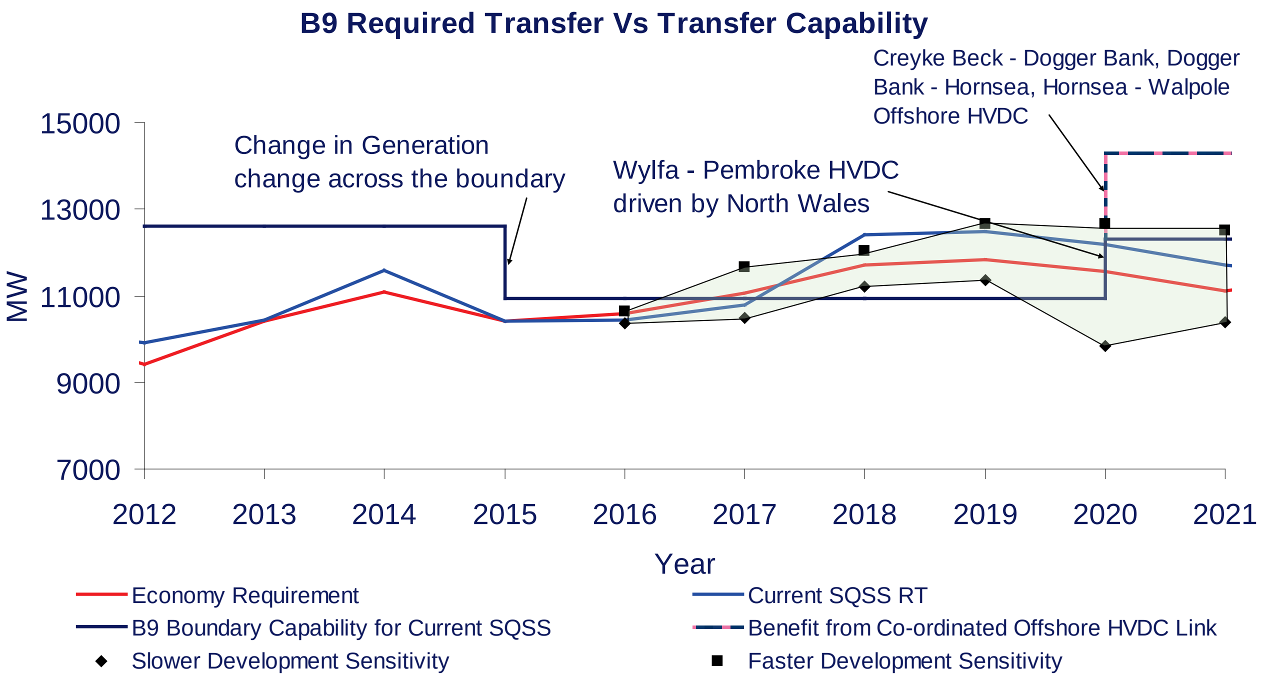


Figure 22: Boundary B9 Required Transfer and Transfer Capability

The existing capability of boundary B9 is 12.6GW. As mentioned previously this boundary capability is sensitive to changes in generation background. The boundary capability decreases due to changes in the generation background but remains well above the required transfer level until 2015.

The boundary becomes non compliant from 2018 onwards but completion of the Wylfa - Pembroke HVDC link in 2020 (identified as an option for increasing capability of the North Wales boundaries) and the Hornsea-Walpole offshore HVDC connection (as discussed in the East Coast and East Anglia boundaries) would provide the required additional capability. Under the economy requirement and the faster development sensitivity there may be a need case to carry out further reinforcement (WB-R01 and WB-R02) or bringing forward the reinforcements shown in Figure 22 but this will be subject to further evaluation.

4.3.4 Cost

The estimated cost of the possible set of reinforcements considered for boundary B8 and B9 in sections 4.3.3.1 and 4.3.3.2 has been covered in section 4.4 and section 4.7 as indentified for the North Wales (NW2 and NW3) and East Coast (EC1) boundary respectively.

4.4 North Wales

4.4.1 Existing Transmission System

The network in North Wales comprises a 400kV circuit ring that connects Pentir, Deeside and Trawsfynydd substations. There is a double circuit spur out to the coast from Pentir to Wylfa that crosses the Menai Strait. A double circuit cable spur from Pentir connects Dinorwig pumped storage power station by Lyn Peris reservoir. In addition, a 275kV spur traverses north of Trawsfynydd to Ffestiniog pumped storage power station. The majority of this overhead line loop around the region forms a double circuit route. The cable section at Glaslyn on the single 400kV circuit connects Pentir to Trawsfynydd within the Snowdonia National Park, is the main limiting factor for capacity in this area.

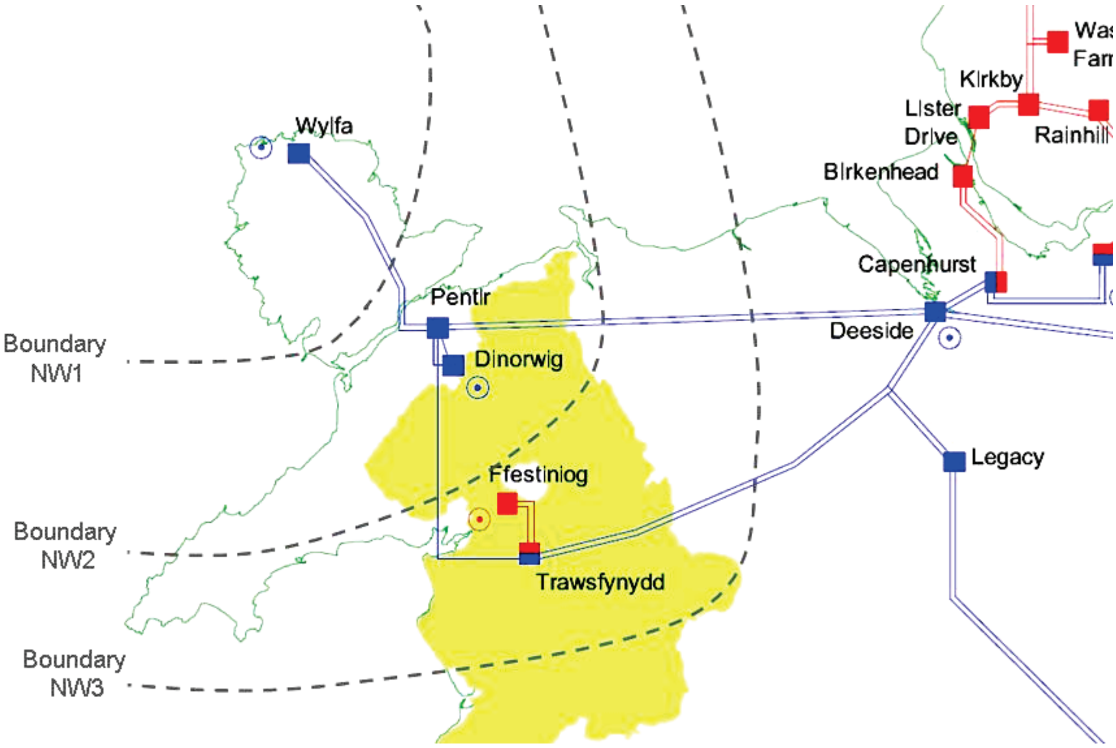


Figure 23: Existing North Wales transmission system with boundaries

4.4.2 Generation Background

Wylfa is expected to remain a nuclear site with the Nuclear National Policy Statement[38] identifying it as potentially suitable for a new nuclear power station before the end of 2025. This position is further supported with a signed connection agreement for a new nuclear power station generating from 2020. There is also a large volume of potential offshore wind generation in the Irish Sea off the north coast of Wales. The Crown Estate's Offshore Wind announcement in January 2010 suggested a potential generation capacity of up to 4.2GW in this area in addition to the Round 1 and Round 2 offshore wind farms, with 500MW of this generation currently having a signed connection agreement to connect by 2017 and a further 500MW by 2018. The offshore zone identified by the Crown Estate is located near to the coastline, and initial proposals suggest that this zone will have some of the earliest Round 3 offshore wind farms to connect.

Table 18 summarises the generation breakdown for the Gone Green 2011 scenario in the North Wales area. The table also includes the generation background that was used in the 2009 ENSG Report under the Gone Green 2008 scenario.

[38] http://www.decc.gov.uk/assets/decc/11/meeting-energy-demand/consents-planning/nps2011/2009-nps-for-nuclear-volumeI.pdf

Ref	Scenario	Capacity at end of 2020 (MW)								Total (MW)
		Thermal	Nuclear	Hydro	Pump Storage	Marine	Biomass	Offshore Wind	Onshore Wind	
2009 ENSG Report	**GG2008**	2096	0	-	2004	0	-	1235	-	5335
2012 ENSG Report	**GG2011**	1590	1200	-	2004	11	-	2574	-	7379

Table 18: Generation background comparison between 2009 and 2012 ENSG Reports in the North Wales area.

A net increase of 2.8GW of generation is forecast to connect under the Gone Green 2011 scenario in the North Wales area by 2020. This includes an interconnector link to Ireland which is expected to be completed before 2012/13.

After the Western HVDC link from Scotland into Deeside substation is established, the control system on this link will be able to provide additional boundary capacity to this region by either reducing the importing power or exporting a percentage of the power during critical outage conditions through post-fault actions.

Careful consideration was given to the potential need for additional reinforcements south of Deeside following the commissioning of the Western HVDC link. This analysis demonstrated that the Western HVDC link did not trigger any additional reinforcements and any additional loading under outage conditions could be managed by controlling power flows on the HVDC link for any subsequent fault.

4.4.3 Demand

The demand in this region is low and therefore North Wales will remain an exporting region, with power flowing out of the area towards the West Midlands. Reinforcements in this region are expected to be predominantly driven by the high levels of the generation outlined in Table 18.

4.4.4 Co-ordinated Strategy Design Approach

The North Wales area has a number of existing onshore connection points for Round 1 and 2 offshore wind farms located in the Irish Sea. The planned Round 3 zone is located between Anglesey and the Isle of Man. The Round 3 windfarm zone development area in the Irish Sea has an expected final capacity of up to 4.2GW.

As the majority of the North West offshore windfarms lie within the south zone and are in close proximity to the shore (less than 50 km), the use of AC technology would be applicable and financially feasible (HVDC offers more economic benefits at longer distances). The northern part of the Irish Sea zone is more than 70 km from shore and would most likely require an HVDC connection.

An offshore co-ordinated network design option has been developed for this zone as shown in Figure 24. It illustrates a design option which would accommodate 2GW of wind expected by 2020 under Gone Green 2011 Scenario and could be expanded to a maximum zonal capacity of 4.2GW for the full Round 3 Irish Sea wind capacity. This option does not prejudge the outcome of the offshore transmission co-ordination project, nor represent any investment decisions and/or contracted arrangements or programme of the project developers or TOs, nor imply the actual connection routes.

This design option would coordinate interconnection between the offshore platforms and the onshore transmission which could potentially reduce the number of connections to shore, the cost of the connections and possibly provide circuit diversity to the offshore generation. These potential benefits would be dependent upon assumptions made for example on timing and scale of generation.

To manage power flows within the offshore transmission, the HVDC converters in this example have been strategically placed to allow direct power transfer between each other and also control the power sent through the circuits to the onshore connection points. The interconnection would also offer the potential advantage that should one of the major circuits need to be disconnected whether due to fault or maintenance the others could be used as a possible alternative path to ensure greater connection security.

4.4.5 Potential Reinforcement

A number of potential reinforcement requirements have been identified for the North Wales region to meet the required high power transfer. Figure 24 shows the areas of the transmission system within the North Wales region which would require reinforcement for NETS SQSS compliance.

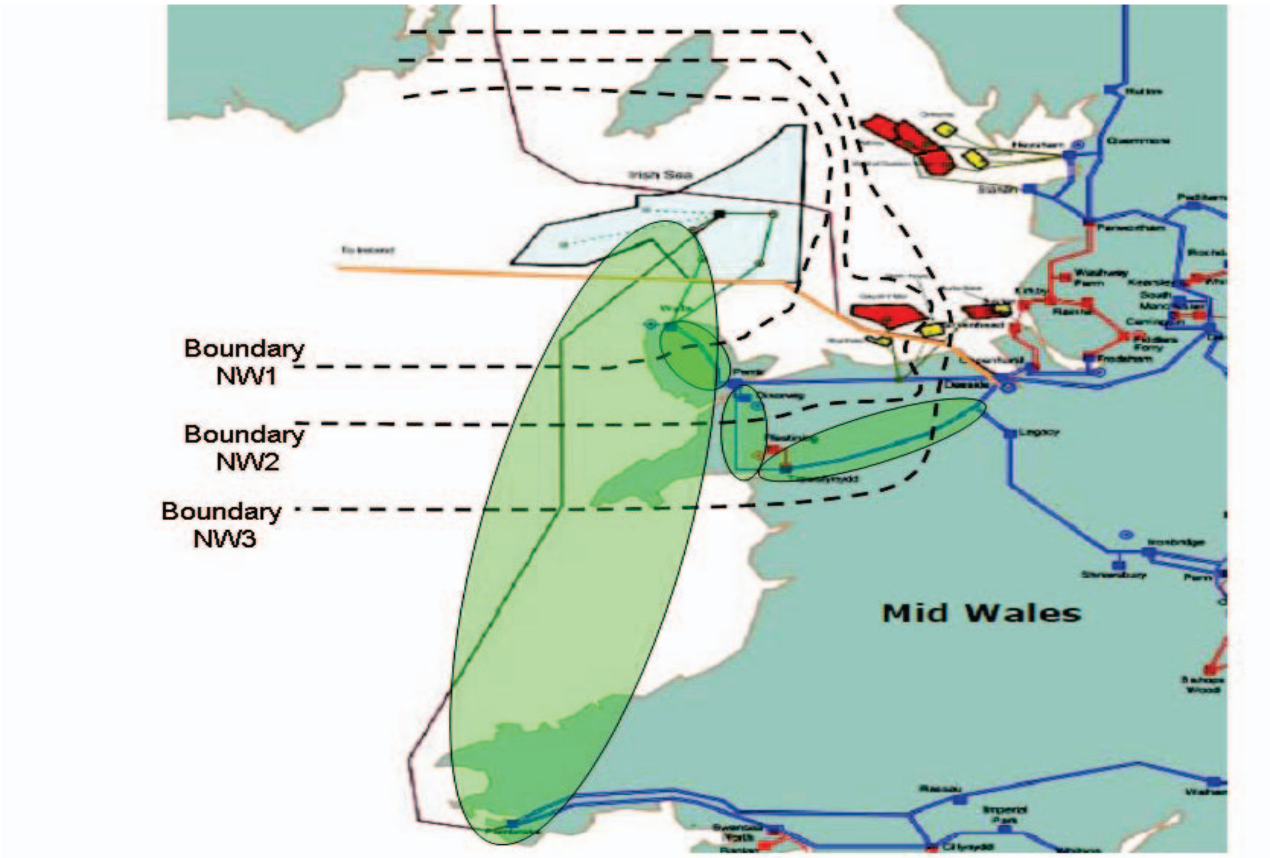


Figure 24: North Wales transmission system with potential reinforcement option

Table 19 lists the possible reinforcements for the North Wales area including a brief scope of work. These reinforcements do not prejudge the preferred option, nor represent any investment decisions and/or contracted arrangements or programme of the TO, nor imply the actual transmission routes.

Ref.	Name	Scope	Additional Boundary Capability (GW)			Earliest Possible Completion Date
			NW1	NW2	NW3	
NW-R01	Establish second Pentir – Trawsfynydd 400 kV circuit	Reconductor existing SP Manweb[39] owned 132 kV circuit, strung between Trawsfynydd and tower 4ZC70, for operation at 400 kV Reconfiguration and extension of Pentir 400 kV substation Increase the capacity of the cable link crossing the Glaslyn Estuary to be equivalent to the overhead line	-	+3.1	-	2016

[39] This option needs further discussion and agreement with SP Manweb

Ref.	Name	Scope	Additional Boundary Capability (GW)			Earliest Possible Completion Date
			NW1	NW2	NW3	
NW-R02	New 400 kV, Pentir – Wylfa two transmission circuits	New Pentir – Wylfa transmission double circuit Extension of Pentir 400 kV substation Modifications to Wylfa substation	+3.5	-		2018
NW-R03	Deeside – Trawsfynydd series compensation	120 Mvar series compensation	-	-	-	2015
NW-R05	Reconductor Trawsfynydd – Treuddyn	Reconductor Trawsfynydd – Treuddyn	-	-	+1.5	2014
NW-R07	Irish Sea-Pembroke HVDC Link	2GW HVDC link from Wylfa/Irish Sea to Pembroke Substation extension at Wylfa and Pembroke	+2.0	+2.0	+2.0	2017
NW-R08	New 400 kV, Pentir – Wylfa single circuit	Construction of a single transmission circuit between Pentir-Wylfa	+2.4	-	-	2018
NW-R09	Pentir – Deeside Reconductoring	Pentir – Deeside existing double circuit reconductor	-	+0.6	+0.6	2015
NW-R10	Pentir – Trawsfynydd Reconductor	Pentir – Trawsfynydd existing and new circuit reconductor	-	+1.0	-	2015

Table 19: List of potential reinforcements in the North Wales region

The series compensation reinforcements (NW-R03) would be primarily required to maintain the stability of large generation units that could be installed on Anglesey. The boundary capability is limited by the thermal rating of the critical circuits and the requirement of series compensation is only for transient stability. Therefore this reinforcement does not show any increase in boundary capability.

4.4.6 North Wales Boundaries

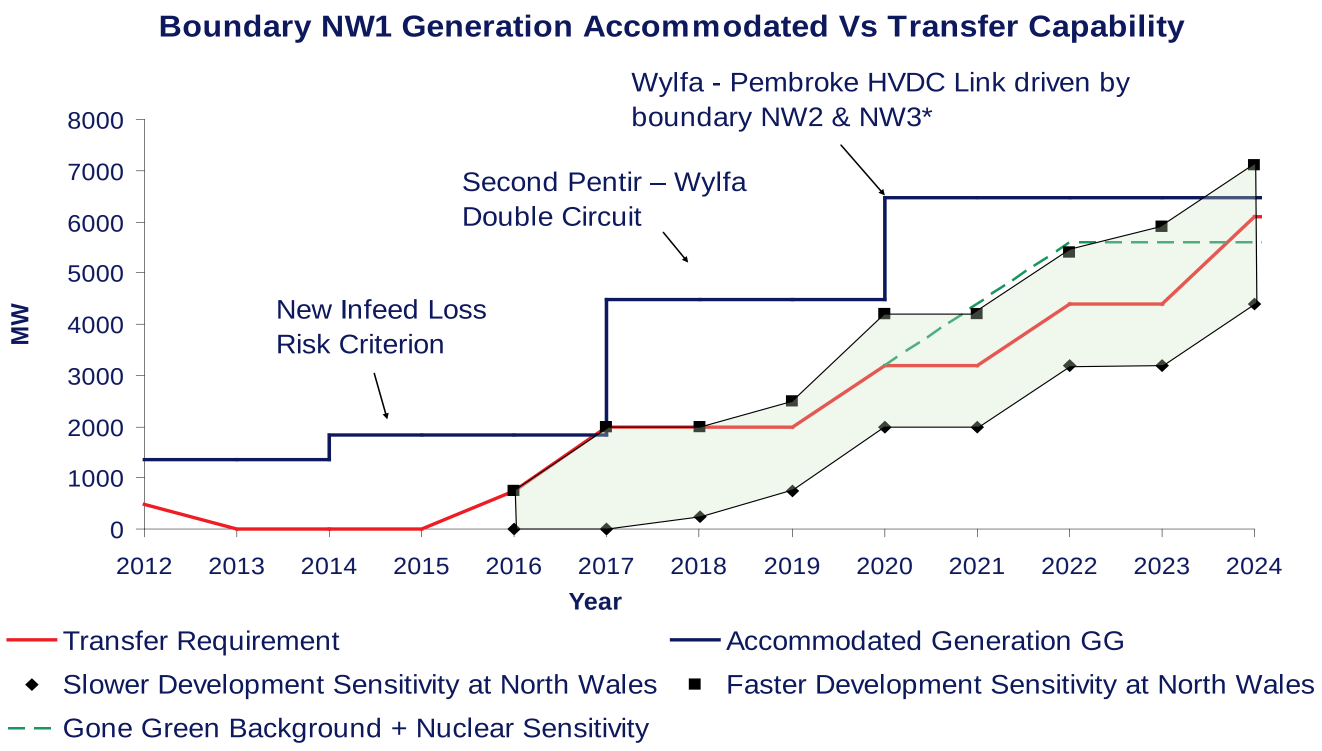
Boundary NW1, NW2 and NW3 are local boundaries, and the generation behind these boundaries is assumed at full capacity for these studies. The analysis therefore looks at “generation accommodated” rather than “transfer requirements”. The generation accommodated for boundary NW1, NW2 and NW3 would be the same for deterministic NETS SQSS criteria and Economy Requirement due to the nature of these boundaries. The boundary capability for these three local boundaries is studied against the Summer Minimum requirement which reflects the most onerous year round conditions (chapter 2 of the NETS SQSS). The North Wales’ Slower and Faster

Development Sensitivities have also been plotted for all the boundaries. No additional reinforcement has been identified for any of the sensitivities. Boundary NW1, NW2 and NW3 graphs are plotted until 2024 to show commissioning dates of the Wylfa C nuclear and its impact on the boundary and the reinforcement requirement.

4.4.7 Boundary NW1

NW1 is a local boundary limited by the infeed loss risk criterion which is currently 1.32GW and will change to 1.8GW from April 2014. When the infeed loss risk criterion is exceeded, further reinforcement of the boundary is necessary.

Figure 25 shows the transfer requirement of boundary NW1 under the Economy Requirement. The boundary capability reflects one possible set of reinforcements from the potential reinforcement options presented in Table 19.



* Wylfa – Pembroke HVDC link could be required for boundary NW2 and NW3 to provide compliance. As a consequence it provides additional boundary capability to the boundary NW1

Figure 25: Boundary NW1 Generation Accommodated Vs Transfer Capability

The sum of the existing generation behind this boundary is 980MW dropping to 480MW in 2012. Based on the Gone Green 2011 scenario, further closure of generation plant would leave no generation connected behind this boundary until 2015. From 2016 onwards, the generation behind this boundary is expected to steadily increase.

Under the Gone Green 2011 scenario when more than 1.8GW of generation is connected at Wylfa, further reinforcement would be required. For this analysis reinforcement NW-R02, Wylfa – Pentir second double circuit, is considered in 2017 increasing the amount of generation that can be accommodated within NW1 to around 4.5GW. Once the three nuclear units at Wylfa are connected the system would require another reinforcement to achieve compliance. Figure 25 also shows the contracted background for the purpose of a more complete comparison with the given Gone Green 2011 scenario. The Wylfa – Pembroke HVDC link, driven by boundaries NW2 and NW3 could provide the additional accommodated generation capacity required for this boundary.

4.4.8 Boundary NW2

This local boundary is considered to be an exporting boundary due to the level of generation behind the boundary. The existing boundary capability is 1.4GW. Figure 26 shows the generation that can be accommodated in the NW2 boundary under the Economy Requirement model. The boundary capability shown in the figure reflects a possible set of reinforcements which could be used to achieve compliance.

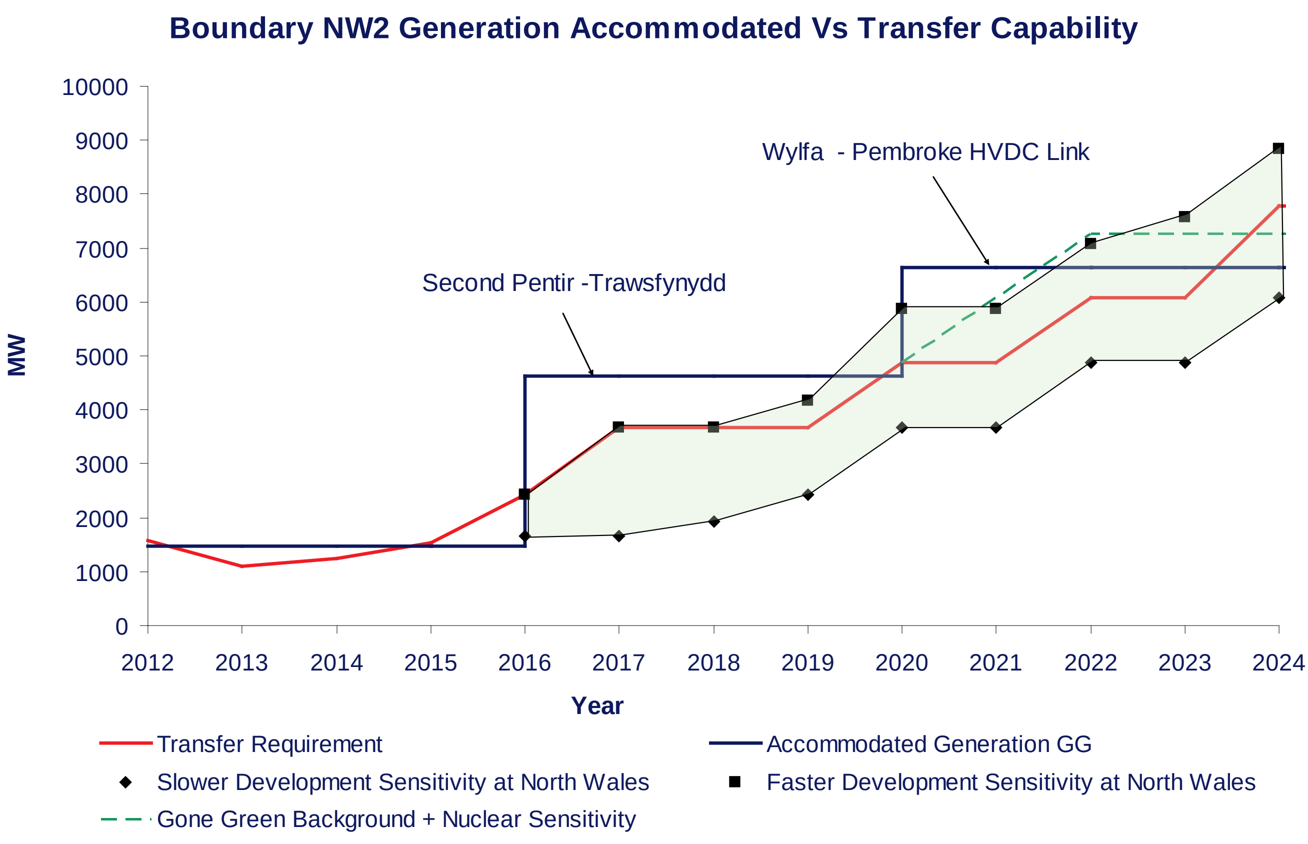


Figure 26: Boundary NW2 Generation Accommodated Vs Transfer Capability

Up to 2015, no investment is triggered in this local area.

When the Round 3 Irish Sea wind farms start to contribute significantly, the system would be unable to meet this additional generation and it would be necessary to create additional boundary capacity. As shown in Figure 26, this could be provided by the installation of a second circuit between Pentir and Trawsfynydd (NW-R01) which would also provide sufficient network capability (approximately 4.6GW) to accommodate further new generation.

In 2020, there would be a need for further reinforcement due to the transfer requirement being higher than accommodated generation capacity. Any reinforcement would be further justified when all the Wylfa C units are operating at full capacity. The extra boundary capability requirement could be provided by the Wylfa - Pembroke HVDC link (NW-R07) as early as 2020. A full CBA will best indicate the timing of this link.

4.4.9 Boundary NW3

Boundary NW3 was studied as a local boundary due to limited generation diversity and a small transmission network consisting of only two double circuits crossing through the boundary. The Boundary NW3 circuits provide capacity for the export of generation connected behind this boundary. The existing boundary capability is 2.85GW. Figure 27 shows the generation accommodated behind boundary NW3. The boundary capability reflects a possible set of reinforcements which could be used to achieve compliance.

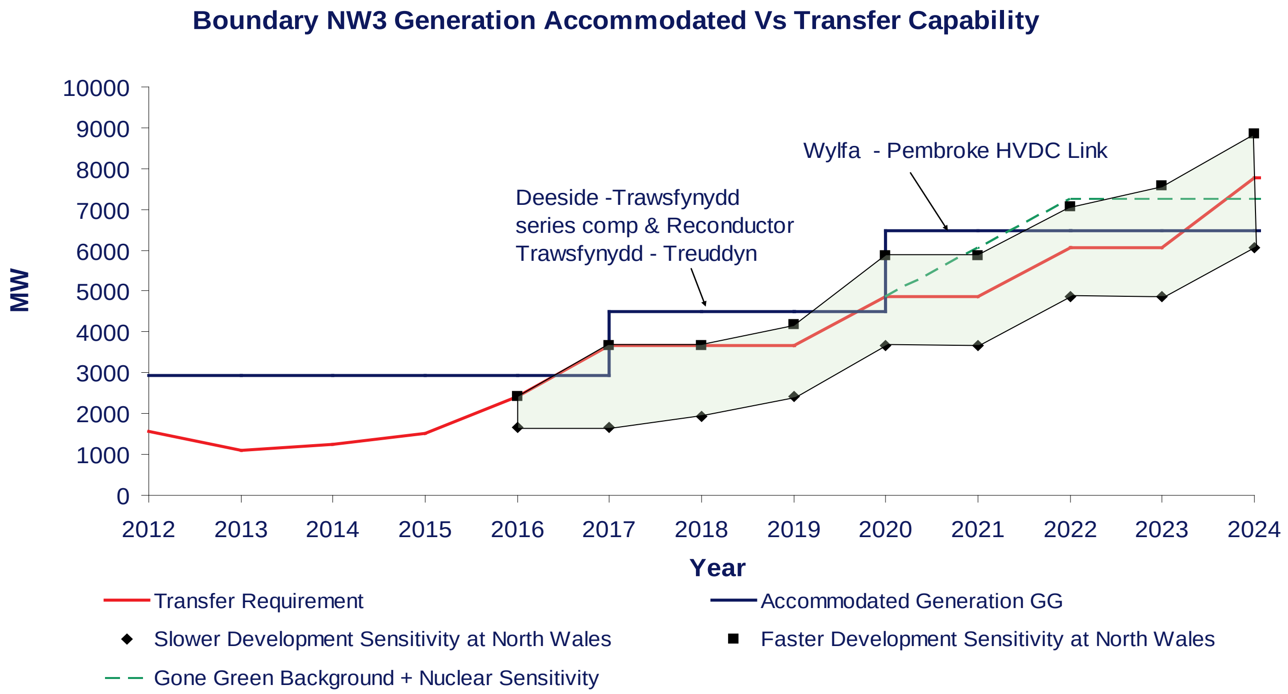


Figure 27: Boundary NW3 Generation Accommodated Vs Transfer Capability

Up to 2016, the expected changes to the generation background do not trigger the need for network reinforcements. The boundary capability is limited by the thermal limit of the existing transmission circuits.

With the significant contribution from the Round 3 offshore Irish Sea wind farms the system would be unable to meet additional generation capacity and it would be necessary to provide additional boundary capability. This could be resolved by reconductoring the Trawsfynydd to Treuddyn Tee legs (NW-R05) which would increase the thermal capability of the boundary to about 4.4GW for the period up to 2020. The reconductoring of the Trawsfynydd to Treuddyn Tee could be completed by 2014 to align the works with a condition-driven fittings only replacement scheme, maximising the efficient use of available outages.

Following the NW-R05 reinforcement this boundary would be limited by transient stability issues at Wylfa following a fault on the Pentir – Deeside line which results in heavy post fault flows from Pentir to Trawsfynydd. Studies found that about 3.5GW generation could be sustained with no stability issues at Wylfa. This limit is reached in 2017.

It was also found that the transient stability limit depends on the mode of operation (on/off) of Deeside generation. When Deeside is assumed to be online, the synchronising power and voltage support it offers slightly increases the stability limit. Series Compensation could be required to provide additional stabilising capacity. Series Capacitors are proposed to the east of Trawsfynydd (NW-R03) providing a reduction in steady state and transient impedance and therefore improving the transient stability limit of the boundary such that the capability of the boundary would again be dependent on thermal limitations at around 4.4GW.

In 2020, there is a further need for extra boundary capability which could be provided by the Wylfa - Pembroke HVDC link. This reinforcement option would be further justified once all the Wylfa C nuclear units are commissioned and further boundary capability is required.

4.4.10 Changes in the Potential Reinforcement since the 2009 ENSG Report

The most significant change in the reinforcements since the 2009 ENSG Report is the consideration of a Wylfa – Pembroke HVDC link which would accommodate an increase in Irish Sea wind and nuclear generation at Wylfa.

The 2012 ENSG Report also provides a list of the potential alternative reinforcements and these are presented in Table 20.

Ref	Name of Alternative Reinforcement
1	New 400 kV, Pentir – Wylfa single circuit
2	Pentir – Deeside Reconductoring

3	Pentir – Trawsfynydd Reconductor

Table 20: List of alternative reinforcements considered in ENSG Refresh

In addition a potential offshore network design has been developed for interconnection between offshore wind platforms in the Irish Sea and the onshore transmission network which could potentially provide additional security to the onshore and offshore network

4.4.11 Cost

The estimated cost of the possible set of reinforcements considered in sections 4.4.7 to 4.4.9 is between £420m for the slower development sensitivity case and £1.12bn for the baseline Gone Green 2011 case.

4.5 Mid-Wales

4.5.1 Existing transmission system

The Mid-Wales area does not have any existing electricity transmission infrastructure. The area has been identified as one that has significant potential for onshore wind generation which would necessitate the construction of new transmission infrastructure.

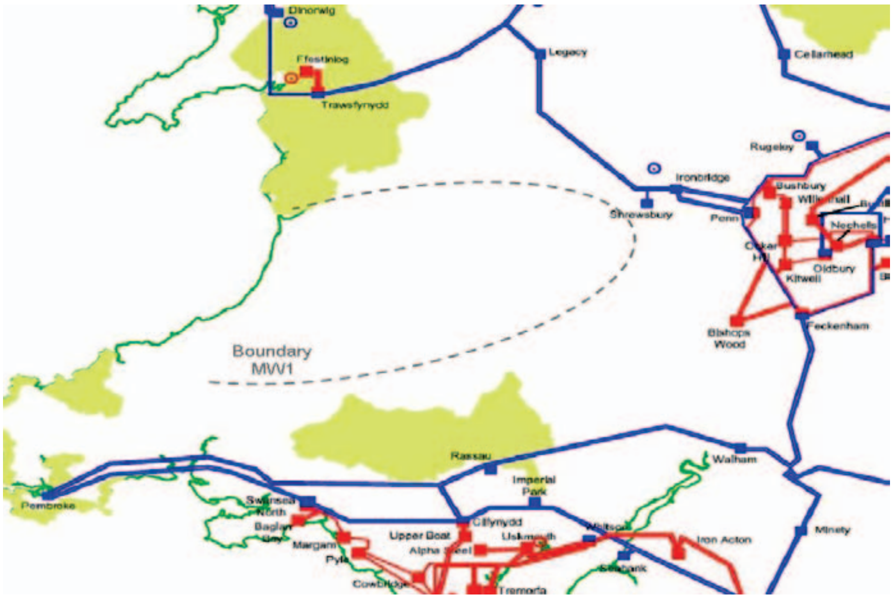


Figure 28: Mid-Wales boundarywithout any existing electricity transmission infrastructure

4.5.2 Generation

Only some onshore wind is assumed to connect under Gone Green 2011 generation background in the Mid-Wales region. Table 21 shows the changes in the generation background in this area since the 2009 ENSG Report.

Ref	Scenario	Capacity at end of 2020 (MW)								Total (MW)
		Thermal	Nuclear	Hydro	Pump Storage	Marine	Biomass	Offshore Wind	Onshore Wind	
2009 ENSG Report	**GG2008**	-	0	-	-	-	-	-	0	0
2012 ENSG Report	**GG2011**	-	-	-	-	-	-	-	760	760

Table 21: *Generation background comparison between the 2009 and 2012 ENSG Reports in the Mid-Wales region.*

4.5.3 Demand

Boundary MW1 is only a generation boundary and therefore there is no demand.

4.5.4 Potential Reinforcement

Around 400MW of wind farm projects currently have a signed offer to connect to the SP Manweb distribution network who in turn have a signed connection offer for this amount to connect to the NETS. It is expected that, once transmission infrastructure is established in Mid-Wales, these embedded generators would access the NETS via the SP Manweb distribution network. However the capacity of the distribution network in the area is not sufficient to accommodate the level of generation currently contracted to connect unless transmission infrastructure is established in Mid-Wales; therefore, if this level of generation does go ahead, connection to the NETS will be required. Additionally another 360MW of onshore wind generation is expected to connect directly to the transmission system from 2015/2016.

NGET has completed a consultation with stakeholders about the projects in Mid-Wales and the options for their connection to the NETS. Six main options were considered within the consultation process with the local communities and the full details of the consultation process and the options considered can be found in the strategic optioneering report on the dedicated Mid-Wales Project website[40].

Figure 29 shows an indication of the area within the Mid-Wales region where reinforcements would be required.

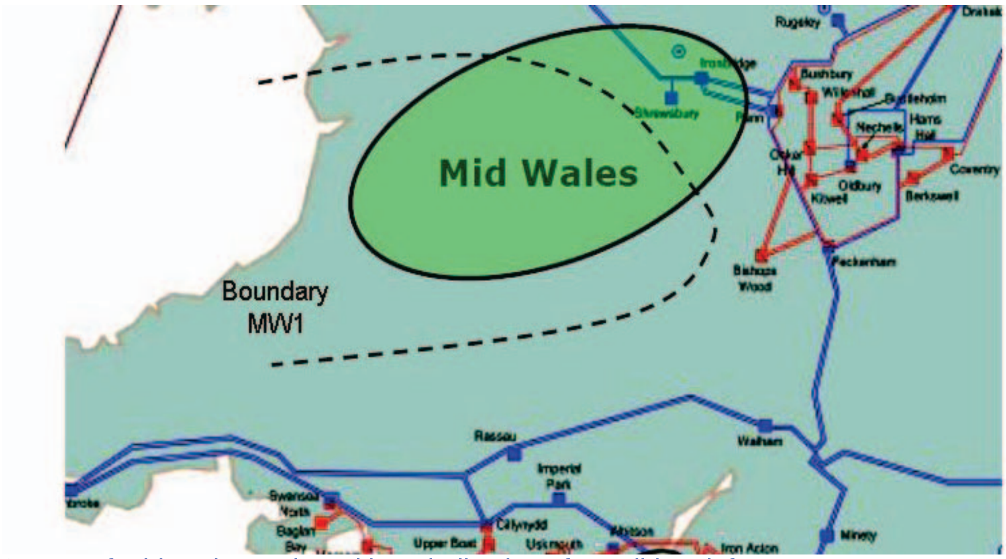


Figure 29: Map of Mid-Wales region with an indication of possible reinforcements

In order to provide a connection for the Mid-Wales projects the following options have been considered.

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[40] Connection of Onshore Wind Farms in Mid-Wales – Strategic Optioneering Report - http://www.nationalgrid.com/NR/rdonlyres/18E52B43-8AB5-4F0B-95F7-0BECCA0647BE/46002/MidWalesSORIssue1_110319.pdf

Ref.	Reinforcement	Scope	Additional Boundary Capability (GW) Boundary MW1	Earliest Completion Date
MW-R01	Mid-Wales Substation and supply point for SP Manweb	Construct a new 132kV substation at Mid-Wales Construct a new 400kV substation at Mid-Wales	-	2016
MW-R02	Construction of a new 400kV double circuit from Mid Wales to Legacy – Shrewsbury - Ironbridge circuits	Construct a new 400kV connection from Mid-Wales to a tee point on the Legacy – Ironbridge and Legacy - Ironbridge double circuits. Establish a new single switch 400kV mesh substation at Shrewsbury and reconfigure the existing tee transformer arrangement such that it connects into the mesh substation.	1.8	2016

Table 22: Lists of potential reinforcements in the Mid-Wales region

The dates for the completion of these works are aligned with the generators' expected connection dates and are subject to the consenting process required by the Planning Act 2008 (Appendix F).

4.5.5 Boundaries

Boundary MW1 is a local boundary which currently has no transmission infrastructure.

4.5.6 Cost

Construction of a new 400kV double circuit from Mid-Wales to Legacy – Shrewsbury - Ironbridge circuits is recommended as the preliminary preferred option in the 'Mid-Wales' Strategic Options Report'. The cost of this development is estimated to be around £200m.

4.6 South West

4.6.1 Existing Transmission system

This area of the NETS south of the Severn Estuary is characterised by large volumes of local generation, high demand levels and limited export capability. In addition to the existing conventional generation, there are plans to connect Round 3 Offshore Wind generation and additional nuclear generation in this area. The area is characterised by boundaries B13 and B13E which are illustrated in Figure 30.

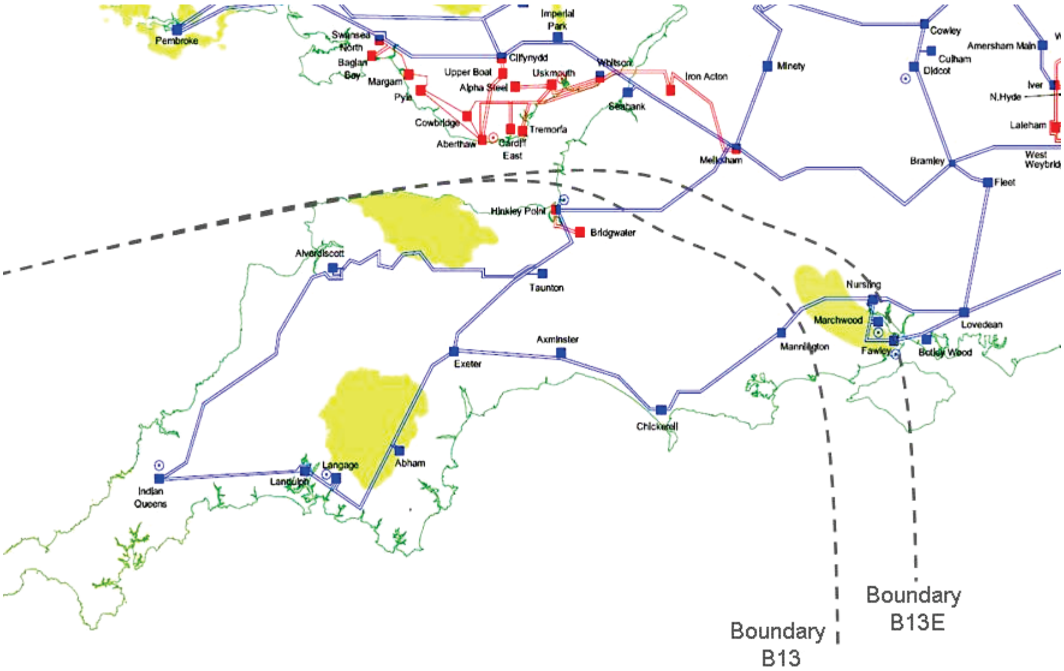

Figure 30: Existing South West transmission system with boundaries

4.6.2 Generation Background

Under the Gone Green 2011 scenario the possibility of a number of wind farms connecting in this region is high. This is consistent with the Crown Estates view as to the potential level of offshore wind generation in the Bristol Channel zone. Connecting these wind farms as and when they materialise will require system reinforcement within the South West.

The Gone Green 2011 generation background forecasts a significant amount of new nuclear and wind generation commissioning in the area over the next decade. Hinkley Point C has been identified as a potentially suitable site for a new nuclear power station in the Nuclear National Policy Statement. This position is further supported with a signed connection agreement with EDF Energy Nuclear Generation Ltd. A total of 2.8GW of generation is forecast to connect in the South West and, together with future possible interconnector links to continental Europe, could have a significant impact on the power flows within this area. There is about 2.2GW of generation comprising nuclear and gas currently connected to the South West region

Table 23 explains the generation breakdown under the 2009 and 2012 ENSG Reports in the South West.

Ref	Scenario	Capacity at end of 2020 (MW)								Total (MW)
		Thermal	Nuclear	Hydro	Pump Storage	Marine	Biomass	Offshore Wind	Onshore Wind	
2009 ENSG Report	GG2008	1045	1650	-	-	0	-	1500	-	4195
2012 ENSG Report	GG2011	1045	2931	-	-	75	-	1110	-	5161

Table 23: Generation background comparison between the 2009 and 2012 ENSG Reports in the South West

4.6.3 Demand

Traditionally, the existing generation in this area matches the local demand closely, resulting in low transfers. The limiting case for exports to the demand centres in the east occurs under summer minimum conditions. With increasing generation in the area, the power flows from this region are expected to increase and strain the existing system, especially during summer minimum conditions, with the area eventually becoming an exporting region in later years especially when Hinkley Point C nuclear is commissioned.

4.6.4 Potential reinforcement

Figure 31 highlights the area within this region where potential reinforcements would be required.

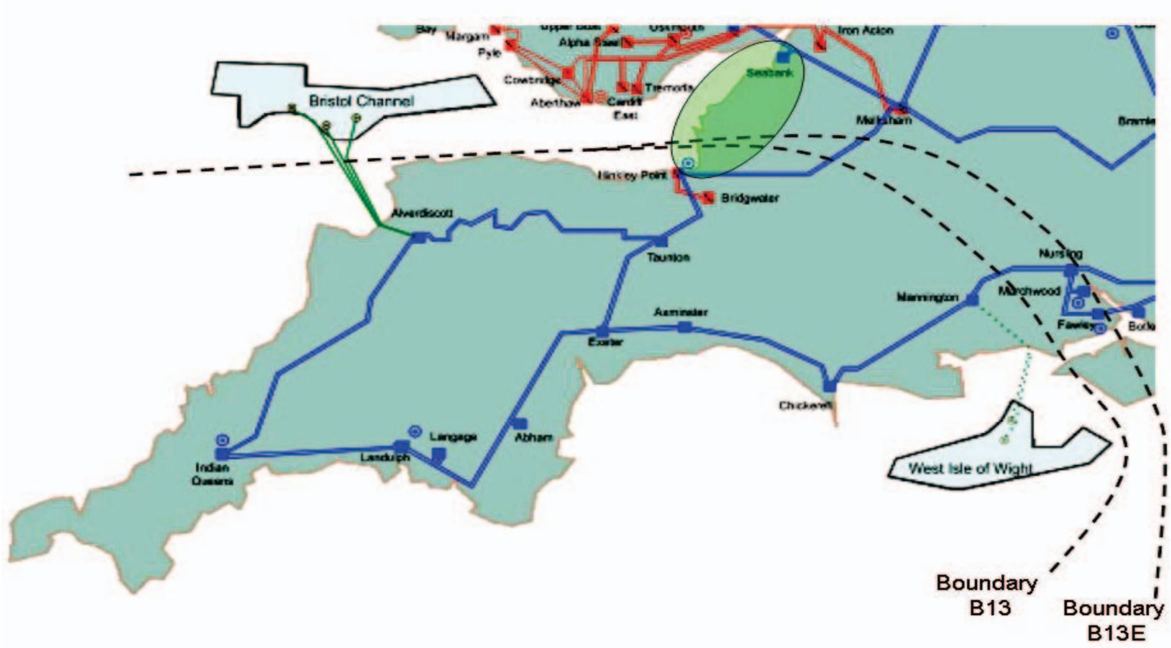

Figure 31: Map of South West transmission system with possible location of reinforcements

A number of reinforcement options have been considered to achieve compliance in this area. These options are described in more details in the strategic optioneering report[41]. Some of these options are summarised in Table 24. Note that only one of these options would be required to achieve compliance.

NGET announced, on 29th September 2011 following two years of extensive public consultation, its preferred route corridor for the Hinkley Point C connection. This route option mostly follows the existing 132kV distribution network which runs from Bridgwater to Seabank and will involve uprating this corridor to 400kV operation (corresponding to one of the route options under SW-R02). Technology options have not been decided at the time of writing. Further information can be found on the dedicated Hinkley Point C connection website[42].

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[41] For more detailed information including costs on the options please consult the strategic optioneering report: http://www.nationalgrid.com/uk/Electricity/MajorProjects/HinkleyConnection/Documents/

[42] http://www.nationalgrid.com/uk/electricity/MajorProjects/HinkleyConnection

Ref	Reinforcement	Works Description	Earliest Possible Completion Date
SW-R01	Hinkley Point- Bridgwater – Seabank 400kV AC Transmission Circuit	New 400kV substation at Hinkley Point New 400kV transmission line from Hinkley to Seabank, uprate section to Melksham Reconstruction of Bridgewater substation for 400kV operation Reconductoring of the Bramley - Melksham and the existing Hinkley - Seabank circuits and uprating the Cowley – Walham – Minety cable	2019
SW-R02	Hinkley Point-Other 400kV AC Transmission Circuit	Route options for reinforcement 1 - Hinkley Point-Whitson, Hinkley Point-Nursling, Hinkley Point-Melksham, Hinkley Point-Bridgwater-Seabank using distribution network route[33]	2019
SW-R03	HVAC subsea cable Hinkley Point-Seabank	400kV GIS Substation at Oldbury-on-Severn Mesh 400kV GIS Substation at Aust 400kV Substation at Hinkley Point Extend Seabank 400kV GIS Install 2 x 400kV Quadrature Boosters at Fawley Re-arrange line entries at Melksham 400kV Construct new Sections and re-conductor existing Overhead Line Connections to Oldbury-on-Severn Re-conductor the Melksham to Bramley Overhead Line Hotwire sections of Aust/Seabank - Oldbury on Severn - Melksham Double Cowley - Walham Cables 1600Mvar 400kV reactive compensation at Hinkley Point 400kV teed substation at Bridgwater 1600Mvar 400kV reactive compensation at Seabank Re-conductor Seabank - Aust Overhead Line Install AC cables between Hinkley Point and Seabank	2017
SW-R04	HVAC subsea cable Hinkley Point-Aberthaw	Route option for reinforcement 3	2017
SW-R05	HVDC cable Hinkley Point - Seabank	400kV GIS Substation at Oldbury-on-Severn Mesh 400kV GIS Substation at Aust 400kV Substation at Hinkley Point Extend Seabank 400kV GIS Install 2 x 400kV Quadrature Boosters at Fawley Re-arrange line entries at Melksham 400kV Construct new Sections and re-conductor existing Overhead Line Connections to Oldbury-on-Severn	2017

Ref	Reinforcement	Works Description	Earliest Possible Completion Date
		Re-conductor the Melksham to Bramley Overhead Line Hotwire sections of Aust/Seabank - Oldbury on Severn - Melksham Double Cowley - Walham Cables 4 x 1000MW DC converter stations at Hinkley Point 400kV teed substation at Bridgwater 4 x 1000MW DC converter stations at Seabank Re-conductor Seabank - Aust Overhead Line Install DC cables between Hinkley Point and Seabank	
SW-R06	HVDC cable Hinkley Point - Aberthaw	Route option for reinforcement 3	2017

Table 24: Potential reinforcement options in the South West

Studies were carried out to estimate the boundary capability increases due to these reinforcements as shown in Table 25. Note that where there are different route options, it is assumed that the capability increase would be the same for the different routes and therefore only one route has been included in Table 25.

Ref	Reinforcement	B13 capability increase			B13E capability increase		
		Voltage	Thermal	Stability	Voltage	Thermal	Stability
SW-R01	Hinkley – Seabank 400kV AC Transmission Circuit	+3GW	+3GW	+6GW	+2.4GW	+3GW	+6GW
SW-R03	HVAC subsea cable Hinkley Point-Seabank	+3GW	+3GW	+6GW	+2.4GW	+3GW	+6GW
SW-R05	HVDC cable Hinkley Point - Seabank	+4GW	+4GW	+4GW	+4GW	+4GW	+4GW

Table 25: Boundary capability increase provided by the potential reinforcement options in the South West

4.6.5 Boundary B13 (SW1) and B13E (SW1E)

Boundary B13 is a wider system boundary as the demand connected behind the boundary is more than 1.5GW. This boundary is defined as the southernmost tip of the UK below the Severn Estuary, around Hinkley Point and as far east as Mannington. It is characterised by the Hinkley Point to Melksham double circuit and the Mannington circuits to Nursling and Fawley. It is a region with a high level of localised generation as well as local zonal demand. As explained previously the boundary is currently an importing boundary with the demand being higher than the merit generation at peak conditions, with the limiting case for exports to the demand centres in the east occurring under summer minimum conditions. The boundary is expected to change to an overall exporting boundary by 2019. As a consequence of this change, it is prudent to re-draw the boundary to accommodate the adjacent generation at Marchwood. This creates boundary B13E. Studies carried out on this boundary effectively reflect the criticality of the boundary more appropriately.

Transient stability studies have shown that double circuit faults on either the Chickerell to Mannington or Hinkley Point to Melksham circuits would cause generator transient instability for the generators connected at Hinkley Point, Langage and Alverdiscott when the boundary transfer exceeds 1.8GW. The pre-reinforcement restriction is illustrated in Figure 32, showing the existing boundary capability as well as expected transfer as a local boundary based on exporting conditions. It should be noted that this representation has been used in this particular boundary to provide additional information for the reader as the required transfer vs. capability graphs do not fully show the extent to which the boundary is restricted by the transient stability limit. Under the Gone Green 2011 scenario the total exporting capacity exceeds the 1.8GW transient stability limit by 2019.

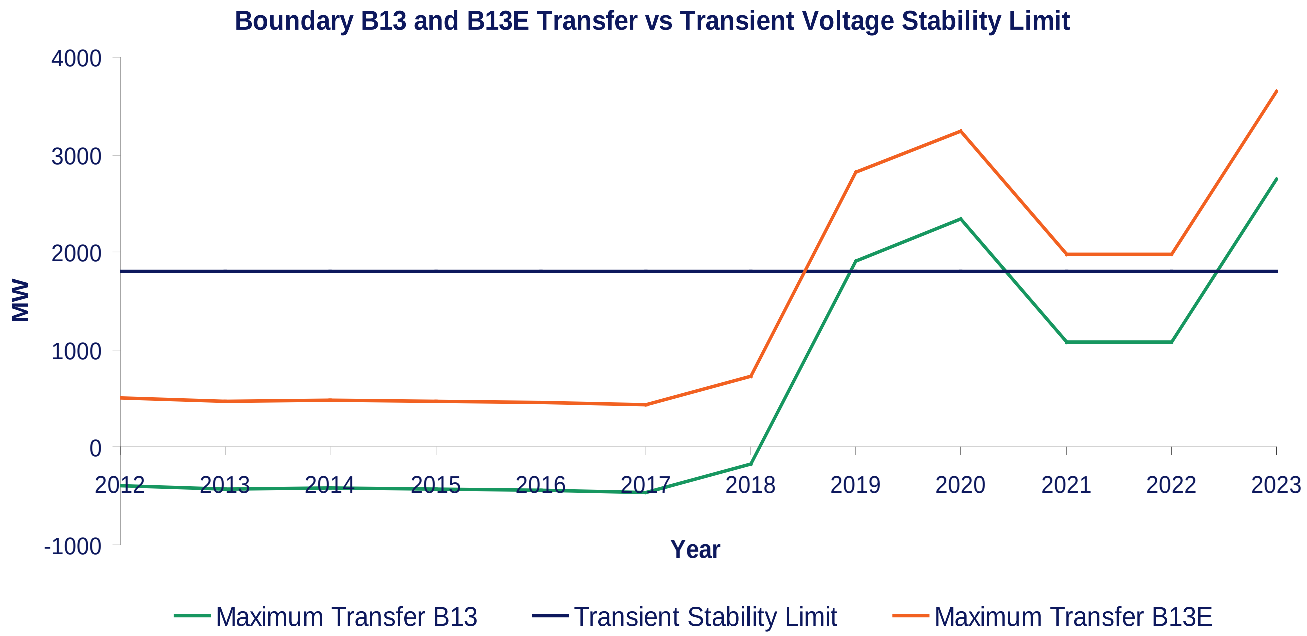


Figure 32: Boundary B13 and B13E transfers with the transient voltage stability limit

Figure 33 and Figure 34 show the required transfer across boundary B13 and B13E. The boundary capability reflects the benefits of reinforcement 1, Hinkley Point- Seabank 400kV transmission line, (see Table 24), for illustrative purposes. The boundary capability is restricted to 1.8GW in earlier years due to the transient stability limit. Once the Hinkley Point-Seabank reinforcement is applied, the stability limit of the boundaries reaches 7.8GW and their capabilities become restricted by voltage compliance limits of 5.4GW and 4.8GW for B13 and B13E respectively. Figure 34 also shows that there is a need case for the Hinkley Point to Seabank reinforcement for boundary B13E from a voltage compliance perspective.

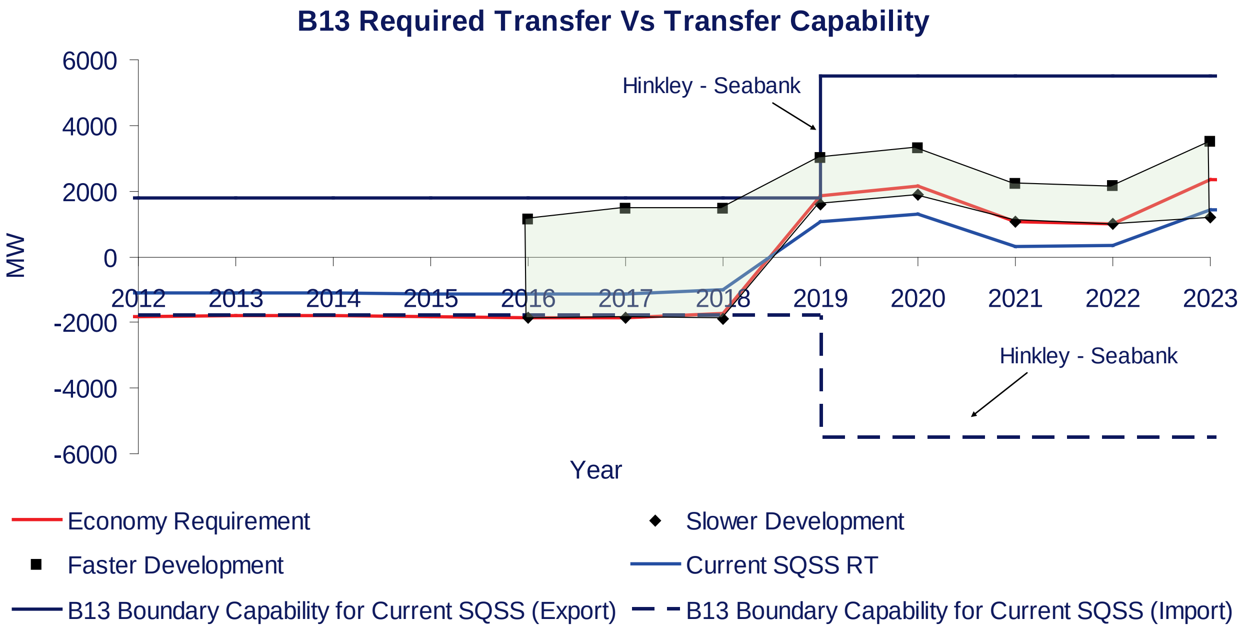


Figure 33: Boundary B13 transfer capability against the required transfers

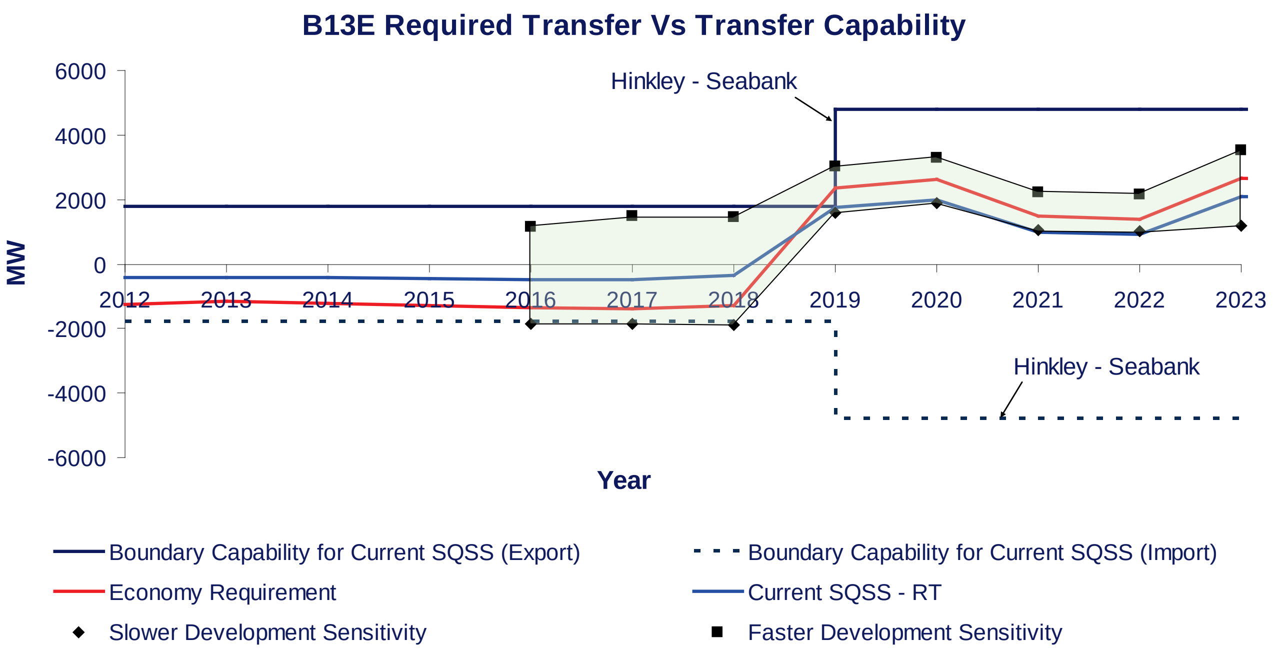


Figure 34: Boundary B13E transfer capability against the required transfers

4.6.6 Cost

The total estimated cost of the possible reinforcement considered for boundary B13 and B13E (SW-R01) is £450m.

4.7 English East Coast and East Anglia

4.7.1 Existing Transmission System

The English East Coast consists of a number of interconnected generation groups (Humber, Walpole area and the East Anglia Loop) connected to the main 400kV system via a strong 400kV spine which enables large power flows from North to South. The East Coast Network configuration and associated boundaries are shown in figure 35.

The Humber group consists of two 400kV lines running from Keadby towards Killingholme, with one line continuing towards Grimsby on the coast. There are also significant generation connections at West Burton and Keadby. The transmission system in the Walpole area is characterised by a double circuit ring that links Walpole, Norwich, Bramford, Pelham and Burwell Main substations. Pelham substation provides additional interconnection between the East Anglia region and other sections of the transmission system.

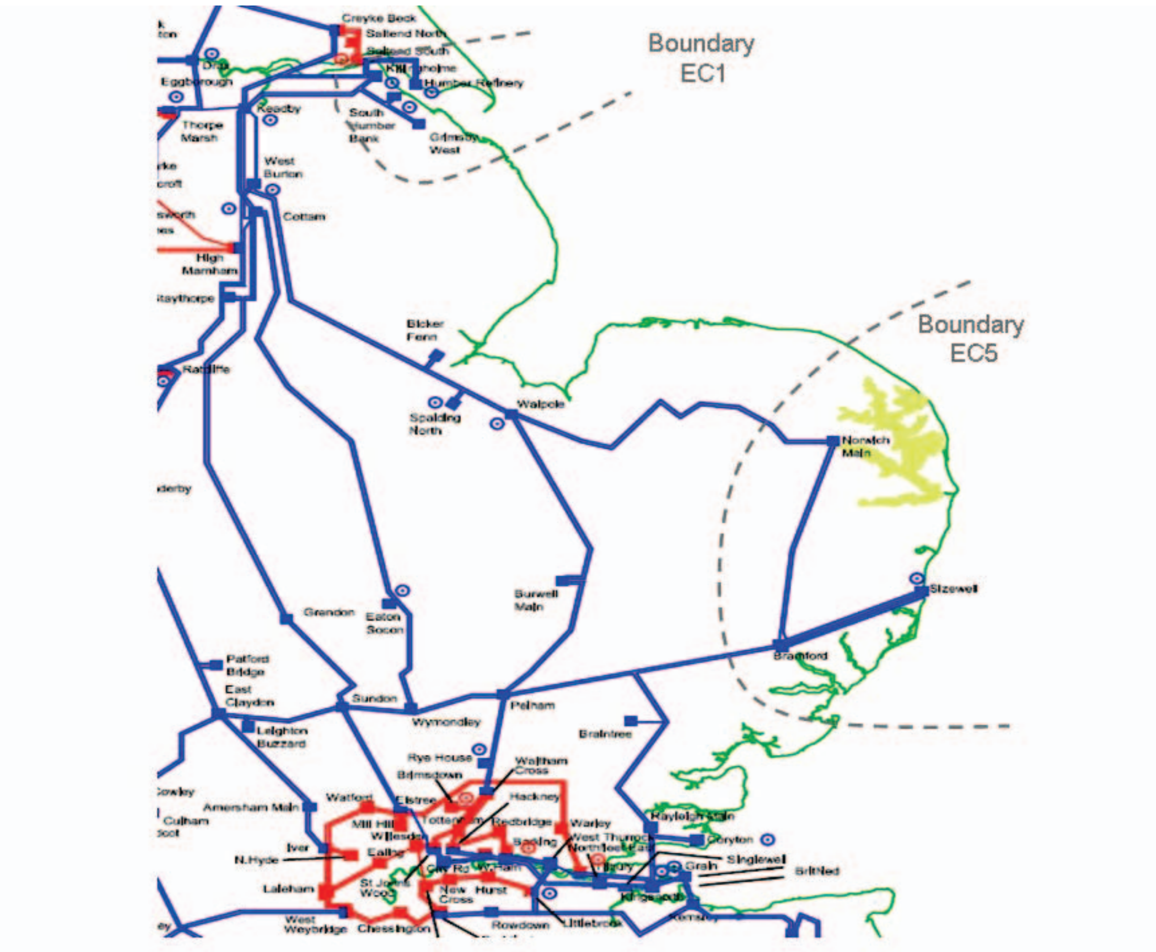


Figure 35: Existing English East Coast and East Anglia transmission system with boundaries

4.7.2 Generation Background

The volume of generation in the East Coast is expected to increase significantly over the study period. The East Coast has been extremely active in terms of proposed generation connections, with the three largest potential offshore wind developments (Dogger Bank, Hornsea and East Anglia, potentially amounting to around 25GW) all seeking to connect (at least in part) into this area. In addition, there are a number of other, smaller, offshore wind developments, proposed new gas-fired generation and potential nuclear power stations. Table 26 shows the generation breakdown under the Gone Green 2011 baseline scenario along with the changes since the 2009 ENSG Report.

Ref	Scenario	Capacity at end of 2020 (MW)								Total (MW)
		Thermal	Nuclear	Hydro	Pump Storage	Marine	Biomass	Offshore Wind	Onshore Wind	
2009 ENSG Report	**GG2008**	6033	1200	-	-	-	-	9365	-	16598
2012 ENSG Report	**GG2011**	4723	1207	-	-	-	290	5899	-	12119

Table 26: Generation background comparison between the 2009 and 2012 ENSG Reports in English East Coast and East Anglia area

The generation profile in this area is potentially very high and uncertain. The actual NETS connection dates of the offshore generation projects are subject to the needs of the developers, current NETS governance framework, planning process (Appendix F), supply chain, technology and financial considerations, all of which have been reflected in the connection dates provided to and agreed by the developers. Furthermore the actual development of the offshore and onshore transmission systems can, and may, differ from that illustrated by the future generation and demand scenarios and sensitivities.

4.7.3 Demand

The demand level within the East Coast and East Anglia as a whole is around 3.5GW, which is relatively low compared to the volume of generation. As a result this remains a heavily exporting region.

4.7.4 Co-ordinated Strategy Design Approach

The North Sea has some of the largest proposed offshore generation projects in the form of the Dogger Bank and Hornsea Crown Estate Round 3 lease zones. There is, potentially, a total capacity of around 25GW from The Crown Estate Round 1, 2 and 3 wind farm projects off the English East Coast. It is assumed that at the end of the study period Dogger Bank, Hornsea would connect 1GW each of wind generation under the Gone Green 2011 scenario. However, under the Faster Development scenario this generation capacity could go up to 4GW and 2.5GW respectively.

The East Anglia region encompasses several Round 1 and Round 2 offshore wind farms including Greater Gabbard and Gunfleet Sands. These are located around Norfolk, in the Thames Estuary and in The Wash. To the east of Norfolk and Suffolk lies the Round 3 Norfolk development area with a potential wind farm capacity of 7.2GW. It is assumed that 1.2GW and 4GW of wind generation could be connected from East Anglia round 3 windfarms under Gone Green 2011 and Faster Development scenario respectively.

A possible coordinated option for the offshore transmission connection has therefore been explored for the purposes of assessing the potential impact on the MITS. This option does not prejudge the outcome of the offshore transmission coordination project, nor represent any investment decisions and/or contracted arrangements or programme of the TOs, nor imply the actual connection routes. The example includes interconnection between generation clusters and would result in the offshore transmission network starting to become an integral part of the wider NETS by offering parallel circuit paths that provide additional connection security and through flow capability. By using the generation connections with through flow capability, this design would have the potential to assist in the management of the onshore power distribution and potentially reduce the requirements on the onshore system. HVDC technology chosen primarily due to the distance from shore has the additional benefit of greater controllability of the HVDC circuits which offers flexibility in power flow management.

The illustrative coordinated design shown in Figure 36 would interconnect the Round 3 projects of Dogger Bank and Hornsea. This would provide offshore transmission capacity connecting to substations along the East Coast and East Anglia. The internal interconnections within the offshore zones have been made with AC cabling and switching. To keep control of the offshore internal zone power flow, the offshore HVDC platforms and AC collectors would have to be joined into HVDC interconnected sections. If the HVDC technology advances to allow practical DC on-load switching, the design may be adapted to make most of the interconnection by HVDC saving on considerable AC cabling.

With the interconnection between the generation stations potentially providing additional security with alternate circuit paths, the full expected 2GW HVDC circuit capacity would be used in this option. To allow for a staged build and control of power between sections, the majority of the HVDC circuits in this example would use a three ended approach in which 2 offshore HVDC converters of 1GW would be used to send a total of 2GW back to shore. For this to work, all of the HVDC converters would need to work at a common voltage suitable for 2GW transmission.

To assist in the management of power transmission this design option would incorporate offshore interconnection with the Dogger Bank, Hornsea and Norfolk zone so North-South power flows could be potentially brought closer to the demand centres.

This option would also potentially allow for the further expansion offshore including wider interconnection with possibly Belgium, the Netherlands and/or Norway.

The potential benefits of this option are dependent upon assumptions on the timing and scale of generation coming forward.

4.7.5 Potential Reinforcement

A number possible reinforcement options have been identified for the East Coast & East Anglia region that could enable the transmission system to meet the required high power transfer levels. Figure 36 gives an indication of the possible reinforcements.

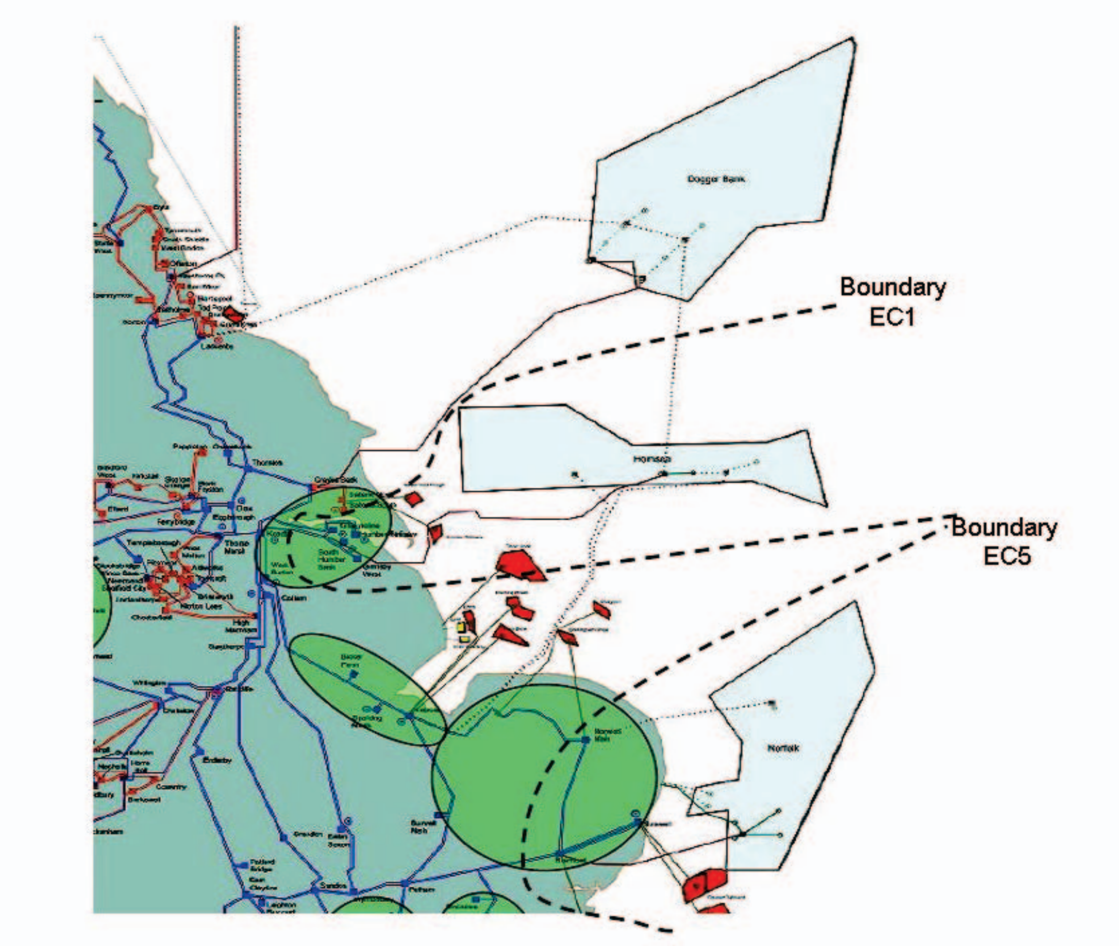


Figure 36: Map of the English East Coast and East Anglia transmission system with possible location of reinforcements

Table 27 lists the possible reinforcement options for the local boundaries within the English East Coast & East Anglia area. The table also includes a brief scope of work and the additional boundary capability provided by the reinforcements.

Ref.	Reinforcement	Works Description	Additional Boundary Capability (GW)		Possible Earliest Completion Date
			EC1	EC5	
EC-R01	Norwich - Sizewell turn-in at Bramford	Turn-in Norwich - Sizewell line into Bramford and reconductor the Norwich - Bramford double circuit.	-	+1.7	2015
EC - R02	Extend Bramford Substation	Extend Bramford 400kV substation to accommodate the turn-in of the Pelham - Sizewell circuit, two new bays for the 400kV route to Twinstead and associated protection and control changes.	-		2015
EC - R03	Bramford – Twinstead	New 400kV double circuit from Bramford to the Twinstead Tee Point creating Bramford-Pelham and Bramford-Braintree-Rayleigh Main double circuits. Installation of MSCs at Barking and St John's Wood	-	+2.5	2018
EC - R04	Braintree – Rayleigh	Reconductoring of the Braintree – Rayleigh circuits	-		2015
EC - R05	Rayleigh - Coryton – Tilbury	Reconductor the existing circuit which runs from Rayleigh Main – Coryton South – Tilbury substation	-	+0.2	2015
EC - R06	Killingholme South Substation and new Double Circuit to West Burton	Creation of a new 400kV substation at Killingholme South and construction of a new double circuit to West Burton.	+1.4	-	2018
EC - R07	Grimsby West - South Humber Bank	A new double circuit from Grimsby West - South Humber Bank.			2018
EC - R08	South Humber Bank – Killingholme	A new double circuit from South Humber Bank – Killingholme.			2018
EC - R09	Humber circuits reconductoring	Reconductoring of the Keadby – Killingholme, Keadby – Grimsby West and Killingholme – South Humber Bank circuits.	+1.5	-	2015
EC - R10	Walpole QBs	Installation of two Quadrature Boosters at Walpole in the Bramford – Norwich circuits.	-	+1.5	2015
EC - R11	Elstree - Waltham Cross – Warley - Tilbury	Uprate the existing 275kV circuit which runs from Elstree-Waltham Cross – Warley – Tilbury to 400 kV by reconductoring the double circuit and substation works. Install 2x Quadrature Boosters at Sundon in the Wymondley circuits.	-	+1.6	2019
EC - R12	Barking – Lakeside	Uprate the existing 275kV circuit which runs from Barking – West Thurrock – Littlebrook to 400 kV and at West Thurrock install 2 switchable series reactors to control power flows	-		2015
EC - R13	Kemsley - Littlebrook – Rowdown	Reconductor the existing double circuit which runs from Kemsley – Littlebrook -Rowdown	-		2015
EC - R14	Rayleigh Reactor	Install one 225 MVAr reactor at Rayleigh Main.	-		2014
EC - R15	Tilbury - Kingsnorth - Northfleet East	Reconductor the existing double circuit which runs from Tilbury – Kingsnorth – Northfleet East	-		2015

Table 27: List of potential reinforcements in the East Coast and East Anglia area[43]

[43] http://www.nationalgrid.com/NR/rdonlyres/F50A1521-D755-4116-A787-E623F77D196E/47714/BTReviewofStrategicOptionsReportJune2011.pdf

Table 28 shows the potential offshore HVDC links that could be required to connect Round 3 offshore windfarms projects of Dogger Bank, Hornsea and Norfolk to the main AC transmission system under a co-ordinated offshore strategy approach. These links could also provide an increase in boundary capability to the EC1 boundary.

<table>
<tr><th rowspan="2">Ref.</th><th rowspan="2">Reinforcement</th><th rowspan="2">Works Description</th><th>Additional Boundary Capability (GW)</th></tr>
<tr><th>EC1</th></tr>
<tr><td>EC-R16</td><td>Offshore HVDC Link between Offshore hubs</td><td>1GW HVDC link to Hornsea from Dogger Bank</td><td rowspan="3">±1.0</td></tr>
<tr><td>EC-R17</td><td>Offshore HVDC Link from Offshore hub to main AC transmission System</td><td>2GW HVDC link from Hornsea to Walpole substation</td></tr>
<tr><td>EC-R18</td><td>Offshore HVDC Link from Offshore hub to main AC transmission System</td><td>1GW HVDC link from Hornsea to Killingholme South substation</td></tr>
<tr><td>EC-R19</td><td>Offshore HVDC Link from Offshore hub to main AC transmission System</td><td>2GW HVDC link from Norfolk to Bramford substation</td><td>TBC</td></tr>
<tr><td>EC-R20</td><td>Offshore HVDC Link from Offshore hub to main AC transmission System</td><td>2GW HVDC link from Norfolk to Norwich Main</td><td>TBC</td></tr>
<tr><td>EC-R21</td><td>Offshore HVDC Link from Offshore hub to main AC transmission System</td><td>2GW HVDC link from Hornsea to Creyke Beck</td><td>TBC</td></tr>
</table>

Table 28: List potential offshore HVDC links under Co-ordinated Offshore Strategy Approach

4.7.6 Overview of the Boundaries

Boundaries EC1 and EC5 are local boundaries as the demand behind them is less than 1.5GW. Therefore the generation behind these boundaries is assumed to be at full capacity for these studies. The analysis looks at “generation accommodated” rather than “transfer requirements”. The generation accommodated for boundaries EC1 and EC2 would be the same for current NETS SQSS and Economy Requirement due to the nature of these boundaries. The boundary capability for these two local boundaries is studied against the Summer Minimum requirement which reflects the most onerous year round conditions (chapter 2 of the NETS SQSS). The Slower and Faster Development Sensitivities have also been plotted for all the boundaries. A possible set of reinforcements are considered in this study amongst the lists shown in the Table 27.

4.7.6.1 Boundary - EC1

Boundary EC1 is a local boundary consisting of four circuits that export power to the Keadby substation. The analysis covers "Generation Accommodated" rather than "Transfer Requirements". There are two circuits from Killingholme and two single circuits from Humber Refinery and Grimsby West. The current boundary transfer capability of EC1 is about 4.1GW.

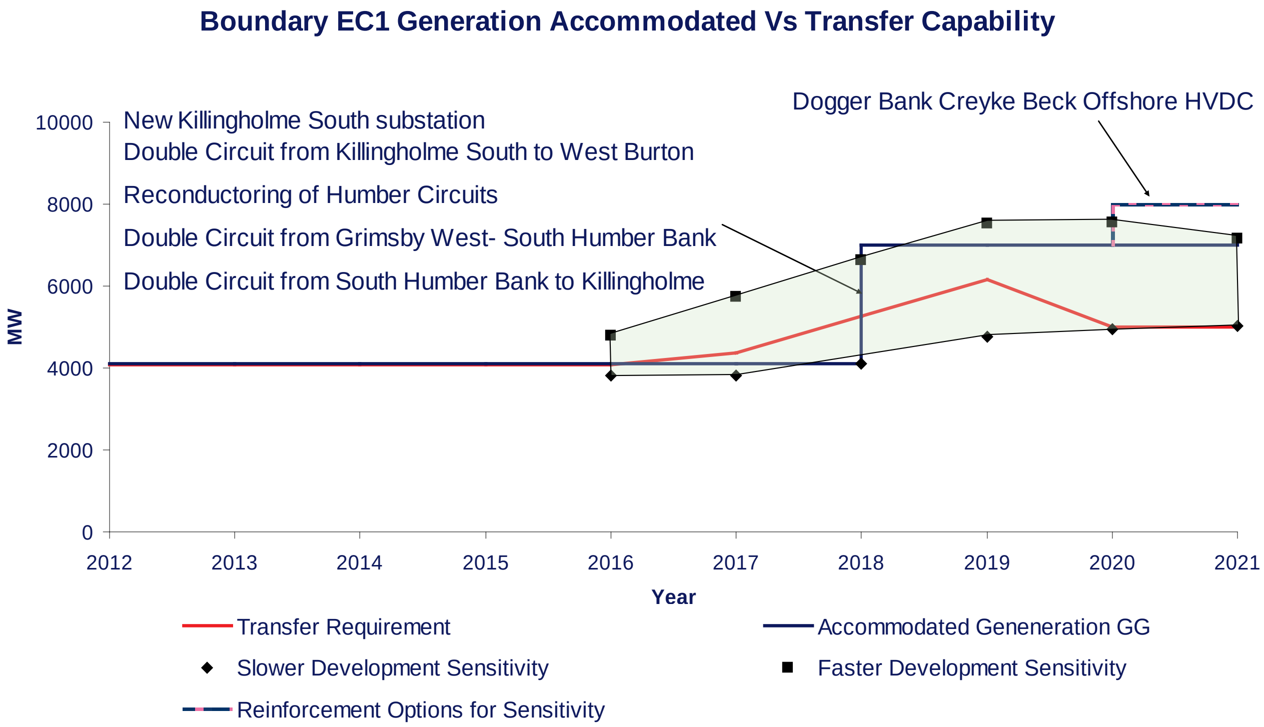


Figure 37: Generation accommodated and transfer capability of EC1 boundary under Gone Green 2011 Scenario

Up to 2016, the existing generation within the EC1 boundary under the Gone Green 2011 scenario can be accommodated without the need for any reinforcement. The generation level remains constant until 2017. Under a specified contingency, the Keadby-Killingholme circuit experiences a thermal overload which could be cleared by reinforcing the network with a new substation at Killingholme South and a new double circuit line between Killingholme South and West Burton. With the addition of the Round 2 windfarms, new double circuits from Grimsby West-South Humber Bank – Killingholme could be required to comply with the infeed loss risk criterion. Furthermore the reconductoring of the Humber circuits (the Keadby – Killingholme, Keadby – Grimsby West and Killingholme – South Humber Bank) could be required with the addition of 2.2GW of wind generation by 2020 under the Gone Green 2011 scenario. The boundary capability increase from this selected set of reinforcements is shown in Figure 37.

4.7.6.2 Boundary - EC5

Boundary EC5 is a local boundary and consists of the following four exporting circuits: a double circuit between Norwich – Walpole and single circuits from Bramford to Pelham and Bramford to Braintree. The existing capability of boundary EC5 is about 2.6GW.

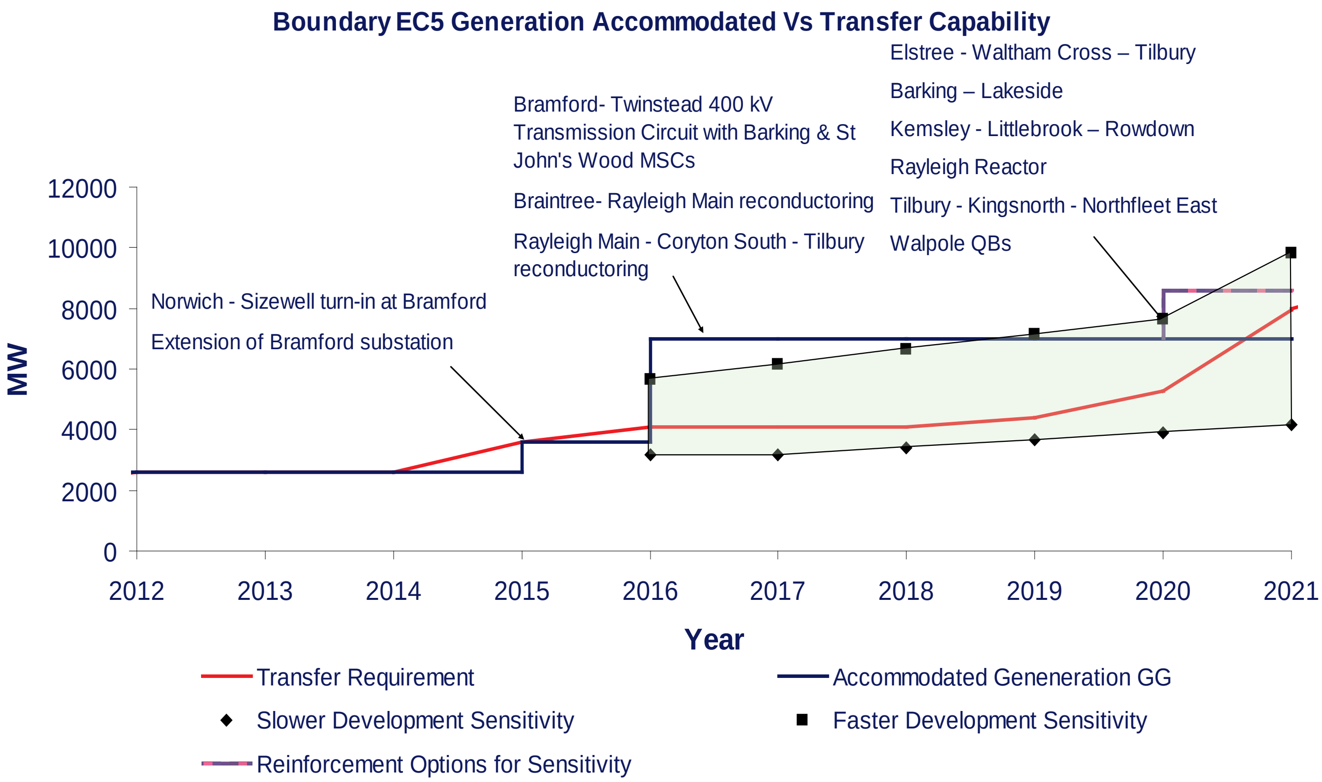


Figure 38: Accommodated generation and transfer capability of EC5 boundary under Gone Green 2011 Scenario

By 2015, additional generation is expected to trigger the need for reinforcements in this region. Reinforcements would be required due to the large power flows and the unequal sharing of the load between the Norwich-Bramford and Norwich- Sizewell circuits which causes thermal overload on various 400kV lines in this region. To clear these thermal overloads, a possible set of reinforcements which includes the reconductoring of the Walpole to Norwich circuits, Bramford – Norwich double circuit and the Norwich-Sizewell turn-in to Bramford could be required. The upgrade of the Bramford substation could be required to accommodate the Norwich- Sizewell turn-in. This reinforcement is also essential to implement the Bramford to Twinstead 400kV circuit which could be required in subsequent years.

From 2016, increasing wind generation from Norfolk and Greater Gabbard wind farms would require reinforcements to the network. The set of reinforcements shown in Figure 38 (Bramford-Twinstead 400 kV transmission circuit, the Barking –St John's Wood MSCs, reconductoring of the Braintree – Rayleigh Main and the Rayleigh Main- Coryton South – Tilbury circuits) would solve the issues associated with this increase in generation. With further generation increase within the EC5 boundary power flows towards the London area increase greatly. This causes voltage depression in the London and Thames Estuary region. A number of MSC's could be required to solve these voltage issues. Altogether these reinforcements would increase the overall capability of the EC5 boundary, accommodating up to 7GW of generation.

Post 2020, the generation required to be accommodated within EC5 boundary exceeds the boundary capability under the Faster Development sensitivity. Therefore a number of potential reinforcements could be required as shown in the Figure 38 to cover this sensitivity.

4.7.7 Changes in the Potential Reinforcement since the 2009 ENSG Report

The 2012 ENSG Report has considered a wide range of potential reinforcements in the English East Coast and East Anglia area. Table 29 shows the list of reinforcements that have been considered in this report in addition to the reinforcements considered in the 2009 ENSG Report.

Ref	Name of Additional Reinforcement
1	Braintree – Rayleigh
2	Rayleigh - Coryton – Tilbury
3	Killingholme South Substation and new Double Circuit to West Burton
4	Grimsby West - South Humber Bank
5	South Humber Bank – Killingholme
6	Humber circuits reconductoring
7	Elstree - Waltham Cross – Warley – Tilbury
8	Barking – Lakeside
9	Kemsley - Littlebrook – Rowdown
10	Rayleigh Reactors
11	Tilbury - Kingsnorth - Northfleet East
12	Coordinated Offshore solution

Table 29: List of potential reinforcements considered in the 2012 ENSG Report in addition to the 2009 ENSG Report

4.7.8 Cost

The cost of reinforcing this region ranges between an estimated £420m and £1.26bn for the slower development and faster development sensitivity scenarios respectively. The total cost of the possible set of reinforcements considered in the boundary EC1 and EC5 study for the Gone Green 2011 base scenario is estimated to be around £790m.

4.8 London, Thames Estuary and South Coast

4.8.1 Existing Transmission system

London is the largest demand centre in the UK and a large proportion of electricity generated nationally flows into the city from the adjacent regions. Apart from some small Combined Heat and Power projects, there is little generation in the London area itself, and regionally the only generation is focused in the lower Thames Estuary where there are large coal, oil and gas-fired stations. Generation support is provided by units further away, such as the nuclear power stations to the South of London. Demand can also be met through the existing interconnectors to France and the Netherlands. Consequently, the demand in London is predominantly met by transmission connections from long distance generation sources.

The area is particularly sensitive to changes from the French interconnector at Sellindge, especially when going from an importing state (i.e. power being brought into England and Wales) to an exporting state (i.e. power transfer to mainland Europe). Depending on the outage, when the interconnector is set to export, the London area is stressed due to much of the power required for the interconnector passing through London, in particular, North London.

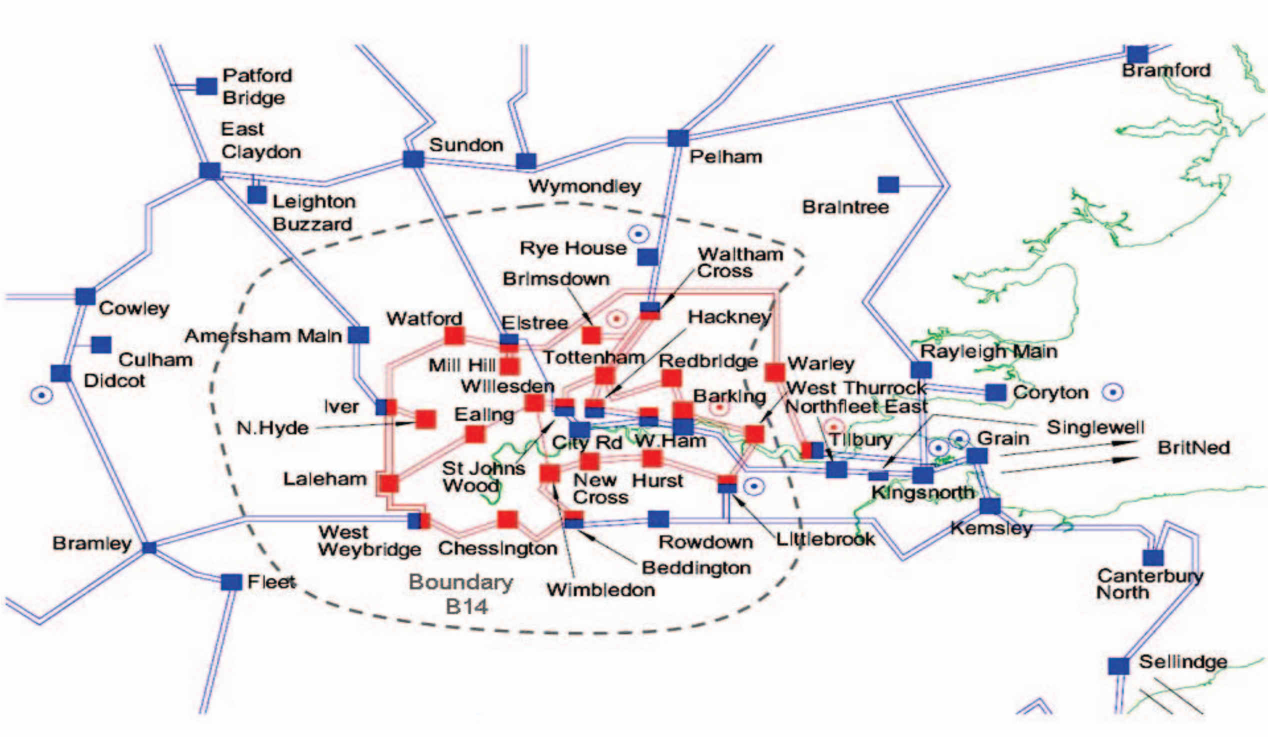


Figure 39: Electricity transmission system in London area with boundaries

4.8.2 Generation background

There are a number of proposed generation and interconnection projects which have signed connection offers and can have a significant impact on boundary B14 although most of them are not within the boundary. Table 30 shows the comparison between Gone Green scenarios used in the 2009 ENSG Report and the 2012 ENSG Report.

Ref	Scenario	Capacity at end of 2020 (MW)								Total (MW)
		Thermal	Nuclear	Hydro	Pump Storage	Marine	Biomass	Offshore Wind	Onshore Wind	
2009 ENSG Report	**GG2008**	11157	1650	-	-	-	-	1463	-	14270
2012 ENSG Report	**GG2011**	6848	1081	-	-	-	-	1464	-	9393

Table 30: Generation background comparison between the 2009 and 2012 ENSG Reports in the London, Thames Estuary and South Coast

4.8.3 Demand

London is a large demand centre, with high power flow import to feed this demand from a wide range of sources and locations. This presents technical challenges in planning the transmission network within this area. The need to plan a system that can securely meet this demand across an entire year of operation requires the consideration of a large number of variables to find the optimum balance for an economic and efficient transmission network.

4.8.4 Potential Reinforcement

Areas within London potentially requiring reinforcements are illustrated in Figure 40. A number of options have been identified in order for the London region to meet the anticipated increase in required power transfers.

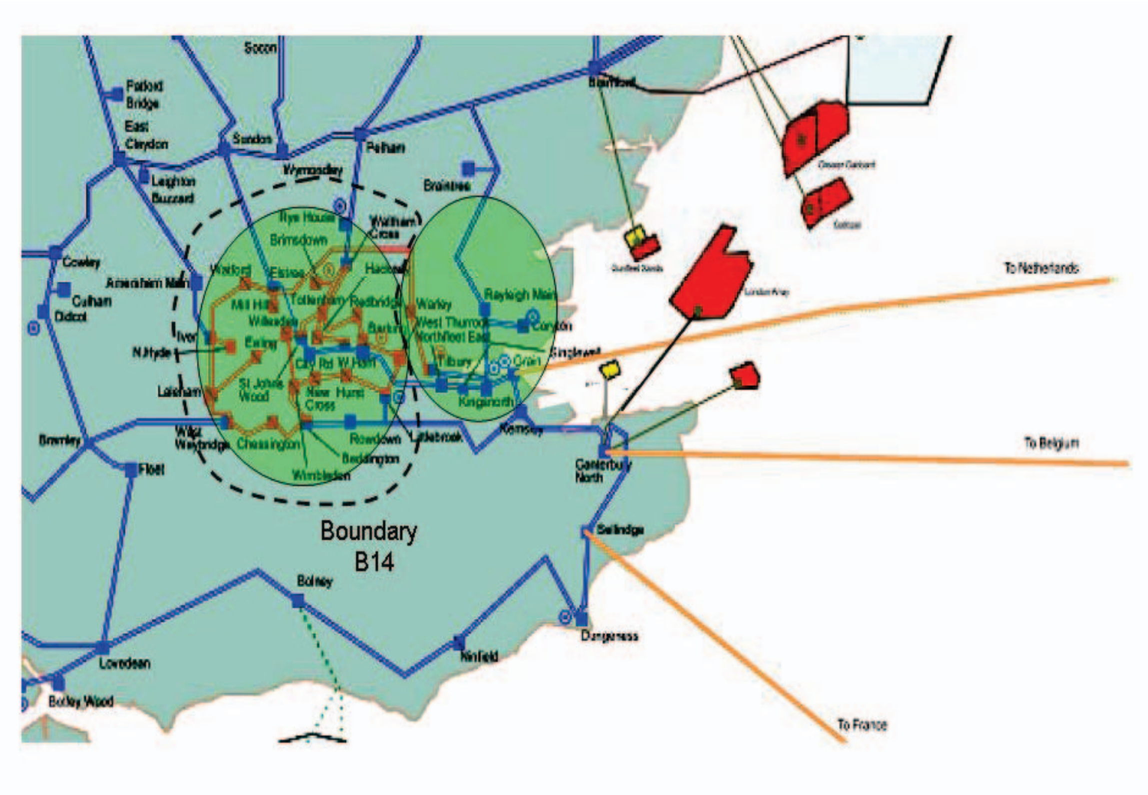


Figure 40: Map of London transmission system with possible location of reinforcements

Table 31 lists the potential reinforcement options and provides a brief scope of work. Note LN-R01 and LN-R02 have been split for a clearer understanding of the works involved but are considered as part of the same reinforcement.

Ref.	Reinforcement	Works Description	Capability Increase (GW)	Possible Earliest Completion Date
LN-R01	Hackney - Tottenham - Waltham Cross	Uprate and reconductor the Hackney - Brimsdown - Waltham Cross double circuit which bypasses Tottenham substation, including the construction of a new 400kV substation at Waltham Cross, and installation of two new 400/275KV interbus transformers at Brimsdown substation.	+0.8	2015
LN-R02	Pelham – Rye House	Reconductor the Pelham – Rye House circuits.		2015
LN-R03	St. John's Wood – Elstree – Sundon	Install 2nd St Johns Wood to Elstree 400kV AC cable Sundon-Elstree circuit reconductoring works Elstree substation extension and site re-configuration to accommodate the new assets e.g. pair of QBs at Elstree	+0.6	2018

Ref.	Reinforcement	Works Description	Capability Increase (GW)	Possible Earliest Completion Date
LN-R04	West Weybridge – Beddington – Chessington	Uprating the 275KV overhead line route connecting substations at West Weybridge, Chessington and Beddington to 400kV	+1.4	2018

Table 31: List of potential reinforcements for the London region.

Some of these reinforcements are currently the subject of public consultation, and the full set of need case, strategic optioneering and consultation reports can be found on the National Grid website[44].

4.8.5 Boundary Overview

Boundary B14 is characterised by high local demand and minimal generation in comparison. London's energy import relies heavily on a number of 400kV and 275kV circuits bringing power from the surrounding areas. Additional stress can be placed on the surrounding circuits if the European interconnectors in the Thames Estuary export to the continent causing increased power flows through London and across B14.

B15 is the Thames Estuary boundary, which has significant generation with both existing and future wind power connecting from the east, generated by Rounds 1 and 2 windfarms as well as a significant amount of nuclear generation. Generation changes across the south coast of England and within Boundary B15 have significant impact on Boundary B14 although B15 does not trigger any reinforcement in itself. Therefore only B14 is explored further in this report.

4.8.5.1 Boundary 14

Boundary 14 encompasses Central London and its surrounding areas, which have the highest zonal demand within the transmission network, with minimal generation compared to other boundaries.

Figure 41 shows the required transfer across boundary B14. As mentioned previously, boundary capability of B14 is dependent on the treatment of the interconnectors within Thames Estuary. A sensitivity study was carried out on the interconnectors' assumption as shown in the Figure 41. The existing capability of this boundary is between 8.3GW to 10.2GW assuming interconnectors are exporting or importing respectively. The boundary capability reflects a potential set of reinforcement options included to achieve compliance (LN-R01 and LN-R02) when the interconnectors are

[44] http://www.nationalgrid.com/uk/Electricity/MajorProjects/NorthLondonReinforcement/

importing. Applying this set of reinforcement does not however achieve compliance when the interconnectors are assumed to be exporting. In the latter case reinforcements LN-R03 and LN-R04 would also be required.

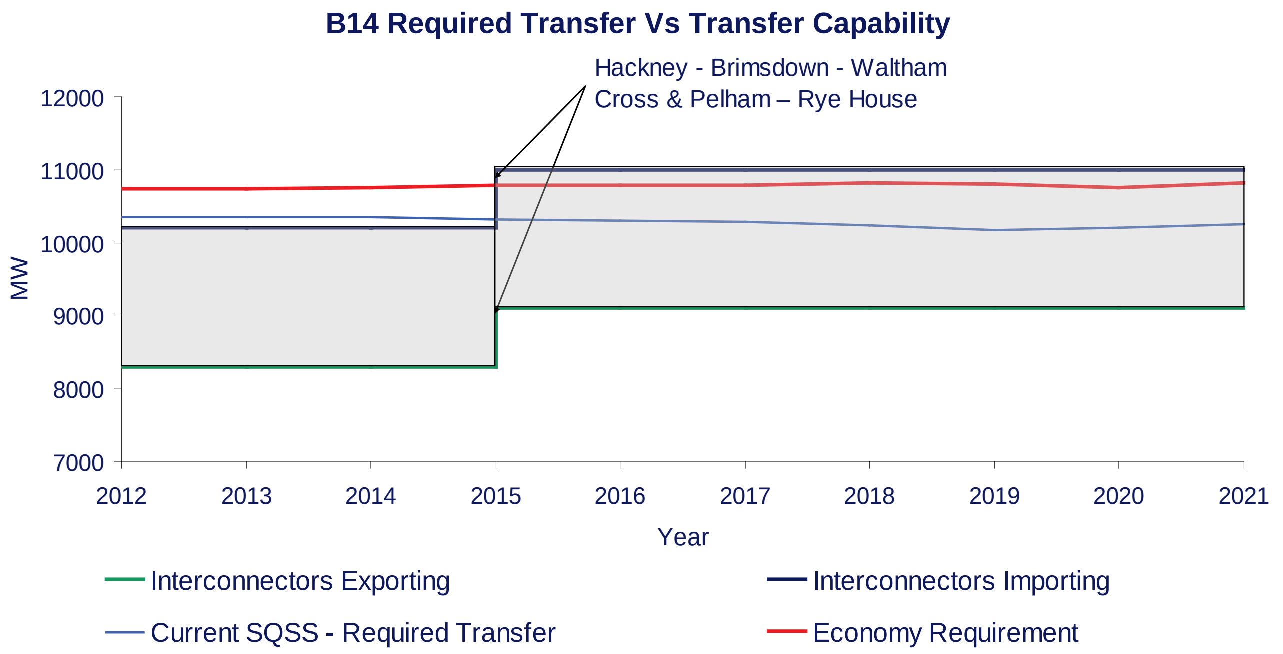


Figure 41: Boundary B14 transfer capability along with Required Transfers under current SQSS and Economy requirement

By 2015 there is a requirement for a new reinforcement to maintain compliance. High demand at Grendon, Eaton Socon and Burwell Main absorb a large amount of reactive power thereby suppressing the voltage in North London. In addition, with the Sellindge interconnector link exporting, the London transmission circuits' experience high thermal power flows therefore the boundary B14 capability drops around 2GW as show in Figure 41. The reinforcement Hackney – Brimsdown - Waltham Cross would support to restore this drop in capability.

4.8.6 Potential Works Associated With Interconnector Sensitivity

In addition to the boundary reinforcements identified, the following non-boundary works could be required to accommodate possible interconnector projects impacting on this region.

At present, NGET has a signed agreement for the connection of a 1GW HVDC interconnector to Belgium of Voltage Source Converter (VSC) design (NEMO), with a connection date of 31 October 2019. The contracted connection point is on the Kent coast.

The commissioning of NEMO coupled with the existing interconnectors to Europe could potentially swing flows from 5GW import to 5GW export depending upon market conditions and generation/demand balance in the UK and mainland Europe. The variations in the power flow would be considered before investment decisions are made.

A number of MSC and SVC could also be required across the South Coast to sustain the export conditions on the interconnector links in the South which otherwise, when combined with the expected closure of Dungeness B in 2018, would lead to post-fault voltage collapse in the local South East area. Should Dungeness B generation remain open, the additional compensation could be required to avoid transient instability of local generation.

In addition to the reactive compensation support, reconductoring of some circuits could be required to address South Coast link export conditions or counter-flowing interconnector conditions, so that the four circuit South East loop between Kemsley and Lovedean remains resilient to local single circuit and two circuit outage conditions at peak or year-round.

4.8.7 Changes in the Potential Reinforcement since ENSG 2009

There is no significant change from the reinforcements considered in the 2009 ENSG Report. However, as previously mentioned, the 2012 ENSG Report considers potential alternative reinforcements which are presented in Table 32.

Ref	Name of Reinforcement
1	St. John's Wood – Elstree – Sundon
2	West Weybridge – Chessington – Beddington uprate from 275kV to 400kV

Table 32: List of significant change in reinforcements since ENSG 2009

4.8.8 Cost

The total estimated cost of the possible reinforcement options (LN-R01&LN-R02) considered for boundary B14 is £200m under interconnector importing conditions and could rise up to £415m under exporting conditions.

5 Innovative Transmission Technology

The 2009 ENSG Report contained a chapter covering innovative transmission technology that described a number of transmission technologies that had either not previously been used in the UK or were new developments which had only recently emerged onto the commercial market. The main options that were considered in that report were Series Compensation, HVDC Links, Energy Storage and developments in land and submarine high voltage cables. Since the report was initially published there have been a number of developments in electricity transmission technology.

5.1 Series Compensation

Series compensation can be used to increase the power transfer capacity of long AC transmission lines by reducing the inductive reactance of a line at power frequency. Capacitors are placed in series with the transmission line reducing the total inductive reactance and making the electrical distance between two ends of a line appear to be electrically shorter. This improves both angular and voltage stability and allows power transfer at levels well in excess of the natural loading of the line.

The main benefit offered by series compensation is the ability to increase the power transfer capability of the network without having to construct new overhead line routes. Upgrading an existing line with series compensation also results in significant cost savings when compared with the construction of a new line. Series compensation can also be used to give greater control over the system such as ensuring balanced power flows to reduce losses.

Although not previously used in the UK, series compensation is a mature technology and has been used extensively throughout the world since the 1950s. However, there are a number of reasons why its use would still represent a major step change in system design in the UK. Series compensation is predominantly used to interconnect separate regions within large countries by compensating very long transmission corridors or to connect remotely located generation such as hydro electric power stations. It has rarely been used as an integral part of a compact and highly meshed network such as the NETS. Reasons for this include the extensive system modelling required to ensure consistent performance under different system conditions and the potential for series compensation to introduce sub-synchronous resonance into the network.

5.2 HVDC Transmission Technologies

There are now three Current Source Converter (CSC) HVDC Links in service on the NETS: Scotland-Northern Ireland, England-French and most recently BritNed. CSC technology has been in use worldwide since the 1950s and is well understood by UK Transmission and Distribution companies.

CSC HVDC is well suited to transmission of large quantities of power over large distances. An installation rated at 6400MW at a voltage of +/- 800kV using overhead lines is in operation today and a 7.2GW installation is planned for commissioning in 2013. However, CSC HVDC systems are much larger and heavier than Voltage Source Converter (VSC) HVDC systems and therefore will be much more difficult to implement in an offshore location.

Fortunately, the worldwide use of VSC HVDC Links has continued to increase steadily since its introduction in 1997. VSC technology is distinguished from the more conventional CSC technology by the use of self commutated semiconductor devices, such as Insulated Gate Bipolar Transistors (IGBT) that have the ability to be turned on and off by a gate signal and endow VSC HVDC systems with a number of advantages for power system applications.

Most of the VSC HVDC systems installed to date use the two or three level converter principle with pulse width modulation (PWM) switching. More recently, a multi-level HVDC converter principle has been introduced by most major manufacturers and it is likely that all future VSC installations will be of a multi-level or hybrid configuration.

There is currently, approximately fifteen operational VSC HVDC Links in service, around the globe, with several more in the planning or construction phase. The most prominent is the connection of offshore wind from the Veja Mate and Global Tech 1 Wind Farms to the mainland German Transmission System. This connection will have a transmission capacity of 800MW at a DC voltage of +/- 300kV and is due to begin operation in 2013. Also of great significance is the two, 1GW, +/- 320kV, 65km HVDC Links connecting Baixas, France and Santa Llogaia, Spain due circa 2013. Both of these projects represent a significant step forward in the use of this type of technology and indicate the potential further advancements that could be made in the near future.

The largest VSC HVDC Link currently in service is rated at 400MW. This is part of the Borwin 1 project that connects the Borkum 2 Wind Farm to the mainland German Transmission System by means of a 125km HVDC circuit comprising submarine and land cables. The connection has a transmission capacity of 400MW at a DC voltage of +/- 150kV and was commissioned in 2010. The Borwin 1 project is the first application of HVDC technology to an offshore wind farm connection.

For the projects being considered to enhance the NETS, links rated at 2GW are required by circa 2015. Manufacturers are confident that these products can be delivered in the required timescales although there have been no projects of this scale delivered previously and we are not aware of any having been ordered. Although VSC technology is a new development, and hence long term operational and reliability information is not available, there is no evidence to suggest that the technology will be any less reliable than conventional HVDC transmission technology.

In addition, considering the projects that are soon to be delivered and the timeframes under discussion for the NETS, through targeted development techniques, focused engineering and standardisation, TOs are hopeful that all innovative transmission technology requirements for the NETS can be fulfilled.

5.3 Cable Technology

When considering HVDC Transmission, the actual cable used to transmit the DC power can represent a significant percentage or in some cases the largest part of the total project cost. It is therefore vital to understand all of the implications related to the cables before any HVDC project can be sanctioned.

There are two predominant types of cable technology currently available; mass impregnated oil insulated cable and extruded polymer insulated cable.

Mass impregnated (MI) cables use oil impregnated paper as an insulator and have been in use for several decades with proven performance and reliability records. Mass impregnated cables can be used for both land and submarine applications and can be used with all types of HVDC converters.

Extruded polymer insulated DC cables are a more recent development that are used with voltage source converters only. Extruded cables are unsuitable for use with current source converters, since they would become polarised during the process of reversing the polarity of the DC voltage. VSC HVDC can reverse power direction by changing the direction of the current only.

Extruded cables offer a number of advantages over mass impregnated cables. The different insulation medium allows for a more compact and lighter design which has a significantly smaller bending radius. This allows greater lengths of cable to be loaded onto drums or laying ships meaning longer sections can be laid before jointing is required. Extruded cables also offer environmental benefits, due to the fact that oil is not used as an insulating medium there is no risk of leakage and pollution. Also, as the cables are more compact they can be easily buried underground with minimum visual impact.

The main drawback associated with extruded insulation DC cables is that they are currently only available at ratings which meet the capability of voltage source converters. Hence for a single bipole cable configuration, the maximum rating offered by manufacturers is 1GW, +/- 320kV.

5.4 Gas Insulated Transmission Lines (GIL)

Gas Insulated Transmission Lines (GIL) have been derived from the well established technology of Gas Insulated Switchgear, which was first installed on the NETS Transmission System back in the 1970s. Development work led to a second generation of gas insulated line technology being available in the 1990s, which achieved cost savings through the use of site-welded enclosure joints and rationalised, modular components.

Today, GIL consists of a high voltage conductor supported within an earthed conducting enclosure, insulated by a mixture of SF_6 and N_2 gas. Its applications include above ground, trench and tunnel installations and it has already been installed on a small scale at various locations around the world.

National Grid is currently involved in researching and developing GIL technology and a number of perceived advantages have been identified. For instance, GIL can often match overhead line ratings, with negligible induced currents and voltages and negligible external electromagnetic fields. In addition, in the event of a GIL internal fault, no external effects are likely to occur and GIL materials pose no additional fire risks and can be easily recycled at their end of life.

In comparison, GIL is not likely to be a cost effective option for small rating requirements; the SF_6 insulating gas mixture has a very high global warming potential and could also pose a safety risk to personnel within confined spaces, hence leakages must be avoided. Furthermore, GIL tunnel installations may be difficult to route when radii of curvature of less than 400m exists and a continuous high level commitment from manufacturers is required to provide technical support and effective repair strategies.

5.5 Innovative Transmission Technology Summary

The ability to enhance the network through maximising the use of existing assets and by building new infrastructure that is less intrusive than conventional design options means that technologies such as Series Compensation and VSC HVDC Links are well suited to playing a key role in the major redevelopment of the NETS.

The technologies described offer many advantages in terms of technical performance, construction requirements, cost and environmental impacts. However, there are areas in which extensive further work will be needed to ensure their suitability for use.

When considering the use of new technologies or technology that has not previously been used on the NETS it is important to ensure that all issues associated with these systems (technical, commercial and environmental) are fully understood prior to commitment to construct. Discussions have already taken place with manufacturers to assess what technologies could be used in future network developments and what designs represent feasible options considering the required timescales. By developing close working relationships with manufacturers it is possible to identify all potential applications for new technologies and hence ensure that maximum benefit can be gained from their use.

In many cases using new technologies appears to offer significant benefits over traditional design options. However, when comparing a new or unused technology with existing design options it will be necessary to quantify any benefits or drawbacks accurately to ensure that the optimum design is selected. This process will need to take into account factors including: capital cost of equipment; consents risks; construction costs and timescales; performance benefits for the transmission system; losses; supply chain issues; maintenance requirements; reliability and environmental impact. This can be achieved through working closely with manufacturers and other TOs with experience of the technology.

Finally, there is a need to look towards “smarter” ways of operating the transmission network to face the increasing challenge of integrating large amounts of variable renewable generation and the advent of varying demand profiles. This could comprise a number of techniques such as the use of dynamic ratings to enhance the thermal rating of lines; the use of automated and co-ordinated systems such as Quadrature Booster (QB) control; and co-ordinated HVDC control systems which work in parallel with the existing HVAC networks.

To that end, it is important to develop a number of wide area monitoring techniques and robust communication networks to ensure that data exchange can be achieved reliably, efficiently and accurately. It is also essential that any control systems are supported and developed in conjunction with the necessary protection systems to ensure operation on the system remains safe and secure.

6 Conclusions

As with the 2009 ENSG Report the predominant power flow on the NETS will continue to be from North towards the South.

In the North of Scotland, generation is assumed to significantly increase with onshore and offshore wind and marine renewable all contributing. The level of demand is not anticipated to increase significantly over the next decade. Accordingly, there is a predominant net export of energy from the region to the Central Belt of Scotland. Additional power flows in the Central Belt of Scotland, within the SPT network, would place a severe strain on the 275 kV elements of the network and, in particular, the north to south and east to west power corridors.

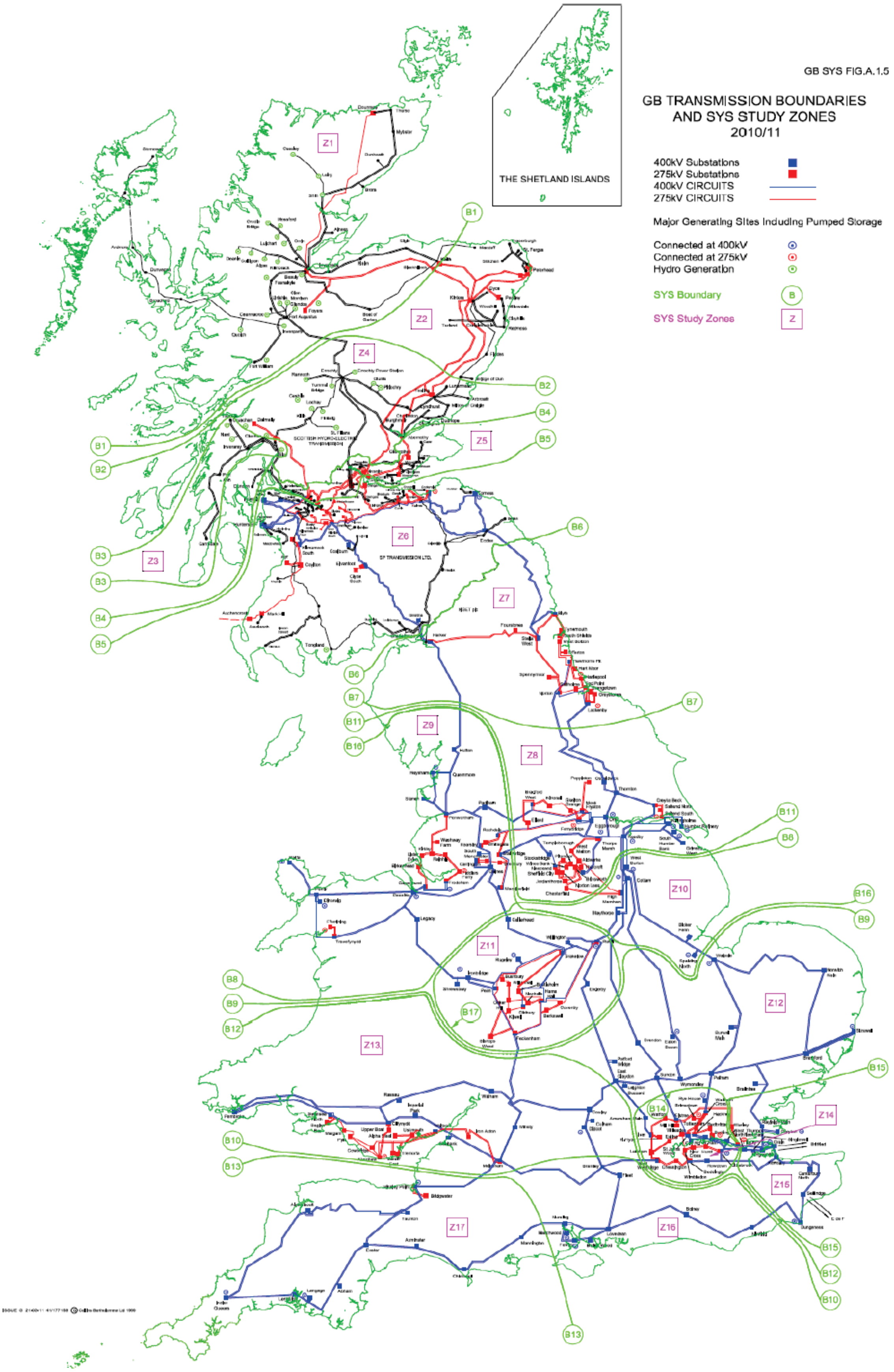
The circuits between Scotland and England are already operating at their maximum capability. Under all the generation scenarios considered, the transfers from Scotland to England increase significantly. Reinforcements identified to relieve the boundary restrictions across these circuits result in power transfers on the Upper North network of the England and Wales transmission system exceeding network capability. South of the Upper North boundary the increased power flows south from Scotland and North West of England progressively diminish as they are offset by the closure and displacement of existing conventional generation along the way. Accordingly, while there are transmission overloads in northern England the effects are greatly muted as the flows travel towards the Midlands.

Offshore wind generation connecting in England and Wales, together with the potential connection of new nuclear power stations raises a number of regional connection issues; particularly in North Wales, South West England and along the English East Coast between the Humber and East Anglia. The anticipated increased power transfers across the North to Midlands boundary and/or the increased generation off the English East Coast and/or Thames Estuary would also result in severe overloading of the northern transmission circuits securing London.

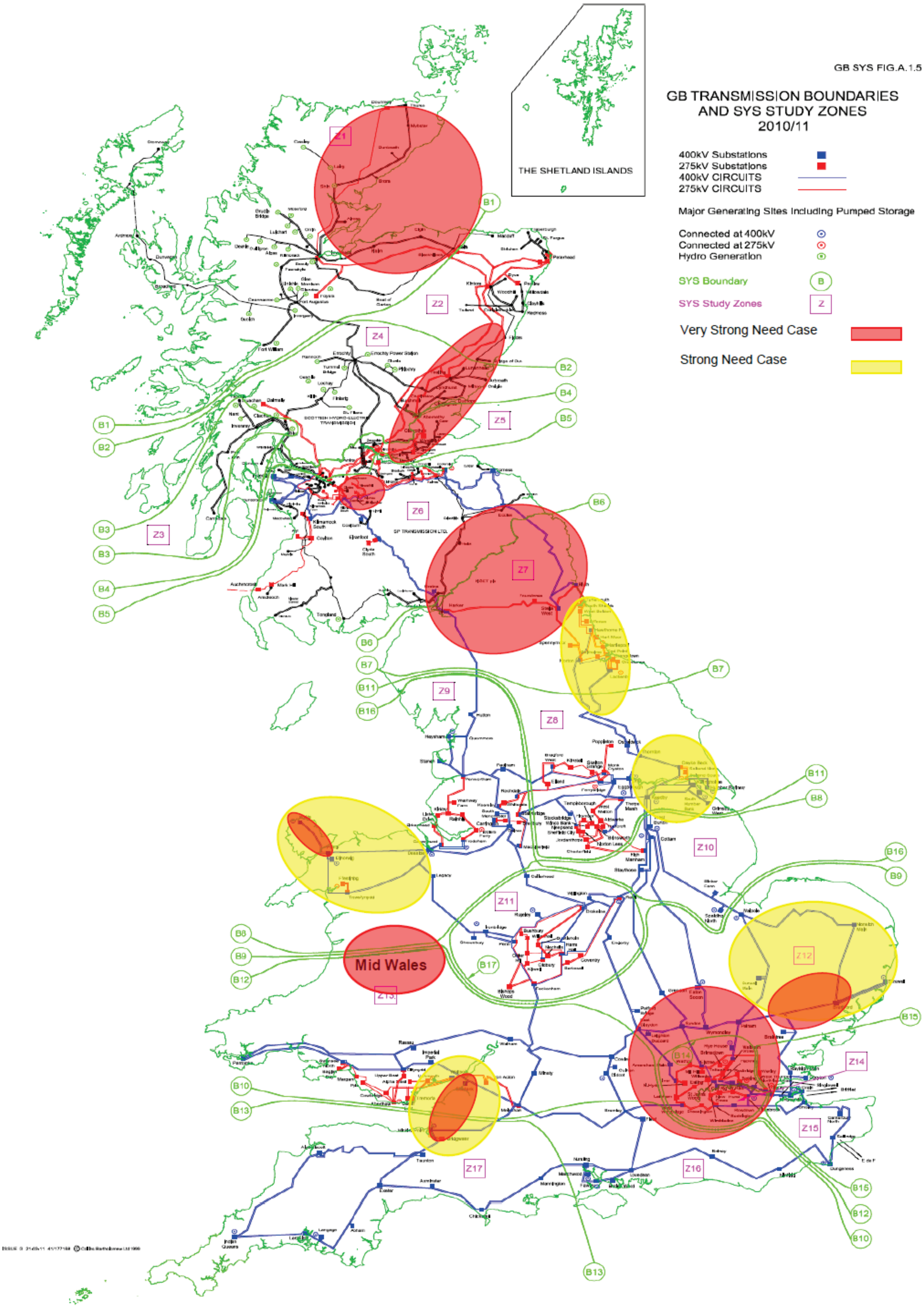
Meeting the network requirements for accommodating new generation under the Gone Green 2011 scenario would require significant investment in the NETS. This report sets out where and how this might be achieved and the factors that influence the need, timing and delivery of this. It shows that the network can respond to the challenges and play a full role in meeting the 2020 renewable energy targets. It is for the TOs to bring forward proposals to Ofgem and the relevant Planning Authorities allowing sufficient time to deliver any projects to accommodate new generation.

The ENSG will maintain an overview of activities and developments that have the potential to impact on the realisation of the high level 'vision' set out in this report including the monitoring of network delivery. It will continue to advise on whether they provide a complete and coherent delivery and development path against the targets.

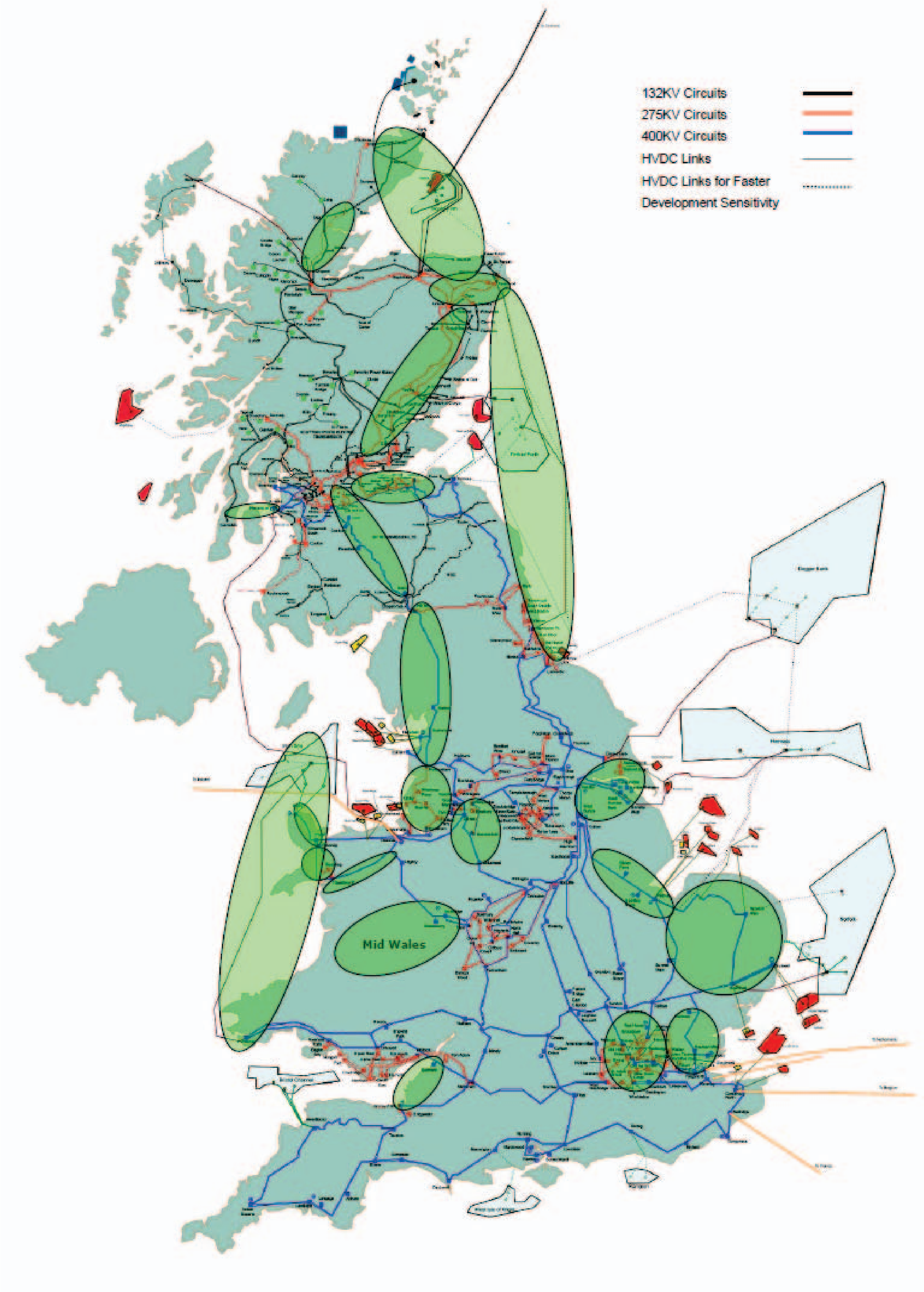
7 Appendix A – Existing NETS



8 Appendix B – NETS Showing Regional Need Case



9 Appendix C – NETS Showing Potential Reinforcements



10 Appendix D– Financial Summary[45]

Region	Additional Generation or Transfer/Cost	Slower Development Sensitivity	Base Gone Green 2011	Faster Development Sensitivity
Scotland	Addition Generation Accommodated[46]	6.6GW	10.2GW	14.5GW
	Cost	£2.14bn	£2.5bn	£4.3bn
Scotland-England	Additional Generation Accommodated	-	1.1GW	-
	Cost	£2.9bn	£3.56bn	£4.1bn
North to Midlands and Midlands to South	Additional Generation Accommodated	-	3.7GW	-
	Cost	-	-	-
North Wales	Additional Generation Accommodated	2.8GW	3.8GW	4.8GW
	Cost	£420m	£1.12bn	£1.12bn
Mid-Wales	Additional Generation Accommodated	-	0.36GW	-
	Cost	-	£200m	-
South West	Additional Generation Accommodated	5.6GW	6.0GW	7.6GW
	Cost	£450m	£450m	£450m
English East Coast and East Anglia	Additional Generation Accommodated	9.4GW	10.8GW	18.1GW
	Cost	£420m	£790m	£1.26bn
London, Thames Estuary and South Coast	Additional Generation Accommodated	-	3.3GW	-
	Cost	-	£200m	-

[45] Costs in 2010 price base aligned with TOs RIIO-T1 submissions and the additional generation shown is for 2020

[46] Additional generation accommodated compared to 2010/11 generation background.

11 Appendix E– Summary of Significant Changes since the 2009 ENSG Report

		2009 ENSG Report	2012 ENSG Report	Comments
Generation (GW)	Coal	19.8	14.5	Increase in assumed nuclear generation due to potential 10-year extensions of existing plants. This results in lower coal generation. Decrease in wind generation due to differences in calculating. The exclusion of energy used in the aviation sector from the overall target calculation reduces renewable capacity required to meet 15% target. This reduction has been applied to wind generation capacity required as it is the main source of renewable energy in the Gone Green 2011 scenario. Further details in Chapter 2.
	Gas	41	41.7	
	Nuclear	6.9	12.3	
	Wind	32.3	28.3	
	Other Renewable	8.2	7.2	
	Other	3.8	3.4	
	Total	112	107.4	
Offshore Wind	Coordinated Offshore Strategy	Not included	Illustrated offshore network designs included for Scotland, East Coast of England and North Wales	The 2012 ENSG Report uses illustrative offshore network designs where relevant and does not represent any investment decisions and/or contractual arrangements or programme of the Transmission Owners, Offshore Transmission Owners or Third Parties nor imply the actual connection routes for new electricity transmission infrastructure. DECC/Ofgem led offshore transmission coordination project is considering different offshore grid configurations under different generation scenarios and potential measures to enable different grid configurations should the analysis support such development.
Potential Reinforcements	Scotland	Potential connections for Scottish Islands	Estimated costs added Additional potential options added for Caithness Moray Shetland reinforcement	Costs for potential connections from Orkney Islands, Western Isles and Shetland Islands to the mainland have been included. A potential Caithness Moray Shetland reinforcement would possibly connect offshore wind as well as the Shetland and Orkney Islands and addressing potential onshore network constraints. In addition illustrative design for interconnection between offshore wind farms at Dogger Bank and Hornsea presented which could potentially provide additional security to onshore network. See “Offshore Wind” section in this table. Further details in Chapter 4
	Scotland-England	Series compensation at the Norton – Spennymoor 400Kv double circuit	Not included	Further details in Chapter 4.
		Potential reinforcements to accommodate increased power flows from Scotland to England	Additional potential reinforcements added: NGET - SPT East Coast HVDC Link	
			Penwortham QBs Mersey Ring uprate	

		2009 ENSG Report	2012 ENSG Report	Comments
	North Wales	Potential reinforcements to accommodate possible nuclear and offshore wind generation	Additional potential reinforcement options added: Wylfa-Pembroke HVDC link New 400 kV, Pentir – Wylfa single circuit Pentir – Deeside Reconductoring Pentir – Trawsfynydd Reconductor	In addition an illustrative design for interconnection between offshore wind platforms in the Irish Sea and the onshore transmission network have been added which could potentially provide additional security to the onshore and offshore network. See “Offshore Wind” section in this table. Further details in Chapter 4.
		Hinkley – Seabank reinforcement to accommodate possible new generation	Alternative reinforcement options for Hinkley - Seabank	Further details in Chapter 4
		Potential Reinforcements to accommodate offshore wind and nuclear generation	Alternative onshore reinforcement options added: Braintree – Rayleigh Rayleigh - Coryton – Tilbury Killingholme South Substation and new Double Circuit to West Burton Grimsby West - South Humber Bank South Humber Bank – Killingholme Humber circuits reconductoring	In addition illustrative design for interconnection between offshore wind farms at Dogger Bank and Hornsea (and separately for Norfolk wind farm) which could potentially provide additional security to onshore network through connections along the English East Coast and East Anglia. See “Offshore Wind” section in this table. Further details in Chapter 4
		Potential reinforcement to accommodate possible changes in generation location, interconnection and demand	Potential reinforcement options added: Reconductor the Pelham – Rye House circuits. St. John’s Wood – Elstree – Sundon reinforcement	Further details in Chapter 4
Interconnectors	Moyle(Northern Ireland-England)	Yes	Yes	Further details of interconnectors are in Chapter 2 (Section 2.1.3.1)
	IFA(France-England)			
	East-West Interconnector (Ireland-Wales)			
	Britned (Netherlands-England)			

<table>
<tr><th colspan="2"></th><th>2009 ENSG Report</th><th>2012 ENSG Report</th><th>Comments</th></tr>
<tr><td rowspan="3"></td><td>East-West Cable 1 (Pentir)</td><td>Yes</td><td>No</td><td rowspan="3"></td></tr>
<tr><td>NEMO (Belgium-England)</td><td rowspan="2">No</td><td rowspan="2">Yes</td></tr>
<tr><td>Norwegian (Norway-England)</td></tr>
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12 Appendix F - Planning Permissions in England, Wales and Scotland

The Planning Act 2008 established a new decision-making body, the Infrastructure Planning Commission (IPC) and a new consenting process for nationally significant infrastructure projects (NSIPs) in England and Wales.

The Government intends to abolish the Infrastructure Planning Commission (IPC) and replace it with a Major Infrastructure Planning Unit (MIPU) in the Planning Inspectorate. Provisions to abolish the IPC are in the Localism Act which received Royal assent on 15 November 2011. Under the Act the MIPU will examine the applications for development consent and will then make a recommendation to the relevant Secretary of State on whether to grant consent. The Secretary of State for Energy and Climate Change will make decisions on major energy infrastructure projects.

The new requirements apply to major energy generation, energy infrastructure in the form of overhead lines and pipelines over certain thresholds, as well as railways, ports, major roads, airports and water and waste infrastructure. National policy will be set out by Ministers in a series of National Policy Statements (NPSs). The suite of energy NPSs (including NPSs for pipelines and electricity network infrastructure) were approved by Parliament and subsequently designated by the Secretary of State for Energy and Climate Change in July 2011. The Act also sets out requirements on developers to undertake pre-application consultation with affected parties, affected local authorities and local communities prior to submitting an application to the IPC.

In Scotland, applications to construct and operate power stations of a certain capacity (greater than 50MW) are made to Scottish Ministers under section 36 of the Electricity Act 1989. Applications for transmission lines are made under section 37 of the Electricity Act 1989. Consent under section 36 and section 37 of the Electricity Act 1989 usually carries with it deemed planning permissions from the Scottish Ministers under section 57(2) of the Town and Country Planning (Scotland) Act 1997. Landowner consents are generally sought by means of a voluntary agreement; however, where this can not be achieved necessary way leaves can be sought under schedule 4 of the Electricity Act 1989.

TOs are committed through their planning procedures to meeting their responsibilities under both the Electricity Act and relevant planning and environmental legislation. Key to this is the need to engage with stakeholders and local communities in the development of infrastructure proposals, demonstrating how such views have been taken into consideration.

13 Appendix G– ENSG Terms of Reference 2011 & Membership

The Electricity Networks Strategy Group (ENSG) provides a high level forum bringing together key stakeholders in electricity networks that work together to support Government in meeting the long-term energy challenges of delivering a thriving, globally competitive, low carbon energy economy.

Specifically the ENSG will:

- Develop and promote a high level 'vision' of how the UK electricity networks could play a full role in effectively and efficiently facilitating the increase in renewable and other low-carbon generation necessary to meet the EU 2020 renewables target and longer-term energy and climate change goals.

- Develop an understanding of the implications of policy for our electricity networks, identifying potential technical, commercial and regulatory barriers to meeting the UK renewables target and provide strategic advice on possible solutions.

- Maintain an overview of activities and developments that have potential to impact on the realisation of the high level 'vision' including the monitoring of network delivery. Advise on whether they provide a complete and coherent delivery and development path against the targets.

- Disseminate the results of its activities to the wider community of relevant stakeholders.

- Review its terms of reference, including the need for its continued operation, not more than 2 years from February 2011.

ENSG Membership

DECC	Jonathan Brearley Director, Energy Markets and Networks (Joint Chair)
Ofgem	Hannah Nixon Acting Senior Partner, Smarter Grids and Governance: Transmission (Joint Chair)
National Grid Electricity Transmission	Nick Winser Executive Director
Scottish Power Transmission	Jim Sutherland Asset Strategy Director
Scottish Hydro-Electric Transmission	Ian Funnell Director of Transmission
CE-Electric UK	Phil Jones President & CEO
Central Power Networks	John Crackett Managing Director
UK Power Networks	Barry Hatton Director Asset Management
Transmission Capital Partners	Chris Veal Managing Director
Energy Networks Association	David Smith Chief Executive
RWE Npower	David Mannering Director of Economic Regulation
Centrica	Sarwjit Sambhi Managing Director of Power Generation
EDF	Rob Rome Head of Transmission and Trading Arrangements
Vattenfall	Jason Ormiston Head of UK Regulatory and Public Affairs
Renewable Energy Systems	Patrick Smart UK Grid Connections Manager
Renewable-UK	Guy Nicholson Head of Grid
The Crown Estate	Chuan Zhang Programme Manager (Technology)
Scottish Government	Colin Imrie Head of the Energy Markets Division
Welsh Assembly	Ron Loveland Energy Advisor to the Welsh Government
DECC	Sandy Sheard Deputy Director, Future Electricity Networks Tom Luff Head of Onshore Electricity Networks

14 Appendix H– ENSG Working Group Terms of Reference (Extract) and Membership

At the meeting on 14 February 2011, the ENSG agreed that a working group should be established to support the ENSG by scoping and delivering a work plan covering the three areas set out below. As ENSG develops its vision for the electricity network for 2020 and beyond, additional working groups may be assigned further tasks.

The ENSG Working Group's key task is to scope and deliver a work plan covering the following:

i. An update of the ENSG 2020 vision report incorporating network responses to changes to generation scenarios, technologies, policy developments, etc.

ii. Assessment and monitoring of network delivery to 2020 in a standardised format to enable ENSG and external stakeholders to see progress made on, and any challenges to, successful delivery.

iii. Post-2020 generation and demand scenarios impacting on pre-2020 investment needs and post-2020 investment and other network solutions.

The Working Group should take into account and build upon related work, in particular that of the Offshore Transmission Coordination Group (which is gathering evidence and considering the future arrangements for developing the offshore grid), the Smart Grid Forum looking at long-term distribution network issues such as demand and distributed generation and the development of RIIO TO Business Plans which are due for completion by end July 2011.

The Working Group should maintain awareness of and take into account other related ongoing activities that have the potential to affect the conclusions and outputs of the Group.

The following have participated in the work of the Group relating to the ENSG 2020 Vision Updated Report

Tom Luff, Chair, DECC
Paul Hawker, DECC
Kristina Dahlstrom, DECC
Simon Cran-McGreehin, Ofgem
Andrew Hiorns, National Grid
Colin Bayfield, Scottish Power
Mike Barlow, SHETL
Bless Kuri, SHETL

Fiona Navesey, Centrica

Louise Schmitz, EDF

Stefan Leedham, EDF

Jeff Douglas, Central Networks

Mark Drye, CE-Electric UK

Mike Lee, Transmission Capital Partners

Sean Kelly, Transmission Capital Partners

Guy Nicholson, Renewable-UK

Alex Murley, Renewable-UK

Alan Claxton, Energy Networks Association

Chuan Zhang, The Crown Estate

Mike McElhinney, Scottish Government

15 Appendix I - Progress on investments identified in the 2009 ENSG Report

Ref	Region	Reinforcement	Position as at January 2012
1	SHETL	Knocknagael	Commissioning
2		Beauly-Dounreay 2nd Conductor and Substation	Construction
3		Beauly – Blackhillock – Kintore Reconductor	Construction
4		400 kV East Coast Re-Insulation	Public consultation
6		Caithness – Moray Link (AC onshore or subsea HVDC)	Public consultation
7		East Coast HVDC Link (Peterhead – Hawthorne Pit)	Optioneering
8		Kintyre – Hunterston Subsea Link	Public consultation
9		Western Isles HVDC Subsea Link	Public consultation
10		Shetland HVDC Subsea Link	Public consultation
11		Orkney AC Subsea Link	Public Consultation
12	SPT	East Coast Upgrade to 400 kV Double Circuit Operation	Optioneering
13		East-West 400 kV Upgrades	Pre-Construction Engineering / Public Consultation
14	Scotland – England Interface	Series Compensation of SPT-NGET Interconnection (SPT section)	Pre-Construction Engineering / Public Consultation
15		West Coast Sub-sea HVDC Link	Construction
16		East Coast Sub-sea HVDC Link	Optioneering
17		Harker – Hutton-Quernmore Reconductor	Construction
18	North Wales	Reconductor Trawsfynydd - Deeside,	Optioneering
19		Series Compensation 120 MVAr installation	
20		Second circuit Pentir- Trawsfynydd	
21		New Line Wylfa- Pentir. 400 kV 35km 3x700 sq. mm.	
22	Mid- Wales	Connection option for Mid-Wales generation	Public Consultation
23	South West	Hinkley Point – Seabank new 400kV transmission route	Public Consultation

Ref	Region	Reinforcement	Position as at January 2012
24	East Coast of England – Humber Region	New 400 kV substation and HVDC converter compound location	Optioneering
25		VSC – HVDC converters in Humber area	
26		VSC – HVDC converters in Walpole area	
27		HVDC cable route (~130 route km)	
28	East Coast of England – East Anglia	Reconductor Walpole – Norwich Bramford Route	Optioneering
29		Walpole substation rebuild	Optioneering
30		Bramford substation rebuild	Optioneering
31		New 400 kV OHL between Bramford and Twinstead tee point	Public Consultation
32		Quadrature Boosters between Walpole and Pelham	Optioneering
33	London	Reconductor Pelham - Waltham Cross	Optioneering
34		Uprate Waltham Cross - Brimsdown - Hackney	Optioneering

16 Glossary

ACS Peak GB Demand

The estimated unrestricted winter peak demand (MW and MVAr) on the National Electricity Transmission System for the Average Cold Spell (ACS) condition. This includes both transmission and distribution losses and represents the demand to be met by Large Power Stations (directly connected or embedded), Medium and Small Power Stations, which are directly connected to the National Electricity Transmission System, and by electricity imported into the National Electricity Transmission System from External Systems across External Interconnections.

AGR

An advanced gas-cooled reactor (AGR) is a type of nuclear reactor. These are the second generation of gas-cooled reactors in Great Britain, using graphite as the neutron moderator and carbon dioxide as coolant.

Average Cold Spell (ACS) Conditions

A particular combination of weather elements which give rise to a level of peak demand within a financial year (1 April to 31 March) which has a 50 per cent chance of being exceeded as a result of weather variation alone.

Boundary Capability

This is the maximum power, which can be transferred across a boundary without causing unacceptable conditions following specified outages as defined in the Licence Standard.

Busbar

This is the common connection point of two or more Transmission Circuits.

Capex

Capital Expenditure.

CCGT

Combined Cycle Gas Turbine . A collection of Generating Units (registered as a CCGT Module under the Grid Code) comprising one or more Gas Turbine Units (or other gas based engine units) and one or more Steam Units where, in normal operation, the waste heat from the Gas Turbines is passed to the water/steam system of the associated Steam Unit or Steam Units and where the component units within the CCGT Module are directly connected by steam or hot gas lines which enable those units to contribute to the efficiency of the combined cycle operation of the CCGT Module.

Deterministic Assessment

An assessment based on fixed set of rules.

Distribution Network

The 132kV and below electricity network in England and Wales and below 132kV electricity network in Scotland and Offshore.

Dynamic Ratings

Overhead line conductors get heated up when current is flowing through them. But, it can get cooled if wind is blowing at higher speed. Therefore at higher wind speed, more current flows through the conductor, which gets cooled off quickly due to the same high wind speed. So, the rating of the overhead line conductor could be increased during the wind blows at higher speed. Dynamic current rating is to utilise this concept and changing the conductor rating dynamically according to the wind speed.

Economy Criteria

The Economy Criterion requires sufficient transmission system capacity to accommodate all types of generation in order to meet varying levels of demand efficiently. The proposed approach involves a set of deterministic parameters which have been derived from a Cost Benefit Analysis (CBA) seeking to identify an appropriate balance between the constraint costs with the costs of transmission reinforcements.

Embedded

Embedded Generation is also referred to as Distributed Generation. Embedded Generation is usually a small generator connected to the distribution system without having any access to the transmission network. These generators are generally located near to the demand.

Fault

Electrical fault on a circuit or piece of transmission equipment for which the circuit/equipment switches out automatically. An N-2 fault indicates loss of 2 single circuits or a double circuit on the NETS.

GEMA

Gas and Electricity Markets Authority also known as “The Authority” is the statutory body which governs Ofgem. GEMA’s principal objective is to protect the interests of existing and future consumers in relation to gas conveyed through pipes and electricity conveyed by distribution or transmission systems. These interests include costs, the reduction of greenhouse gases and security of supply.

Generating Unit

Any apparatus which produces electricity including, for the avoidance of doubt, a CCGT unit.

Generator

A person who generates electricity under licence or exemption under the Electricity Act acting in its capacity as a generator.

Great Britain or GB

Great Britain means the landmass of England and Wales and Scotland, including internal waters.

Grid Code

The Grid Code is an interface document setting out the planning and operating procedures and principles governing NGET’s relationship with all Users of the National Electricity Transmission System, be they Generators, DC Converter owners, Suppliers or Non-Embedded Customers. The Grid Code specifies the day to day procedures for both planning and operational purposes and covers both normal and exceptional circumstances. The Grid Code is drawn up pursuant to the Transmission licence, and from time to time revised in accordance with the Transmission Licence.

Grid Supply Point (GSP)

A point of supply from the National Electricity Transmission System to Network Operators or Non-Embedded Customers.

Grid System Review (GSR009)

Amendment report to NETS SQSS - Review of required boundary transfer capability with significant volumes of intermittent connection. The changes put increased emphasis on ensuring appropriate balance between the constraint costs with the costs of the transmission reinforcements. For areas where there are high volumes of renewable generation, this will drive the requirement for more transmission capacity than the application of the deterministic rules as set out in version 2.1 of the NETS SQSS.

GW

Gigawatt. 1,000,000,000 Watts.

HV

High Voltage i.e. 275KV and 400KV.

HVAC

High Voltage Alternating Current

HVDC

High Voltage Direct Current

Interconnection

Apparatus for the transmission of electricity to or from the National Electricity Transmission System, or to or from a User System in Great Britain, into or out of an External System. External Interconnections may comprise several circuits operating in parallel.

Interconnection Allowance

An allowance in MW to be added in whole or in part to transfers arising out of the Planned Transfer Condition to take some account of non-average conditions (e.g. Power Station availability, weather and demand). This allowance is calculated by an empirical method described in the NETS SQSS.

IPC

Infrastructure Planning Commission was established on 1 October 2009 under the Planning Act 2008 to streamline the planning system for nationally significant infrastructure projects (NSIPs) in England and Wales. In England, it examines applications for development consent from the energy, transport, waste, waste water and waste sectors. In Wales, it examines applications for energy and harbour development, subject to detailed provisions in the Act; other matters are for Welsh Ministers.

kV

Kilovolt (1000 volts)

Large Power Station

A Power Station in NGET's Transmission Area with a Registered Capacity of 100MW or more or a Power Station in SPT's Transmission Area with a Registered Capacity of 30MW or more or a Power Station in SHETL's Transmission Area with a Registered Capacity of 10MW or more.

Medium Power Station

A Power Station in NGET's Transmission Area with a Registered Capacity of 50MW or more, but less than 100MW. The Medium Power Station category does not exist in the Transmission Areas of SPT or SHETL.

Merit

In relation to a generator, the cost of generating electricity from that generator relative to other generators, such that a high merit generator is less expensive, and hence more likely to operate, than a low merit generator.

MITS

Main Interconnected Transmission System. This comprises all the 400kV and 275kV elements of the National Grid Transmission System and, in Scotland, the 132kV elements of the National Electricity Transmission System but excludes Generation Circuits, transformer connections to lower voltage systems and External Interconnections between the National Grid Transmission System and External Systems.

MSC

Mechanically Switched Capacitor. These devices are the most economical reactive power compensation devices. They are a simple and low-cost, but low-speed solution for voltage control and network stabilization under heavy load conditions[47].

MVA

The flow of 'active' power is measured in Megawatts (MW). When compounded with the flow of 'reactive' power, which is measured in Mvar, the resultant is measured in Megavolt-amperes (MVA).

MW

Megawatts, 1,000,000 watts

N-2 and N-D Fault Condition

In the context of this report, N-1 refers to the fault outage of any single generation circuit or single section of busbar or mesh corner. The N-2 refers to the concurrent fault outage of any two Transmission Circuits on the same double circuit or the fault outage of a single Transmission Circuit during the planned outage of any other single Transmission Circuit, where N refers to the intact system. N-D is a special case of N-2. The N-D refers to the concurrent fault outage of any two parallel Transmission Circuits.

NDA

Nuclear Decommissioning Authority is a non-departmental public body. It is a strategic authority that owns 19 sites and the associated civil nuclear liabilities and assets of the public sector. Its purpose is to deliver the decommissioning and clean-up of the UK's civil nuclear legacy in a safe and cost-effective manner, and where possible to accelerate programmes of work that reduce hazard.

NETS

National Electricity Transmission System – This comprises all onshore and offshore transmission networks ie above 132kV in England and Wales and 132kV and above in Scotland and Offshore.

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[47] http://www.energy.siemens.com/br/en/power-transmission/facts/mechanical-switched-capacitor/

NETS SQSS

The National Electricity Transmission System Security and Quality of Supply Standards set out a coordinated set of criteria and methodologies that Transmission Licensees (both onshore and offshore) shall use in the planning and operation of the National Electricity Transmission System. These will determine the need for services provided to the Transmission Licensees[48].

Network Operator

A person with a User System directly connected to the National Electricity Transmission System to which Customers and/or Power Stations (not forming part of that system) are connected, acting in its capacity as an operator of the User System, but shall not include a person who operates an External System.

NGET

National Grid Electricity Transmission plc. The Transmission Owner for England and Wales. NGET is a member of the National Grid ("National Grid") group of companies.

Ofgem

Office of the Gas and Electricity Markets the regulator of the GB energy market.

OFTO

Offshore Transmission Owner. Owner of transmission assets connecting offshore windfarms to the onshore network granted a licence through competitive tendering run by Ofgem.

Planned Transfer

The power transfer arising from the Planned Transfer Condition.

Planned Transfer Condition

This is defined by scaling the output capacities of all directly connected Power Stations and embedded Large Power Stations to equal the ACS Peak Demand minus imports from External Systems. This scaling shall follow the straight scaling technique and, where the Plant Margin exceeds 20%, also follow the ranking order technique, both of which are described in Appendix C of the Licence Standard.

Plant

Fixed and movable items used in the generation and/or supply and/or transmission of electricity, other than Apparatus.

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[48] http://www.nationalgrid.com/uk/Electricity/Codes/gbsqsscode/DocLibrary/

Plant Margin

The amount by which the total installed capacity of directly connected Power Stations and Embedded Large Power Stations and imports across directly connected External Interconnections exceeds the ACS Peak Demand. This is often expressed as a percentage (e.g. 20%) or as a decimal fraction (e.g. 0.2) of the ACS Peak Demand.

Power Station

An installation comprising one or more Generating Units (even where sited separately) owned and/or controlled by the same Generator, which may reasonably be considered as being managed as one Power Station.

Rating

The continuous rating of a Transmission Circuit is the maximum power flow that can be passed through the Transmission Circuit, without damaging equipment, or infringing statutory clearances on overhead lines. This will normally be for a period within 24 hours. This rating varies for each season of the year, because of the effect of differing climatic conditions on equipment performance.

Reactive Power

Reactive power is a concept used 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.

Reconductoring

Replacing of overhead line or cable with high capacity conductor

Required transfer

Sum of the planned transfer and full and half interconnector allowance in case of N-1 and N-2/N-D contingency respectively

RIIO-T1

RIIO-T1 is the first transmission price control to use the RIIO framework, and will run from 1 April 2013 to 31 March 2021. RIIO stands for Revenue=Incentives+Innovation+Outputs. The TOs submitted initial electricity transmission business plans to Ofgem in July 2011 covering the RIIO-T1 period.

Security Model

Security model requires sufficient transmission system capacity such that peak demand can be met without intermittent generation.

Series compensation

Series Compensation is a well established technology that primarily is used to reduce transfer reactance, most notably in bulk transmission corridors. The result is a significant increase in the transmission system transient and voltage stability. Series Compensation is self regulating in the sense that its reactive power output follows the variations in transmission line current, a fact that makes the series compensation concept extremely straightforward and cost effective.

Thyristor Controlled Series Capacitors adds another controllability dimension, as thyristors are used to dynamically modulate the reactance of provided by the inserted capacitor. This is primarily used to provide inter-area damping of prospective low frequency electromechanical oscillations, but it also makes the whole Series Compensation scheme immune to Sub synchronous Resonance (SSR)[49].

SHETL

Scottish Hydro-Electric Transmission Ltd. The Transmission Owner for Northern Scotland.

Small Power Station

A Power Station in NGET's Transmission Area with a Registered Capacity of less than 50MW or a Power Station in SPT's Transmission Area with a Registered Capacity less than 30MW or a Power Station in SHETL's Transmission Area with a Registered Capacity less than 10MW.

SPT

SP Transmission. The Transmission Owner for Central and Southern Scotland.

STW

Scottish Territorial Waters. The definition of this area is set out in The Scottish Adjacent Waters Boundaries Order 1999.

Summer Minimum Condition

In summer the rating of the conductors and other equipments are low and the demand in the network also less.

Supergrid Transformer (SGT)

Power transformers which interconnect the 400kV and 275kV transmission system with the distribution systems (typically 132KVor 66KV).

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49 http://www.abb.co.uk/industries/us/9AAC30200082.aspx

Thermal capability

The ability of a network to transmit maximum power without overloading any circuit.

TII

The Transmission Investment Incentives is a mechanism whereby Ofgem sets the allowance for, and monitors, transmission investment projects in most urgent need of funding, including some identified in the 2009 ENSG Report.

TIRG

Transmission Investment for Renewable Generation. This is a mechanism designed to fund transmission projects specific to connecting renewable generation outside of the price control allowance to minimise delays. TIRG comprises four projects: Beauly Denny, Sloy, South West Scotland and the Scotland-England Interconnector[50].

TO

This means the holder, for the time being, of a Transmission Licence. Onshore this is National Grid Electricity Transmission plc, Scottish Power Transmission Ltd, Scottish Hydro-Electric Transmission Limited. Offshore it is the OFTOs.

Transmission Circuit

Part of the National Electricity Transmission System between two or more circuit-breakers which includes, for example, transformers, reactors, cables and overhead lines but excludes Busbars and Generation Circuits.

Transmission Licence

The Licence granted under Section 6(1)(b) of the Electricity Act 1989 (as amended by the Utilities Act 2000 and the Energy Act 2004).

Transmission Licensee

This means the holder, for the time being, of a Transmission Licence. Onshore this is National Grid Electricity Transmission plc, Scottish Power Transmission Ltd, Scottish Hydro-Electric Transmission Limited. Offshore it is the OFTOs.

Transient Stability

Synchronous generators throughout the GB transmission system operate at the exact same electrical frequency of 50 Hertz and are electrically coupled together by the system so that they

[50] http://www.ofgem.gov.uk/Networks/Trans/ElecTransPolicy/CriticalInvestments/TIRG/Pages/TIRG.aspx

remain in step with one another. It is therefore important that synchronism is maintained. In the event of an instantaneous fault occurring on the transmission system (a transient situation); circumstances can arise in which generators close to the fault begin to accelerate relative to others further away. If the fault is not removed sufficiently quickly, then the generator or generators affected may accelerate so much that they become out of step with the remainder of the system (loss of synchronism / pole slipping). In this instance, generators themselves can be severely damaged possibly leading to failure of major components.

Uprating

Changing the capacity of existing overhead line by replacing the existing conductors with larger capacity conductors, or increasing the maximum operating temperature of the existing conductor system.

Zone

A zone is an area of the country (i.e. in England, Wales or Scotland), with strong internal electrical connections, but which may have weaker connection to the rest of the System.