nationalgrid

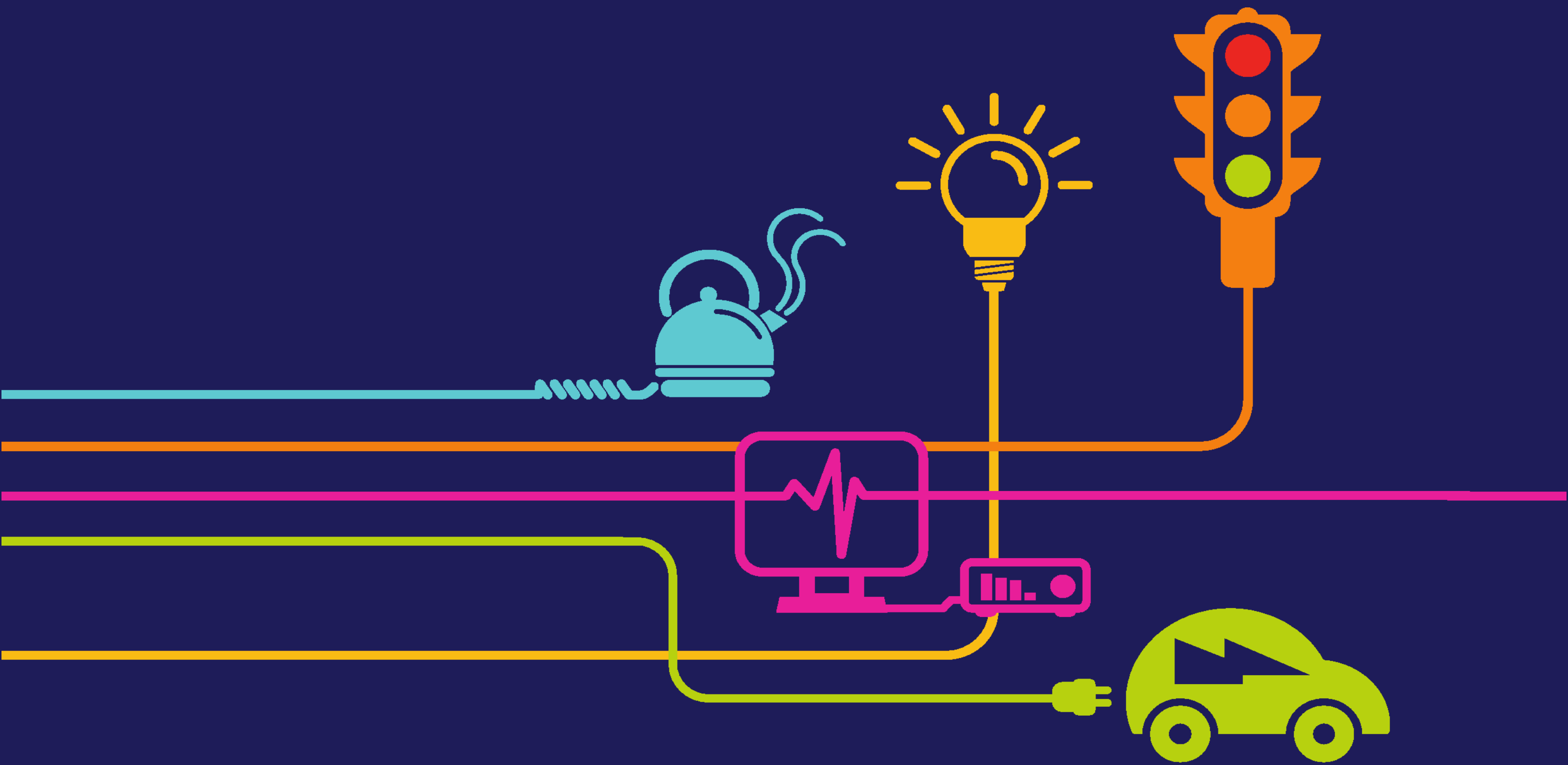
DOCUMENT 9.8.2

Historic Strategic Options Report (2015)

National Grid (North Wales Connection Project)

Regulation 5(2)(q) of the Infrastructure Planning
(Applications: Prescribed Forms and Procedure) Regulations 2009

First published January 2015



North Wales Connections

Strategic Options Report

National Grid

National Grid House

Warwick Technology Park

Gallows Hill

Warwick

CV34 6DA

9 January 2015

North Wales Connections

Strategic Options Report

Table of Contents Page

1 Introduction

1.1 This Strategic Options Report (the Report) has been prepared in accordance with the pre-application procedures adopted by National Grid Electricity Transmission plc ("National Grid") for major infrastructure projects which may require an application to the Planning Inspectorate [1] for development consents.

1.2 This is an updated version of the Strategic Options Report that was published in October 2012. This version reflects the changes in contracted generation that have occurred since that time and updates the design and cost assumptions for the identified Strategic Options.

1.3 National Grid is contractually bound to connect 2.8 GW of new generation to the National Electricity Transmission System ("NETS") in Anglesey:

- a 2.8 GW nuclear power station, which is proposed to be constructed by Horizon Nuclear Power at Wylfa

1.4 National Grid is also contractually bound to connect four additional wind farms to the NETS on the North Wales mainland:

- Gwynt y Môr Offshore Wind farm, 565 MW, located off the coast of North Wales and connected at Bodelwyddan in Denbighshire (completed late 2014)
- Burbo Bank Extension Wind farm, 254 MW, also to be located off the coast of North Wales and also connected at Bodelwyddan
- Greenwire Wind Farm, 1 GW, located onshore in Ireland, to be connected at Pentir in Gwynedd, and
- Codling Park Wind Farm, 1 GW, located offshore in Ireland, also to be connected at Pentir.

1.5 National Grid has published an accompanying Need Case report that demonstrates that this level of generation cannot be connected to the transmission system without installing additional transmission infrastructure. The full Need Case report and more detail on the new generation and impact on the transmission system can be found at:

[1] Following the abolition of the Infrastructure Planning Commission (IPC) on 1 April 2012, the Planning Inspectorate became the government agency responsible for examining planning applications for Nationally Significant Infrastructure Projects.

http://www.northwalesconnection.com/

1.6 This Strategic Options Report has been produced by National Grid to inform interested parties of its appraisal of the range of options and technologies which could provide the additional transmission infrastructure. A preliminary preferred option is identified in the report.

1.7 This report provides an overview of the multi-criteria analysis that National Grid uses to appraise strategic options (the "Strategic Optioneering Process"). As part of the Strategic Optioneering Process, National Grid considers relevant technical, environmental, socio-economic and cost factors.

1.8 This document, and other information regarding the North Wales Connections, can be found on the National Grid website at:

http://www.nationalgrid.com/uk/Electricity/MajorProjects/NorthWalesConnection/.

1.9 This report provides:

- background to the electricity industry and National Grid's approach in developing proposals for new transmission routes (Section 2)
- an explanation of the need case for reinforcements in North Wales (Section 3)
- a description of the potential options which were parked prior to the strategic options appraisal process and an explanation of the reasons why (Section 4)
- an overview of the strategic options that National Grid identified for the North Wales Connections (Section 5)
- the results of the strategic options appraisal process (Sections 6 to 17)
- the main conclusions drawn from National Grid's analysis (Section 18)

1.10 This report also includes seven appendices and a glossary of terms and abbreviations. These provide further detailed information as follows:

- a summary of National Grid's legal obligations (Appendix A)
- a summary of the requirements for development consent (Appendix B)

- an overview of the technology options for electricity transmission (Appendix C)
- an overview of National Grid’s economic appraisal (Appendix D)
- an explanation of the methodology used for AC losses calculation (Appendix E)
- an overview of the scope of the environmental and socio-economic appraisal (Appendix F)
- constraint maps for each strategic option (Appendix G), and
- a glossary of the terms and acronyms used in this report.

1.11 Throughout the options appraisal process, National Grid will continue to regularly review the identified need for new transmission infrastructure in North Wales and the strategic options that could meet that need in light of changes of circumstances that could materially affect the analysis. These include, but are not limited to, technology developments, cost updates, changes to generation and demand requirements and consultation responses.

1.12 Comments on the content, analysis and conclusions contained in this report are welcome and will be taken into account in the on-going development of the project.

2 Background

Overview of the Electricity Industry

2.1 A single electricity market serves the whole of Great Britain. In this competitive, wholesale market generators and suppliers trade electricity on a half hourly basis. Generators produce electricity from a variety of fuel sources, including coal, gas, nuclear and wind, and sell electricity produced in the wholesale market. Suppliers purchase electricity in the wholesale market and supply to end customers.

2.2 Generation of electricity at a power station of 100 MW or greater capacity, in Great Britain and its offshore waters, requires permission by a generation licence[2]. Generation licensees are bound by legal obligations that are set out in the Electricity Act and the generation licence.

2.3 Electricity is transported via network infrastructure from locations where it is generated to demand centres where it is used. In England and Wales, network infrastructure is classed as transmission if operated at a voltage:

(a) above 132 kV, or

(b) of 132 kV or above where used to transport electricity from a power station located offshore.

2.1 Transmission of electricity in Great Britain requires permission by a licence granted under Section 6(1)(b) of the Electricity Act[3] 1989 ("the Electricity Act"). Transmission licensees are bound by the legal obligations, which are primarily set out in the Electricity Act and the transmission licence. A summary4 of legal obligations that are relevant to National Grid is set out in Appendix A.

2.2 National Grid has been granted a transmission licence and is the operator of the high voltage transmission system for Great Britain and its offshore waters, which is known as the National Electricity Transmission System (the "NETS"), and is the owner of the high voltage transmission system in England and Wales5.

[2] A generation licence granted under Section 6(1)(a) of the Electricity Act 1989 (the "Electricity Act").
[3] The Electricity Act 1989: **http://www.legislation.gov.uk/ukpga/1989/29/contents**
[4] This summary is not intended as an exhaustive list of National Grid's legal obligations but seeks to provide information about the obligations that are particularly relevant to the Report.
[5] The transmission network in Scotland is owned by SP Transmission Limited in southern and central Scotland and by Scottish Hydro-Electric Transmission Limited in the north of Scotland. Offshore transmission networks will be owned by transmission licensees following the grant of

2.3 National Grid's transmission system consists of approximately 7,200 km of overhead lines and a further 700 km of underground cabling, operating at 400 kV and 275 kV. These overhead line and underground cable circuits connect between around 340 substations forming a highly interconnected transmission system. Further details of the transmission system including geographic and schematic representations are published by National Grid annually as part of its Electricity Ten Year Statement6 ("ETYS").

2.4 In general, 400 kV circuits have a higher power carrying capability than 275 kV circuits. Circuits are those parts of the system used to connect between substations on the NETS. The system is composed of double-circuits (in the case of overhead lines carried on two sides of a single pylon) and single-circuits. Substations provide points of connection to the NETS for power stations, distribution networks7, transmission connected demand customers (e.g. large industrial customers) and interconnectors.

2.5 Distribution networks operate at 132 kV and below in England & Wales and are mainly used to transport electricity from the NETS to the majority of end customers.

2.4 Electricity can also be traded on the single market in Great Britain by generators and suppliers in other European countries. Interconnectors with transmission systems in France, Northern Ireland and the Netherlands are used to transfer electricity to and from the NETS.

<u>Requirement for Changes to Electricity Network Infrastructure</u>

2.5 Six National Policy Statements for energy infrastructure were designated by the Secretary of State for Energy and Climate Change in July 2011[8]. The Overarching National Policy Statement for Energy ("EN-1") sets out that it is critical that the UK continues to have secure and reliable supplies of electricity as part of the transition to a low carbon economy. EN-1 also highlights an urgent need for new electricity transmission and distribution infrastructure to be provided[9].

new licences by Ofgem.

6 Electricity Ten Year Statement: http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/Electricity-Ten-Year-Statement/

7 In England and Wales, distribution networks operate at voltages from 132 kV down to 230 V (at which voltage, the power is distributed to domestic consumers).

8 DECC website : **http://www.decc.gov.uk/en/content/cms/meeting_energy/consents_planning/nps_en_infra/nps_en_infra.aspx**

9 Paragraph 3.7.10 of EN-1 : **https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/47854/1938-overarching-nps-for-energy-en1.pdf**

2.6 National Policy Statement for Electricity Networks Infrastructure ("EN-5") explains circumstances where applications for consent for new electricity network infrastructure developments may be considered without an accompanying application for a generating station[10]. EN-5 states "*new lines will have to be built, and the location of renewable energy sources and designated sites for new nuclear power stations makes it inevitable that a significant proportion of those new lines will have to cross areas where there is little or no transmission infrastructure at present, or which it may be claimed should be protected from such intrusions".* EN-5 also explains that the need for a transmission project can be assessed on the basis of contracted generation or reasonably anticipated future requirements.

2.7 Developing the transmission system in England and Wales may require one or more statutory consents, depending on the type and scale of the project. These may include planning permission or permitted development rights under the Town and Country Planning Act 1990, a marine licence under the Marine and Coastal Access Act 2009 and a Development Consent Order (DCO) under the Planning Act 2008. The requirement for development consent for works on the transmission system is outlined in more detail in Appendix B.

2.8 Each transmission licensee is legally required to provide an efficient, economic and coordinated system of electricity transmission within the geographic area specified in its transmission licence. Transmission infrastructure needs to be and remain (as customer requirements change) capable of transporting electricity from and to customers and of maintaining a minimum level of security of supply. Customers make decisions in respect of developments that require connection to and/or use of the NETS and in respect of which developments will be taken forward. These customer decisions are influenced by the parameters set by Government[11] as well as other commercial factors (including the volume of works required to connect to the NETS).

2.9 National Grid's consideration of future energy scenarios is reported in the ETYS. The annual ETYS publication[12] includes explanation of methods used by National Grid to manage the uncertainty of future energy scenarios in both planning and operating the transmission system.

[10] Paragraph 2.3.3 of EN-5 : **https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/47858/1942-national-policy-statement-electricity-networks.pdf**
[11] Energy policy information is available from the Department of Energy and Climate Change website: **https://www.gov.uk/government/topics/energy**
[12] National Grid's ETYS is published annually in November.

2.10 Recently, a large volume of applications have been made to National Grid for connection of new generation at locations that are remote from the existing transmission system or in the vicinity of parts of the transmission system that does not have sufficient capacity available for the new connection. The majority of these applications have been for low-carbon generation projects. Areas that are rich in low-carbon energy sources are often in locations that are remote from existing transmission system infrastructure.

2.11 The NETS needs to cater for demand changes. The locations of demand centres are broadly constant and, historically, demand increases annually. National Grid prepares demand forecasts for each connection point on an annual basis. These forecasts take account of forecast information that is provided to National Grid by its customers, as well as new demand connection requests and other economic factors.

National Grid Transmission System Development

2.12 National Grid is required to provide an efficient, economic and coordinated transmission system in England and Wales which is and remains capable as customer requirements change. The transmission system infrastructure needs to be capable of

(a) transporting electricity from and to customers, and

(b) maintaining a minimum level of security of supply as defined within the National Electricity Transmission System Security and Quality of Supply Standards (NETS SQSS[13]). The NETS SQSS defines performance requirements for a range of operating conditions including circumstances where sections of the NETS are not available.

2.13 Schedule 9[14] of the Electricity Act 1989 requires National Grid, when formulating proposals for new lines and other works, to:

"*…have regard to the desirability of preserving natural beauty, of conserving flora, fauna, and geological or physiographical features of special interest and of protecting sites, buildings and objects of architectural, historic or archaeological interest; and shall do what [it] reasonably can to mitigate any effect which the*

[13] NETS SQSS v 2.2: **http://www2.nationalgrid.com/UK/Industry-information/Electricity-codes/SQSS/The-SQSS/**
[14] Section 38 of the Electricity Act states that Schedule 9 shall have effect.

proposals would have on the natural beauty of the countryside or on any such flora, fauna, features, sites, buildings or objects".[15]

2.14 National Grid considers options for enhancing existing transmission infrastructure before options requiring wholly new transmission infrastructure. This is consistent with its statutory duty to have regard to amenity under Section 38 and Schedule 9 of the Electricity Act 1989 and promotes more sustainable development. This position is detailed in National Grid's Stakeholder, Community and Amenity Policy[16] (the "Policy").

2.15 In accordance with the Policy, National Grid will only propose to build new transmission infrastructure where existing infrastructure cannot be technically or economically upgraded to meet customer requirements and legal obligations. Where there is no viable existing upgrade option, National Grid will identify solution options (e.g. the installation or construction of a new circuit) that seeks to achieve the most appropriate integration of its statutory and licence duties and obligations. The Policy refers to the application of best practice methods to assess the environmental impacts of proposals and identify appropriate mitigation and/or offsetting measures.

2.16 In addition to the Policy, National Grid has published a document[17] that explains its approach to the design and routeing of new electricity transmission lines. This document sets out how in principle National Grid identifies the most appropriate location and technology for any new transmission route. The approach is then specifically tailored to the circumstances of each case.

Options Appraisal

2.17 When identifying an initial range of possible options to meet an identified need for transmission system reinforcement, National Grid considers opportunities to use and/or enhance existing transmission system circuits and equipment as well as options that require new transmission system infrastructure.

2.18 At the initial stage for any project that requires a new transmission route[18], National Grid identifies potential options for transmission system infrastructure

[15] Schedule 9 of the Electricity Act: **http://www.legislation.gov.uk/ukpga/1989/29/contents**
[16] Stakeholder Community and Amenity Policy: http://www.nationalgrid.com/NR/rdonlyres/21448661-909B-428D-86F0-2C4B9554C30E/39991/SCADocument6_2_Final_24_2_10.pdf
[17] Our approach to the design and routeing of new electricity transmission lines: http://www2.nationalgrid.com/UK/In-your-area/Community-Engagement/.
[18] National Grid's assessment of a need for transmission system development is set out in section 3 of this Report.

development (the "Strategic Options") for assessment based upon high level design information. National Grid's Options Appraisal process has been developed to provide a framework for the careful analysis of and appropriate consultation in respect of Strategic Options.

2.19 National Grid has published a document[19] that explains the Options Appraisal process that is used to inform its decision making in respect of major infrastructure projects. Whilst this process was primarily developed for projects that may require a Development Consent Order under the Planning Act, National Grid may also choose to apply this process to gather information to inform decision making in respect of other types of projects.

2.20 Each potential Strategic Option is initially assessed by National Grid to ensure that it meets the reinforcement need and that the resultant transmission system would comply with the minimum standards for security and quality of supply defined in the NETS SQSS. National Grid will discount potential Strategic Options which do not meet the reinforcement need or otherwise would not meet the standards set out in the NETS SQSS.

2.21 As part of the Options Appraisal, National Grid reviews the suitability of each of a range of technology options for each Strategic Option. There are a number of different technologies that can be used to provide transmission system infrastructure. Appendix C provides an overview of each of the Alternating Current ("AC") overhead line, AC underground cable, AC Gas Insulated Line ("GIL") and High Voltage Direct Current ("HVDC") technology options that National Grid considers.

2.22 A technology option may be assessed as not technically viable for a Strategic Option. For example, for any offshore circuits National Grid would not consider overhead line technology as viable. Where a technology option is not considered viable, it would not be considered further as part of National Grid's appraisal of that Strategic Option.

2.23 National Grid assesses the factors that differentiate the remaining Strategic Options. Any Strategic Option, for which distinct benefits when compared to other options are not identified as part of this initial comparative assessment ("Benefits Filter"), is not considered further as part of the Options Appraisal. This Benefits

[19] Our approach to Options Appraisal: http://www2.nationalgrid.com/UK/In-your-area/Community-Engagement/.

Filter is a tool National Grid uses to narrow down the number of Strategic Options for appraisal.

2.24 National Grid identifies an indicative scope of works using high level design information for each viable technology option identified for each of the Strategic Options. The indicative scope of works information can include works required to extend and/or upgrade the NETS as well as contingent transmission works. This scope of works information is used as part of the comparative assessment of each Strategic Option.

2.25 For each Strategic Option, using the scope of works relevant for each technology option, National Grid prepares indicative capital cost estimates. National Grid's capital cost estimates include costs for the transmission equipment and also for the installation of that equipment. All capital cost estimates within this Report are based on current financial year prices that are applicable at the Report's publication date.

2.26 National Grid prepares lifetime cost estimates for any new transmission circuits required as part of a Strategic Option. These lifetime cost estimates include the capital cost estimates and also take account of the transmission losses and maintenance costs for transmission equipment over a 40 year lifetime as well as the associated indicative capital cost estimate.

2.27 More detailed information about the basis of capital and lifetime cost estimates prepared by National Grid is provided in Appendix D of this Report.

2.28 National Grid identifies the environmental factors that differentiate Strategic Options, which are of sufficient importance to influence decision making at the Options Appraisal stage. Generally, these factors include constraints or issues of national or international importance.

2.29 Information about the environmental factors considered by National Grid as part of an Options Appraisal is provided in Appendix F of this Report.

2.30 National Grid identifies the socio-economic factors that differentiate Strategic Options, which are of sufficient importance to influence decision making at the Options Appraisal stage.

2.31 Information about the socio-economic factors considered by National Grid as part of an Options Appraisal is provided in Appendix F of this Report.

2.32 The Options Appraisal considers for each of a range of possible technology options, high level cost estimates and the environmental and socio-economic effects associated with each Strategic Option. National Grid needs to balance cost, environmental and socio-economic considerations when identifying option(s) which would best meet its various statutory and licence obligations (the "Preferred Strategic Option(s)").

2.33 If the Preferred Strategic Option(s) would require changes to National Grid's transmission system which would be regarded as a nationally significant infrastructure project[20], a project-specific Strategic Options Report will form part of National Grid's pre-application consultation process.

2.34 Changes to background conditions (e.g. to the contractual requirements of one or more of National Grid's customers) that National Grid assumed for an Options Appraisal may arise during the pre-application consultation process. National Grid would conduct a further review, where changes to background conditions are considered to have material, consequential impacts on Strategic Option selection decisions that have been made which form the basis of the proposed development. Feedback from public consultations is also included in this process.

[20] As defined in the Planning Act 2008. Nationally significant infrastructure projects require a Development Consent Order (DCO). Decisions in respect of applications for DCOs are made by the Secretary of State for Energy and Climate Change (DECC).

3 The Need for Transmission Reinforcements in North Wales

3.1 The existing transmission system capacity in North Wales is sufficient to comply with the minimum standard for security and quality of supply defined in the National Electricity Transmission System Security and Quality of Supply Standard (NETS SQSS) [21] for current levels of generation and demand. However, the amount of new generation expected to connect means that by 2018 the transmission system will no longer be compliant unless National Grid installs new capacity.

3.2 A Need Case (version 1.3) has been published [22] which explains in detail the existing capacity of the transmission system and the requirement to add new capacity by 2018.

3.3 Table 1 gives details of those companies who have connection agreements with National Grid in North Wales and details of their proposed projects.

[21] The NETS SQSS can be viewed at https://www.nationalgrid.com/uk/Electricity/Codes/gbsqsscode/
[22] The Need Case can be viewed at https://www.nationalgrid.com/uk/Electricity/MajorProjects/NorthWalesConnection/

Company	Generator Name	Substation	Completion Date	Plant Type	Capacity (MW)
NDA	Wylfa	Wylfa	Existing	Nuclear	450
First Hydro Company	Dinorwig	Dinorwig	Existing	Pumped Storage	1,644
First Hydro Company	Ffestiniog	Ffestiniog	Existing	Pumped Storage	360
RWE NPower PLC	Dolgarrog	Embedded (Pentir)	Existing	Hydro	39
NDA	Maentwrog	Embedded (Trawsfynydd)	Existing	Hydro	30
RWE NPower PLC	Cwm Dyli	Embedded (Trawsfynydd)	Existing	Hydro	10
Gwynt y Môr Offshore Wind farm Ltd	Gwynt y Môr	Bodelwyddan (Denbighshire)	Completed Late 2014	Offshore wind	565
Dong Wind (UK) Ltd	Burbo Bank Extension	Bodelwyddan (Denbighshire)	2016	Offshore wind	254
Greenwire Limited	Greenwire Wind Farm - Pentir	Pentir	2018	Onshore Wind (Ireland)	1,000
Fred Olsen Renewables	Codling Park Wind Farm	Pentir	2018	Offshore Wind (Ireland)	1,000
Horizon Nuclear Power Wylfa Limited	Wylfa	Wylfa (Anglesey)	2024 - 2025	Nuclear	2,800
				Total	**8,152**

Table 3.1 – Generators with agreements to connect in North Wales

3.4 The Need Case demonstrates that the connection of Gwynt y Môr in 2014 and Burbo Bank Extension in 2015 does not require an increase in transmission capacity. However, the addition of 2 GW from Codling Park and Greenwire wind generation trigger the need for additional capacity across boundaries NW2 and NW3 by 2018. The subsequent connection of Horizon's proposed 2.8 GW of nuclear generation triggers the need for additional transmission infrastructure across boundary NW1 by 2024.

3.5 National Grid makes use of boundaries on the transmission system when assessing the system against the various criteria contained in the NETS SQSS. In considering the North Wales area three boundaries have been developed and these are shown in Figure 3.1. The Need Case demonstrates that the power transfer capacities across these three boundaries are insufficient to transfer the required amount of power once the new generators have been connected.

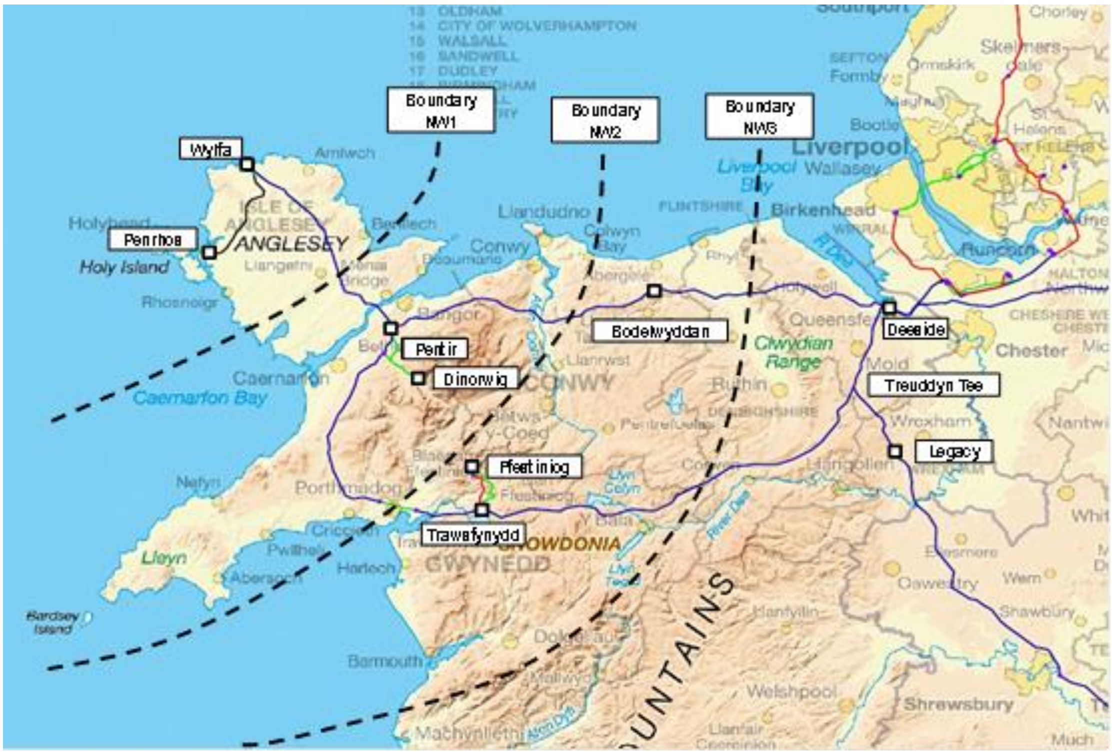


Figure 3.1 – The North Wales Transmission System and System Boundaries

3.6 The existing transmission system within North Wales consists of:

- a 400 kV double circuit overhead line between Wylfa and Pentir
- a 400 kV double circuit overhead line between Pentir and Deeside
- two 400 kV circuits (partly cable, partly overhead line) between Pentir and Dinorwig
- a 400 kV single circuit between Pentir and Trawsfynydd (an underground cable between Wern and Y Garth and occupying one side of the 400 kV double circuit overhead line over the remainder of the route.)
- a 400 kV double circuit overhead line between Trawsfynydd, Legacy and Deeside
- a 275 kV double circuit overhead line between Trawsfynydd and Ffestiniog, and
- a 132 kV double circuit overhead line between Wylfa and Penrhos.

3.7 SP Manweb, the local Distribution Network Operator (DNO), has a single 132 kV circuit carried along the southern half of the Pentir to Trawsfynydd overhead line route which provides supplies to the Llyn Peninsula.

3.8 The double circuit between Wylfa and Pentir connects Wylfa Power Station, a magnox nuclear station, to the transmission system. The owner, the Nuclear Decommissioning Authority, plans to cease generation at the station in December 2015.

3.9 The two circuits between Pentir and Dinorwig substations connect Dinorwig Power Station to the transmission system. Dinorwig Power Station is a pumped storage power station owned by First Hydro Company and is located at Llanberis, Gwynedd.

3.10 The 275 kV double circuit overhead line between Trawsfynydd and Ffestiniog connects Ffestiniog Power Station to the transmission system. Ffestiniog Power Station is also a pumped storage power station owned by First Hydro Company and is located at Ffestiniog, Gwynedd.

3.11 The transmission system within North Wales is connected to the rest of the transmission system by six 400 kV circuits:

- a 400 kV double circuit overhead line between Deeside and Daines
- a 400 kV double circuit overhead line between Deeside and the Mersey region, connecting into Capenhurst and Frodsham substations, and
- a 400 kV double circuit overhead line between Legacy and Ironbridge substations.

3.12 Boundary NW1 is principally limited by the two circuits connecting Wylfa and Pentir. The Need Case demonstrates that this boundary needs to be reinforced by 2025. Three circuits cross boundary NW2 and additional capacity will be required in this area by 2018.

3.13 Four circuits cross boundary NW3 and additional capacity will be required by 2025. This can be achieved by upgrading the existing transmission circuits.

4 Potential Reinforcement Options Identified

4.1 There are many ways in which the need for additional capacity could be met and many of these are very similar. In view of that, the list of potential strategic options taken forward for stakeholder consideration and detailed appraisal was reduced by careful analysis, ensuring that those remaining had a sufficient spread of benefits and dis-benefits.

4.2 The reinforcement options identified can be grouped into two broad categories, onshore options and offshore options. The following reinforcement options were initially identified for the North Wales transmission system.

Onshore Reinforcement Options

- Wylfa – Pentir
- Pentir – Trawsfynydd
- Pentir – Deeside
- Pentir – Treuddyn Tee
- Pentir – Legacy
- Pentir – Mid Wales

Offshore Reinforcement Options

- Wylfa – Deeside
- Wylfa - Pentir
- Wylfa – Pembroke
- Wylfa – Bodelwyddan
- Wylfa – Capenhurst
- Wylfa – Birkenhead
- Wylfa – Stanah
- Wylfa – Heysham

4.3 A number of these reinforcement options were parked prior to being taken through to the detailed strategic options appraisal phase on the basis that they did not offer any benefits, either to the transmission system or in terms of environmental impact, over other reinforcement options.

Onshore Reinforcement Options

4.4 The onshore reinforcement option Wylfa – Pentir was taken forward as this is the only onshore option which meets the need to provide additional transmission capacity across Anglesey (boundary NW1), as described in section 3, and on the mainland east of Pentir 400 kV substation (boundaries NW2 and NW3). No AC strategic options which provided additional capacity across boundary NW1 were parked; they were all taken forward to the strategic options appraisal, the results of which are set out in sections 11 – 13 in this report.

4.5 A number of reinforcement options to provide additional capacity on the North Wales mainland (boundaries NW2 and NW3) involving new AC transmission circuits out of Pentir were considered:

- Pentir to Deeside
- Pentir to Treuddyn Tee
- Pentir to Legacy
- Pentir to Mid-Wales.

4.6 Each of these would require new transmission circuits and either new or modified substations, potentially creating significant environmental impacts across Snowdonia National Park and incurring significant levels of capital costs over other options.

4.7 The alternative to a new circuit out of Pentir to one of the four locations identified in paragraph 4.5 is the development of the second Pentir to Trawsfynydd circuit, which,

- does not require any new transmission routes and could make use of existing pylons
- is less expensive, but
- does require infrastructure work between Wern and Garth and would require modifications to the SP Manweb distribution network.

4.8 National Grid has a statutory duty to “consider the desirability of preserving amenity” when undertaking projects which includes impacts on communities, landscape and visual amenity, cultural heritage and ecological resources. To satisfy this duty, we seek to avoid areas which are nationally or internationally designated for their landscape, wildlife or cultural significance, such as National Parks.

4.9 In addition, National Grid always investigates whether the existing network can be upgraded economically and efficiently to accommodate additional capacity needs before proposing to build new infrastructure.

4.10 The possibility of developing new onshore routes across North Wales was discussed with key statutory stakeholders. Following these discussions, National Grid reached the conclusion that connections between Pentir and Deeside, Legacy, Treuddyn Tee or Mid-Wales would offer no significant benefit over the development of the second Pentir to Trawsfynydd circuit. For these reasons, the reinforcement options of new transmission routes out of Pentir to Deeside, Legacy, Treuddyn Tee and to Mid-Wales were all parked.

Offshore Reinforcement Options

4.11 A number of additional potential locations were considered for the connection of HVDC subsea circuits and this section discusses which were parked and why. Various locations on the north coast of Wales and the Lancashire coast were considered as connection points for the ‘receiving’ end of the HVDC circuits.

4.12 The following paragraphs take each potential connection point for an HVDC subsea connection in turn and discuss their merits, limitations and the result of the preliminary assessment. The potential connection points are shown in Figure 4.1.

Figure 4.1 – Potential Connection Points for Subsea HVDC, along with Other Relevant Substations

<u>Bodelwyddan 400 kV substation</u>

4.13 Bodelwyddan is a new 400 kV substation recently completed approximately mid-way along the Pentir to Deeside route and will be the connection point for Gwynt y Môr and Burbo Bank Extension offshore wind farms.

4.14 The substation is located approximately 5 km inland which would require the HVDC cables from Anglesey to be laid underground along the final part of the route.

4.15 While an HVDC connection to Bodelwyddan could resolve the constraints on boundaries NW1 and NW2 it would not fully resolve the constraint on boundary NW3. The power would still need to get across boundary NW3, either to Deeside, Legacy or beyond and further reinforcements would be required. The cost of extending the HVDC circuits to Deeside is such that this would provide a far more efficient option.

4.16 For these reasons a connection to Bodelwyddan was parked.

Capenhurst and Birkenhead 275 kV substations

4.17 These substations are located near the coast and are connected into the transmission network on Merseyside.

4.18 Connection of significant amounts of HVDC to either or both of these substations could trigger wider reinforcements and upgrades in Merseyside, incurring significant levels of capital costs. In addition, land at Birkenhead is constrained. These connection points would offer no significant advantage over connecting to Deeside which would not require upgrades in Merseyside and for these reasons connections to Birkenhead and Capenhurst were both parked.

Stanah and Heysham 400 kV substations

4.19 Stanah and Heysham substations are located on the Lancashire coast.

4.20 In addition to existing generation at these substations, there are further advanced plans to connect

- West of Duddon Sands offshore wind farm to Heysham, 374 MW by 2014, and
- Walney Extension offshore wind farm to Heysham, 752 MW by 2016.

4.21 Connection in a north-easterly direction from Wylfa to either of these substations would result in increases in power losses, increased circuit lengths (and consequential increases in capital and lifetime costs) and would be likely to trigger additional transmission reinforcements in Lancashire. Power injected at these locations would generally flow south to Penwortham (near Preston), Daines and Deeside so these connections would offer no significant advantage over connecting directly to Deeside. For these reasons connections to Stanah and Heysham were both parked.

4.22 The following reinforcement options remained:

Onshore Options

- Wylfa – Pentir
- Pentir – Trawsfynydd

Offshore Options

- Wylfa – Deeside
- Wylfa - Pentir
- Wylfa – Pembroke

4.23 The remaining options can be combined to create five unique strategic options; these are described in section 5.

4.24 As part of National Grid's consultation process, we received feedback that stakeholders would like to see a reinforcement option considered that included the replacement of the existing 132kV overhead line route between Wylfa and Valley. As a result of this feedback, National Grid has included a new option in this version of the Strategic Options Report. This option is a combination of onshore and offshore reinforcements and is described fully in section 12.

5 Strategic Options Identified for the North Wales Connections

5.1 Six strategic options have been identified for the reinforcement of the electricity transmission system in North Wales (following the refinement of the list of potential strategic options discussed in Chapter 4). National Grid considers that each of these options would be able to meet the additional transmission system requirements in North Wales and has taken these options forward for strategic option appraisal.

5.2 The six strategic options are:

Option 1 - Two subsea cable circuits between Wylfa and Deeside substations

Option 2 - One subsea circuit between Wylfa and Deeside and one subsea cable circuit between Wylfa and Pembroke

Option 3 – Two new onshore circuits connecting Wylfa and Pentir , one new AC circuit between Pentir and Trawsfynydd to be installed on existing pylons, a new connection between Wern and Y Garth, a new substation in west Gwynedd, re-conductoring of existing circuits in North Wales, the installation of series compensation equipment and modifications at existing substations.

Option 4 – Two new offshore circuits east of Anglesey connecting Wylfa and Pentir , one new AC circuit between Pentir and Trawsfynydd to be installed on existing pylons, a new connection between Wern and Y Garth, a new substation in west Gwynedd, re-conductoring of existing circuits in North Wales, the installation of series compensation equipment and modifications at existing substations.

Option 5 – Two new offshore circuits west of Anglesey connecting Wylfa and Pentir , one new AC circuit between Pentir and Trawsfynydd to be installed on existing pylons, a new connection between Wern and Y Garth, a new substation in west Gwynedd, re-conductoring of existing circuits in North Wales, the installation of series compensation equipment and modifications at existing substations.

Option 6 - Replace the existing 132kV overhead line between Wylfa and Valley with a 400kV overhead line, two new circuits (largely offshore) between Valley and a new substation in the vicinity of west Gwynedd, one new AC circuit between Pentir and Trawsfynydd to be installed on existing pylons, a new connection between Wern and Y Garth, re-conductoring of existing circuits in North Wales, the installation of series compensation equipment and modifications at existing substations.

5.3 Strategic Option 6 was not included in the previous version of the Strategic Options Report. It has been included here as a result of feedback received during stage 1 of National Grid's consultation.

5.4 The technology choices, environmental considerations, and cost of these strategic options are appraised in the following sections.

6 Strategic Option 1

6.1 This option would provide the required additional transmission capacity across Anglesey and North Wales (reinforcing each of the three boundaries described in section 3) through the installation of approximately 106 km long subsea and onshore cable circuits between Wylfa and Deeside 400 kV substations.

6.2 Deeside substation is capable of receiving the additional power, all of which can be transferred deeper into the transmission system without directly triggering the need to construct any new routes east of Deeside.

6.3 A geographical illustration of Strategic Option 1 is shown in Figure 6.1.

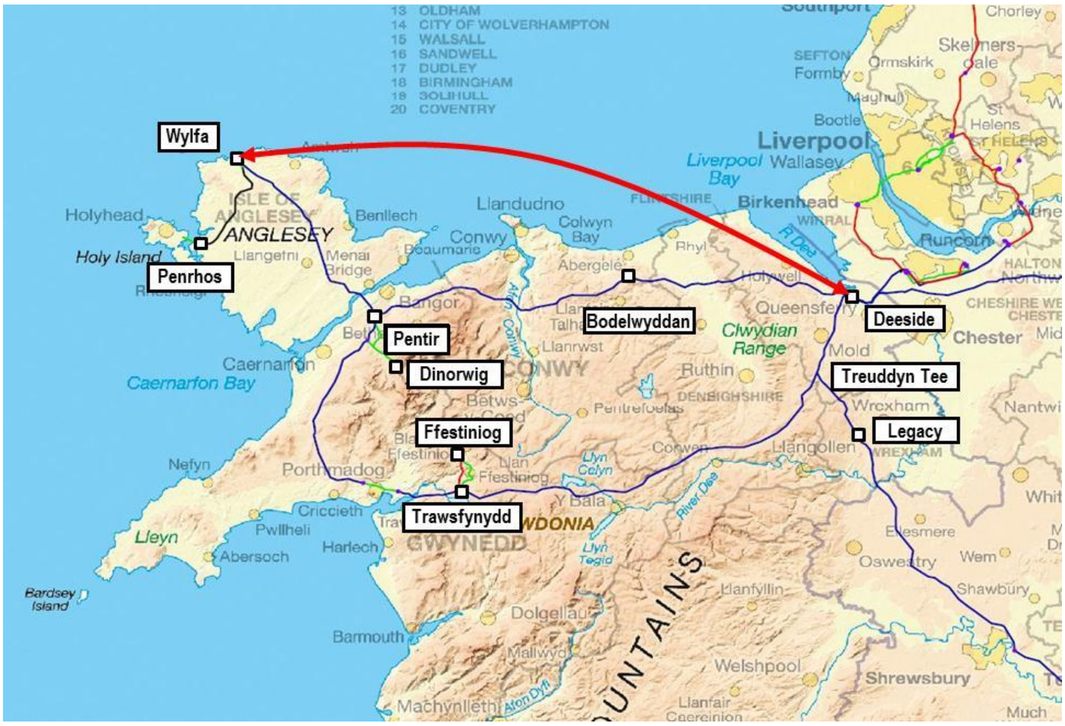


Figure 6.1 – Geographical illustration of Strategic Option 1

Technology considered

6.4 Strategic Option 1 is essentially a subsea / underground option and does not propose any new overhead line circuits.

6.5 Two technologies were initially considered for this option, namely HVDC cables and AC cables. GIL was not considered as it is not suitable for subsea installations.

6.6 The required transmission capacity could be established by the installation of two "Medium"[23] rated AC cable circuits.

6.7 AC cables with a length of over ~75km may require reactive compensation equipment to be installed along the cable length to optimise power carrying capacity on the cable. This is a requirement common to all AC cable types and is not an issue specific to this project. With a route length of 106 km, it is likely that the AC cable would need to be brought ashore at least once along the route for the connection of reactive compensation (shunt reactors) within switchgear compounds.[24]

6.8 Taking into account the environmental impact of the switchgear compounds, the additional cost of the reactive compensation and the higher cost of the AC cable, National Grid reached the conclusion that AC cable did not, in this case, offer any benefit over HVDC. Therefore, AC cable technology was not considered further for this strategic option and was not subject to detailed option appraisal.

6.9 The only remaining technology for this option is HVDC. HVDC cables do not require reactive compensation along the route and, as such, the cable would not need to be brought to shore for connection to this equipment. The majority of the route could be subsea with some underground sections at either end. As these new circuits are required to connect a power station, it is assumed at this stage that Voltage Source Converter (VSC) HVDC technology would be required. This assumption applies to all HVDC options described in this report.

6.10 To comply with the NETS SQSS, two HVDC circuits would be required, each with a capacity of 2,000 MW. [25] Four converter stations would be required, two at or near Wylfa and two at Deeside.

6.11 The main works required for Strategic Option 1, two HVDC circuits connecting Wylfa and Deeside, are:

- modification of the existing 400 kV substation at Wylfa
- modification of the existing 400 kV substation at Deeside
- construction of two converter stations at Wylfa and two at Deeside, and

[23] Circuit rating information is given in Appendix D

[24] Mid-point reactive compensation could be installed on offshore platforms but that would be a very expensive solution.

[25] All transmission equipment is procured in standard ratings to achieve economies of scale. Following discussions with manufacturers National Grid's appraisal of these options is based on a standard 2 GW converter rating.

- installation of two HVDC 2 GW subsea circuits between Wylfa and Deeside, a distance of 106 km.

Appraisal Study Area

6.12 The study area for this strategic option is shown in Figure 6.1. It is based on a direct route which, all other things being equal, would give rise to the lowest impacts and costs, with a corridor of 10 km on either side to provide reasonable opportunity to avoid constraints. In recognition of the potential restrictions imposed by existing and proposed wind farms off the North Wales coast, and the ecological sensitivity of the Dee Estuary, the study area has been extended northwards within Liverpool Bay and further inland along the eastern and western banks of the Dee Estuary to include potential cable landfall along the Denbighshire and north Wirral coast. The coast around Great Orme has been omitted from the study area as no landfall would need to be made in this location.

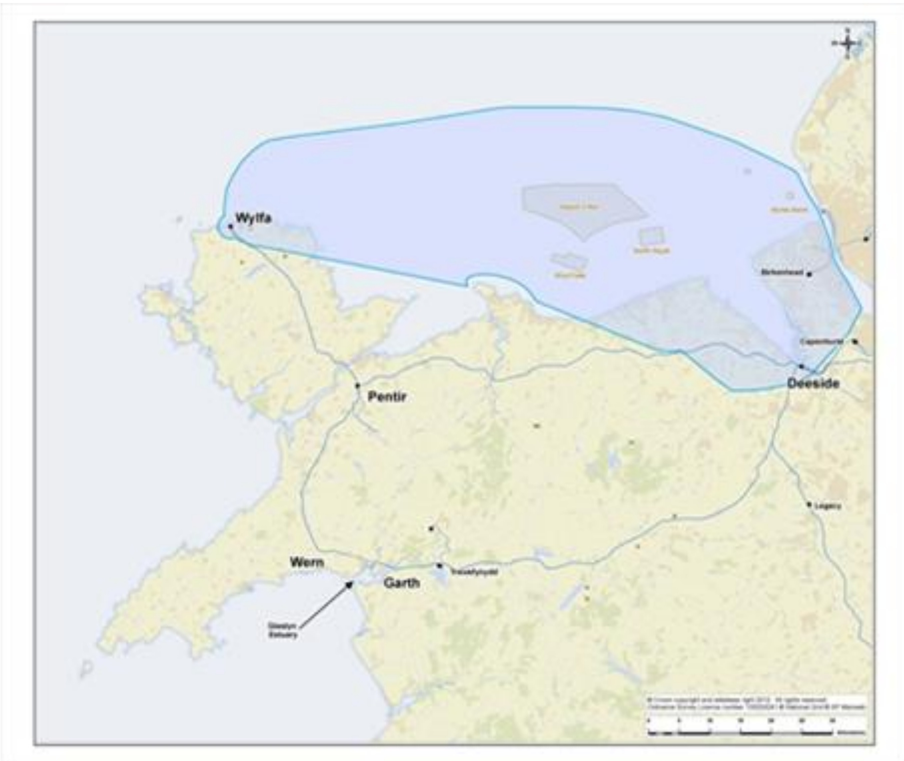


Figure 6.2 – Study Area for Strategic Option 1

6.13 The study area therefore includes an area around the existing Wylfa power station, a small portion of Anglesey's north east coast, a large area offshore including parts of Liverpool Bay, the whole of the Dee Estuary and part of the Irish

Sea, a large onshore area either side of the Dee Estuary in Denbighshire, Flintshire and The Wirral, for the routeing of three pairs of DC (marine or terrestrial) cables.

6.14 The following paragraphs set out the results of the option appraisal.

Technical and Cost Appraisal

6.15 This option would require two converter stations at Wylfa and two at Deeside, each typically having a footprint of a large warehouse and being around 25 m high.

6.16 At the time of writing there are no examples of 2 GW VSC HVDC converter stations in commercial service anywhere in the world. However, marketing material from some manufacturers does indicate that converter stations at this rating are available. As yet no orders have been placed for such equipment.

6.17 If it were to transpire that 2 GW VSC HVDC converter stations could not be delivered in the timescales necessary for this project then the required capacity would potentially have to be achieved using two converter stations of a lower rating at each end of the HVDC circuit (i.e. four converter stations in total per circuit). Use of two converters per end would increase delivery costs and land-take requirements of any HVDC option.

6.18 It should also be noted that the connection of large synchronous generators (such as the new Wylfa nuclear plant) via HVDC links is not worldwide common practice due to the increased technical complexities of this type of connection. In the event of the existing AC Wylfa to Pentir double circuit overhead line being de-energised (either planned or unplanned), the nuclear power station would be connected to the transmission system solely by HVDC circuits. This can cause significant issues with both the generator and the HVDC circuits; highly complex control and protection schemes would be required to ensure that the transmission system (both locally and nationally) remained stable and secure following such an event.

6.19 To date, no nuclear power station in the world has been connected solely by HVDC circuits. National Grid is currently undertaking a research project titled "Feasibility study of connecting a nuclear power station to the GB transmission system via HVDC technology". This work has indicated that, in theory, a connection via HVDC is feasible. However, this study is likely to recommend that a significant amount of additional research and study work would be required before any connection of this type could actually be progressed.

6.20 As a result of the current uncertainty around the feasibility technical implications of an HVDC connection, the use of HVDC circuits for the nuclear power station connection in this project is considered to represent an unproven technology risk which may result in material additional costs and delays being incurred to develop an acceptable solution. This position is supported by the generator developer, Horizon Nuclear Power, who holds the view that:

"Horizon is not aware of any precedent for a nuclear power station grid connection being achieved using HVDC technology, either in part or solely connected using that technology. We therefore see such a connection design as introducing significant additional technical risk for both normal and abnormal grid operating scenarios and we would anticipate the need for National Grid to carry out a range of studies to fully understand the nature and extent of those risks. For its part, Horizon would also wish to carry out its own independent studies to assess the technical implications of employing a connection achieved partly using HVDC technology and it is likely that a significant programme of work would need to be undertaken to enable Horizon to make such a judgement."

6.21 National Grid is continuing to monitor closely the development of VSC HVDC converter station technology and how this could be utilised in this and any future projects.

6.22 There is a possibility that harmonic issues could arise at Deeside (distortion of the power waveform quality). However, it is believed these can be designed out.

6.23 Four HVDC circuits [26] terminating at Deeside is likely to introduce complex substation control issues. However, it is believed these can be managed.

6.24 Manufacturing capacity, delivery and installation is a manageable programme risk.

[26] Two connecting to Wylfa, one to to Ireland and one to Hunterston (Scotland), the latter is currently under construction.

Costs

6.25 The capital and lifetime cost estimates for this option are shown in Tables 6.1 and 6.2.

Item	Need	Cost
Wylfa 400 kV substation	Connect power station and HVDC circuits	£38m
Deeside 400 kV substation	Connect HVDC circuits	£16m
HVDC Cable and converter stations	Increase capacity	£1,080m
Total capital cost		**£1,134m**

Table 6.1 Strategic Option 1 – Capital Cost Estimates

Capital Cost of New Circuits	£1,080m
NPV of Cost of Losses over 40 years	£314m
NPV of Operation & Maintenance Costs over 40 years	£98m
Lifetime Cost of New Circuits [27]	**£1,492m**

Table 6.2 Strategic Option 1 – New Circuits: Capital and Lifetime Cost Estimates

6.26 In summary, the estimated total capital cost of Strategic Option 1 is £1,134m and the estimated lifetime cost of the new circuits is £1,492m.

Environmental - Ecology and Biodiversity

6.27 The principal ecological sites affecting this option are shown in Figure G.2 in Appendix G of this report. The study area offshore and onshore around the Liverpool Bay and Dee Estuary areas has a high concentration of designated sites. Ecological constraints considered to be material to the decision are:

- Liverpool Bay SPA
- Dee Estuary SAC SPA SSSI and Ramsar
- Halkyn Mountain SAC and SSSI
- Halkyn Common And Holywell Grasslands SSSI
- Gronant Dunes SSSI.

[27] The lifetime cost calculation methodology is explained in Appendix D. It is used to compare the cost of connecting transmission substations using various technologies for the new circuits. It does not include the capital or lifetime costs of substation equipment. The lifetime cost is the net present value of the costs of transmission losses and maintenance over 40 years. A discount rate of 3.5% is used.

6.28 The Liverpool Bay SPA is considered material to the decision. While it cannot be avoided and there is a high likelihood of there being some effects in combination with other developments, feedback from early consultation suggests that mitigation measures could minimise the impact on the site thereby avoiding the risk of affecting the site's integrity. All of the other ecological sites listed above are also considered to be material although they can be avoided by careful routeing. However, due to the concentration around the Dee Estuary, the only area where the HVDC cables could land that would avoid these material constraints would be between Prestatyn and Rhyl, leading to more extensive onshore works.

Environmental - Cultural Heritage, Landscape and Visual

6.29 The principal cultural heritage and landscape designations affecting this option are shown in Figure G.2 in Appendix G of this report. From a cultural heritage, landscape and visual aspect, the majority of constraints on-land around the North Wales coast and the Wirral can be individually avoided by careful routeing of the HVDC cables, therefore they have not been identified as being material to the decision when considered individually (except for settlements). However, there is a very high concentration of settlements, Scheduled Monuments and Registered Parks and Gardens onshore around the Dee Estuary (east and west). These together with the Holywell Common and Halkyn Mountain Registered Historic Landscape significantly limit route availability, and thus are material to the decision. Given the industrial context of the immediate area around Deeside the landscape and visual impact resulting from converter stations are not considered material to the decision. The study area around Wylfa has a number of cultural heritage, landscape and visual constraints. The risk of directly impacting constraints in the area around Wylfa can be managed through careful routeing, siting and appropriate mitigation. It is, however, noted that converter stations near Wylfa may indirectly affect the Anglesey AONB but this will be seen in context with other developments in this area, such as Horizon's nuclear power station.

Environmental - Other Environmental Sub-topics

6.30 No constraints considered to be material to the decision within the sub-topics noise and vibration, soil and geology, and hydrology and flood risk have been identified.

Environmental - Consideration of combined Environmental Sub-topics

6.31 When considered in combination, the features and designated sites identified across all environmental sub-topics form a number of constrained 'belts' and 'hubs' of high concentrations across the study area. Such constraints are considered to be significant especially within Flintshire and the Wirral. In isolation effects upon these constraints can generally be mitigated or avoided but in combination they are material to the decision.

Socio-Economic - Economic Activity & People and Communities

6.32 Constraints appraised within these sub-topics do not provide sufficient definition between options so as to be considered material to the decision at this level of appraisal. However key socio-economic issues have been identified.

6.33 Socio-economic impacts are considered to be more extensive during construction than during operation for this strategic option. Areas that are considered likely to receive most of the direct socio-economic impacts during construction are around Wylfa and the Dee Estuary.

6.34 Construction of converter stations and the onshore section of the HVDC cables will require a large workforce, a proportion of which can be sourced locally. The works to be undertaken offshore would mostly utilise a specialist workforce. Construction-related employment would particularly benefit Anglesey and Deeside.

6.35 The study area around the Dee Estuary has dense transport infrastructure which will be impacted upon as a result of the trenching for HVDC cables. Some disruption to the road and rail networks around the Dee Estuary area would be expected during construction.

6.36 There are no expected impacts on tourism for this strategic option as any road and rail disruption is unlikely to deter tourists from the area - although locally tourists may substitute one site for another. The most significant economic activity on Anglesey is tourism and there are some tourism destinations in proximity to Deeside; however regionally this option is unlikely to have an impact on the tourism industry.

6.37 Potential benefits from this strategic option include an increase in economic activity due to a specialised work force being located in the area for approximately four years and the opportunities for local employment.

Feedback from Stage 1 Consultation Events

6.38 A number of respondents identified Strategic Options 1 and 2 as their favoured Options because they considered them to have the least visual impact and considered that any associated technical difficulties of using HVDC cables could be overcome. Respondents considered that a subsea connection would be affordable in the long term, especially when costs were spread out across GB electricity consumers.

7 Strategic Option 2

7.1 Strategic Option 2 would provide the additional transmission capacity required across Anglesey and North Wales (reinforcing each of the three boundaries described in section 3)through the installation of approximately 106 km of subsea cable between Wylfa and Deeside and the installation of approximately 231 km of subsea cable between Wylfa and Pembroke.

7.2 A geographical illustration of Strategic Option 2 is shown in Figure 7.1.

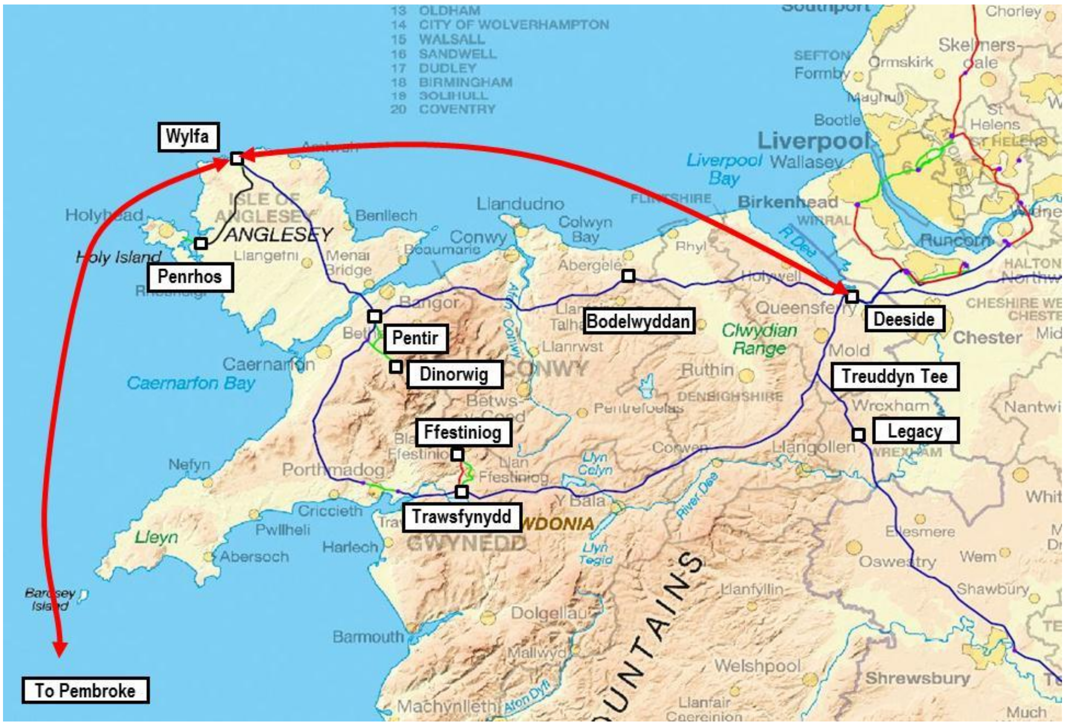


Figure 7.1 – Geographical illustration of Strategic Option 2

<u>Technology considered</u>

7.3 Like strategic option 1, option 2 is essentially a subsea / underground option and does not propose any new overhead line circuits.

7.4 Again, two technology options were initially considered for this option, namely HVDC cables and AC cables. GIL was not considered as it is not suitable for subsea installations.

7.5 The required transmission capacity could be established by the installation of one

"Medium" rated AC cable circuit between Wylfa and Deeside and one "Medium" rated AC cable circuit between Wylfa and Pembroke.

7.6 As with option 1, with route lengths of 106 km (Wylfa to Deeside) and 231 km (Wylfa to Pembroke) the AC cables would likely require mid-point compensation to be installed and therefore may need to be brought ashore at several locations along the route for the connection of reactive compensation (shunt reactors) within switchgear compounds. [28]

7.7 Taking into account the environmental impact of the switchgear compounds, the additional cost of the reactive compensation and the higher cost of the AC cable, National Grid reached the conclusion that AC cable did not offer, in this case, any benefit over HVDC. Therefore, AC cable technology was not considered further for this strategic option and was not subject to detailed option appraisal.

7.8 The only remaining technology for this option is HVDC. HVDC does not require reactive compensation along the route and, as such, the cable would not need to be brought to shore for connection to this equipment. Most of the route could be subsea with some underground sections at either end.

7.9 In order to comply with the NETS SQSS, two HVDC circuits would be required, each with a capacity of 2,000 MW. Taking more than 2,000 MW to Pembroke would trigger transmission reinforcements in South Wales and for that reason this option comprises one HVDC circuit to Deeside and a second circuit to Pembroke. Two converter stations would be required at Wylfa, one at Deeside and one at Pembroke.

7.10 The main works required for Strategic Option 2, one HVDC circuit connecting Wylfa and Deeside and one HVDC circuit connecting Wylfa and Pembroke, are:

- modification of the existing 400 kV substation at Wylfa
- modification of the existing 400 kV substations at Deeside and Pembroke
- construction of two converter stations at Wylfa, one at Deeside and one at Pembroke
- installation of one HVDC 2 GW subsea circuit between Wylfa and Deeside, a distance of 106 km

[28] `As with Strategic Option 1, mid-point reactive compensation could be installed on offshore platforms but that would be a very expensive solution.

- installation of one HVDC 2 GW subsea circuits between Wylfa and Pembroke, a distance of 231 km.

<u>Appraisal Study Area</u>

7.11 The study area for this strategic option is shown in Figure 7.2. It is based on a direct route, which all other things being equal, would give rise to the lowest impacts and costs, with a corridor of 10 km on either side to provide reasonable opportunity to avoid constraints.

7.12 The area for the two Wylfa to Deeside circuit is as for Strategic Option 1. The study area for the single Wylfa to Pembroke circuit is based upon a reasonable direct route between the two sites. The study area is generally 20 km wide, except where it narrows to exclude consideration of additional onshore constraints on Anglesey and the Llyn Peninsula. An alternative study area, based upon a landfall on the south Pembrokeshire coast was considered, but would have encompassed significant areas of additional constraint and resulted in higher costs due to increased route length.

Figure 7.2 – Study Area for Strategic Option 2

7.13 The study area therefore includes an area around the existing Wylfa power station, a small portion of Anglesey's north east coast, a large area off-shore including parts of the Irish Sea and Liverpool Bay, the whole of the Dee Estuary and a large onshore area either side of the Dee Estuary in Denbighshire, Flintshire and The Wirral. It also includes a separate study area running south from Wylfa, through Cardigan Bay, making landfall on the north Pembrokeshire Coast and includes a large swathe between the coast and Pembroke substation.

7.14 The following paragraphs set out the results of the option appraisal.

Technical and Cost Appraisal

7.15 This option would require two converter stations at Wylfa, one at Deeside and one at Pembroke, each typically having a footprint of a large warehouse and being around 25 m high.

7.16 As with Strategic Option 1, at the time of writing there are no examples of 2 GW VSC HVDC converter stations in commercial service anywhere in the world. However, marketing material from some manufacturers does indicate that converter stations at this rating are available. However, as yet no orders have yet been placed for such equipment.

7.17 If it were to transpire that 2 GW VSC HVDC converter stations could not be delivered in the timescales necessary for this project then the required capacity would potentially have to be achieved using two converter stations of a lower rating at each end of the HVDC circuit. Use of two converters per end would increase delivery costs and land-take requirements of any HVDC option.

7.18 It should also be noted that the connection of large synchronous generators (such as the new Wylfa nuclear plant) via HVDC links is not worldwide common practice due to the increased technical complexities of this type of connection. In the event of the existing AC Wylfa to Pentir double circuit overhead line being de-energised (either planned or unplanned), the nuclear power station would be connected to the transmission system solely by HVDC circuits. This can cause significant issues with both the generator and the HVDC circuits; highly complex control and protection schemes would be required to ensure that the transmission system (both locally and nationally) remained stable and secure following such an event.

7.19 To date, no nuclear power station in the world has been connected solely by HVDC circuits. National Grid is currently undertaking a research project titled "Feasibility study of connecting a nuclear power station to the GB transmission system via HVDC technology". This work has indicated that, in theory, a connection via HVDC is feasible. However, this study is likely to recommend that a significant amount of additional research and study work would be required before any connection of this type could actually be progressed.

7.20 As a result of the current uncertainty around the feasibility technical implications of an HVDC connection, the use of HVDC circuits for the nuclear power station connection in this project is considered to represent an unproven technology risk which may result in material additional costs and delays being incurred to develop an acceptable solution. This position is supported by the generator developer, Horizon Nuclear Power, who holds the view that:

7.21 "Horizon is not aware of any precedent for a nuclear power station grid connection being achieved using HVDC technology, either in part or solely connected using that technology. We therefore see such a connection design as introducing significant additional technical risk for both normal and abnormal grid operating scenarios and we would anticipate the need for National Grid to carry out a range of studies to fully understand the nature and extent of those risks. For its part, Horizon would also wish to carry out its own independent studies to assess the technical implications of employing a connection achieved partly using HVDC technology and it is likely that a significant programme of work would need to be undertaken to enable Horizon to make such a judgement." National Grid is continuing to monitor closely the development of VSC HVDC converter station technology and how this could be utilised in this and any future projects.

7.22 There is a possibility that harmonic issues could arise at Deeside (distortion of the power waveform quality). However, it is believed these can be designed out.

7.23 Three HVDC circuits [29] terminating at Deeside is likely to introduce complex substation control issues. However, it is believed these can be managed.

7.24 Manufacturing capacity, delivery and installation is a manageable programme risk.

7.25 This option has a potential advantage over option 1 in that it takes some power to

[29] One connecting to Wylfa, one to Ireland and one to Hunterston (Scotland), the latter currently under construction.

South Wales and might therefore avoid overloading the transmission system in the North West and the West Midlands.

Costs

7.26 The capital and lifetime cost estimates for this option are shown in Tables 7.1 and 7.2.

Item	Need	Cost
Wylfa 400 kV substation	Connect power station and HVDC circuits	£38m
Modify Deeside and Pembroke substations	Connect HVDC circuits	£15m
HVDC Cable and converter stations	Increase capacity	£1,325m
Total capital cost		**£1,378m**

Table 7.1 Strategic Option 2 – Capital Cost Estimates

Capital Cost of New Circuits	£1,325m
NPV of Cost of Losses over 40 years	£314m
NPV of Operation & Maintenance Costs over 40 years	£98m
Lifetime Cost of New Circuits [30]	**£1,737m**

Table 7.2 Strategic Option 2 – New Circuits: Capital and Lifetime Cost Estimates

7.27 In summary, the estimated total capital cost of Strategic Option 2 is £1,378m and the estimated lifetime cost of the new circuits is £1,737m.

Environmental - Ecology and Biodiversity

7.28 The principal ecological sites affecting this option are shown in Figure G.3 in Appendix G of this report. The study area offshore and on-land around the Liverpool Bay, Dee Estuary and in Pembrokeshire has a high concentration of designated sites. Ecological constraints considered to be material to the decision are;

- Liverpool Bay SPA

[30] The lifetime cost calculation methodology is explained in Appendix D. It is used to compare the cost of connecting transmission substations using various technologies for the new circuits. It does not include the capital or lifetime costs of substation equipment. The lifetime cost is the net present value of capital costs, the costs of transmission losses and maintenance costs over 40 years. A discount rate of 3.5% is used.

- Dee Estuary SAC SPA SSSI and Ramsar
- Halkyn Mountain SAC and SSSI
- Halkyn Common And Holywell Grasslands SSSI
- Gronant Dunes SSSI
- Cleddau Rivers SAC
- St David's SAC
- Milford Haven Waterway SSSI
- Pembrokeshire Marine SAC
- Eastern Cleddau River SSSI
- Strumble Head - Llechdafad Cliffs SSSI
- Western Cleddau River SSSI.

7.29 Milford Haven Waterway SSSI and Pembrokeshire Marine SAC are considered material to the decision as these cannot be avoided. However, it is recognised that mitigation measures may be available which would minimise the impact on all of these sites. The Liverpool Bay SPA is considered material to the decision. While it cannot be avoided and there is a high likelihood of there being some effects in combination with other developments, feedback from early consultation suggests that mitigation measures could minimise the impact on the site thereby avoiding the risk of affecting the site's integrity. All of the other constraints are considered to be material as they can be avoided by careful routeing. However, due to the concentration around the Dee Estuary and the north Pembrokeshire coast, the only area where the HVDC cables can come ashore avoiding material constraints is between Prestatyn and Rhyl and in the vicinity of Fishguard respectively.

Environmental - Cultural Heritage, Landscape and Visual

7.30 The principal cultural heritage and landscape designations affecting this option are shown in Figure G.3 in Appendix G of this report. From a cultural heritage, landscape and visual aspect, the majority of constraints on-land around the North Wales coast and the Wirral can be individually avoided by careful routeing of the HVDC cables, and therefore they have not been identified as being material to the decision when considered individually (except for settlements). However, there is a very high concentration of settlements, Scheduled Monuments and Registered

Parks and Gardens onshore around the Dee Estuary (east and west). These together with the Holywell Common and Halkyn Mountain Registered Historic Landscape significantly limit route availability, and thus are material to the decision. Given the industrial context of the immediate area around Deeside the landscape and visual impact resulting from converter stations is not considered significant. The study area around Wylfa has a number of cultural heritage, landscape and visual constraints. The direct risk of impacting constraints in the area around Wylfa can be managed through careful routeing, siting and appropriate mitigation. It is, however, noted that converter stations near Wylfa may indirectly affect the Anglesey AONB but this will be seen in context with other developments in this area such as Horizon's nuclear power station.

7.31 Within the Pembrokeshire study area, there is also a high concentration of cultural heritage, landscape and visual constraints which are considered material to the decision

- Milford Haven Waterway, Registered Historic Landscape of Outstanding Interest
- Pembrokeshire Coast National Park
- Dinas Head Heritage Coast
- St.David's Peninsula Heritage Coast
- Pen Gaer: Garn Fawr and Strumble Registered Historic Landscape of Special Interest
- Seven areas of landscape along the Pembrokeshire coast identified as having outstanding value in visual terms (CCW LANDMAP Visual and Sensory aspect).

7.32 Milford Haven Historic Landscape cannot be avoided, however the landscape around Pembroke substation is industrial in character, therefore there would be minimal impacts to this constraint due to the nature of the area. All of the other constraints listed above can be avoided through careful routeing; however the concentration of constraints limits available landing points and cable routes.

7.33 There are a significant number of constraints, specifically on-land around the Dee Estuary and along the coast of Pembrokeshire, but of a type where mitigation is generally believed to be effective.

Environmental – Other Environmental Sub-topics

7.34 No constraints considered to be material to the decision within the sub-topics noise and vibration, soil and geology and hydrology and flood risk have been identified.

Environmental - Consideration of combined Environmental Sub-topics

7.35 When considered in combination, the constraints identified across all environmental sub-topics form a number of constrained 'belts' across the study area, and hubs of high concentrations of assets considered to be significant especially within Flintshire, the Wirral and north Pembrokeshire. In isolation effects upon these constraints can generally be mitigated or avoided but in combination they are material to the decision.

Socio-Economic - Economic Activity & People and Communities

7.36 No constraints appraised within this sub-topic are considered material to the decision at this level of appraisal. However key socio-economic issues have been identified.

7.37 Socio-economic impacts are considered to be more extensive during construction than during operation for this strategic option. Areas that are considered likely to receive most of the direct socio-economic impacts during construction are around Wylfa, the Dee Estuary and Pembrokeshire.

7.38 Construction of converter stations and the on-shore section of the HVDC cables will require a large workforce, a proportion of which can be sourced locally. The works to be undertaken off-shore would mostly utilise a specialist workforce. Construction-related employment would particularly benefit Anglesey, Deeside and south Pembrokeshire.

7.39 The study areas around the Dee Estuary and Pembroke have dense transport infrastructure which will be impacted upon as a result of the trenching of HVDC cable. Disruption to the road and rail networks in these areas is expected during construction.

7.40 There are no expected impacts to tourism for this option as any road and rail disruption is unlikely to deter tourists from the areas - although locally tourists may substitute one site for another. The most significant economic activity on Anglesey is tourism and there are tourism destinations in Pembrokeshire and in proximity to Deeside. However, regionally this option is unlikely to have an impact on the tourism industry.

7.41 Potential benefits from this strategic option include an increase in economic activity due to a specialised work force being located in the area for approximately four years and the opportunities for local employment.

Feedback from Stage 1 Consultation Events

7.42 A number of respondents identified Strategic Option 1 and 2 as their favoured Options because they considered them to have the least visual impact and considered that any associated technical difficulties of using HVDC cables could be overcome. Respondents considered that a subsea connection would be affordable in the long term, especially when costs were spread out across GB electricity consumers.

8 Strategic Options 3, 4, 5 and 6

8.1 These four options can all be split into two distinct parts, works between Wylfa and Pentir (reinforcing boundary NW1), and works on the North Wales mainland (reinforcing boundaries NW2 and NW3).

8.2 The works proposed on the North Wales mainland to reinforce boundaries NW2 and NW3 are identical for all four of these strategic options.

8.3 The unique elements of these options (the works on Anglesey between Wylfa and Pentir to reinforce boundary NW1) will be appraised individually and the common elements (the works on the mainland to reinforce boundaries NW2 and NW3) appraised separately only once in section 13.

Technology Options between Wylfa and Pentir

8.4 Four technology options were considered to resolve the constraint between Wylfa and Pentir (across boundary NW1), namely AC overhead line, AC cables (underground or subsea), GIL and HVDC (underground or subsea).

8.5 There are two key NETS SQSS requirements when assessing this part of the existing system:

- Paragraph 2.6.4 of the NETS SQSS requires that following the concurrent de-energisation of any two transmission circuits the loss of power infeed to the system shall not exceed a defined value. From 1 April 2014 that value has been set at 1,800 MW (1.8GW)
- Paragraph 2.10 of the NETS SQSS requires that the transmission capacity for the connection of a power station(s) shall be planned such that in the event of the de-energisation of two circuits there shall not be any unacceptable overloading of any transmission equipment.

8.6 The new nuclear generator planned to connect at Wylfa 400kV substation has a capacity of 2.8 GW. Therefore, if no new circuits are installed, the de-energisation of the existing two circuits will result in a loss of power infeed that is greater than the 1.8 GW limit.

AC Overhead Line

8.7 The additional capacity across Anglesey could be established by the construction of a 40 km AC double-circuit overhead line.

8.8 Since AC overhead line is only suitable for onshore applications, this technology is only considered for Strategic Option 3 and for the onshore section of Strategic Option 6.

AC Underground Cable

8.9 The additional transmission capacity could also be established by the installation of two AC cable circuits between Wylfa and Pentir. These cables could be laid either underground or subsea, going round the east or the west of Anglesey. Accordingly, this technology is considered for strategic options 3, 4, 5 and 6.

8.10 This option would require substation modifications at Wylfa and Pentir with the installation of new switchgear and connection of reactive compensation equipment.

GIL

8.11 Two GIL circuits could also provide the necessary capacity for boundary NW1. GIL cannot be laid subsea and would therefore be a land-based, underground option only. Accordingly, this technology is only considered for Strategic Option 3 and for the onshore section of Strategic Option 6.

HVDC

8.12 HVDC could also be used to create the required capacity between Wylfa and Pentir. The HVDC cables could be laid either underground or subsea, going round the east or the west of Anglesey. This technology is therefore considered for strategic options 3, 4, 5, and for the offshore section of Strategic Option 6.

8.13 Two HVDC circuits with a total capacity of 3 GW would be required, with four converter stations, two at Wylfa and two at Pentir.

9 Appraisal of Strategic Option 3 – Wylfa - Pentir Works

9.1 Strategic Option 3 would provide the additional transmission capacity required across Anglesey, to reinforce boundary NW1, through the installation of approximately 40 km of onshore circuits between Wylfa and Pentir.

9.2 A geographical illustration of Strategic Option 3 is shown in Figure 9.1.

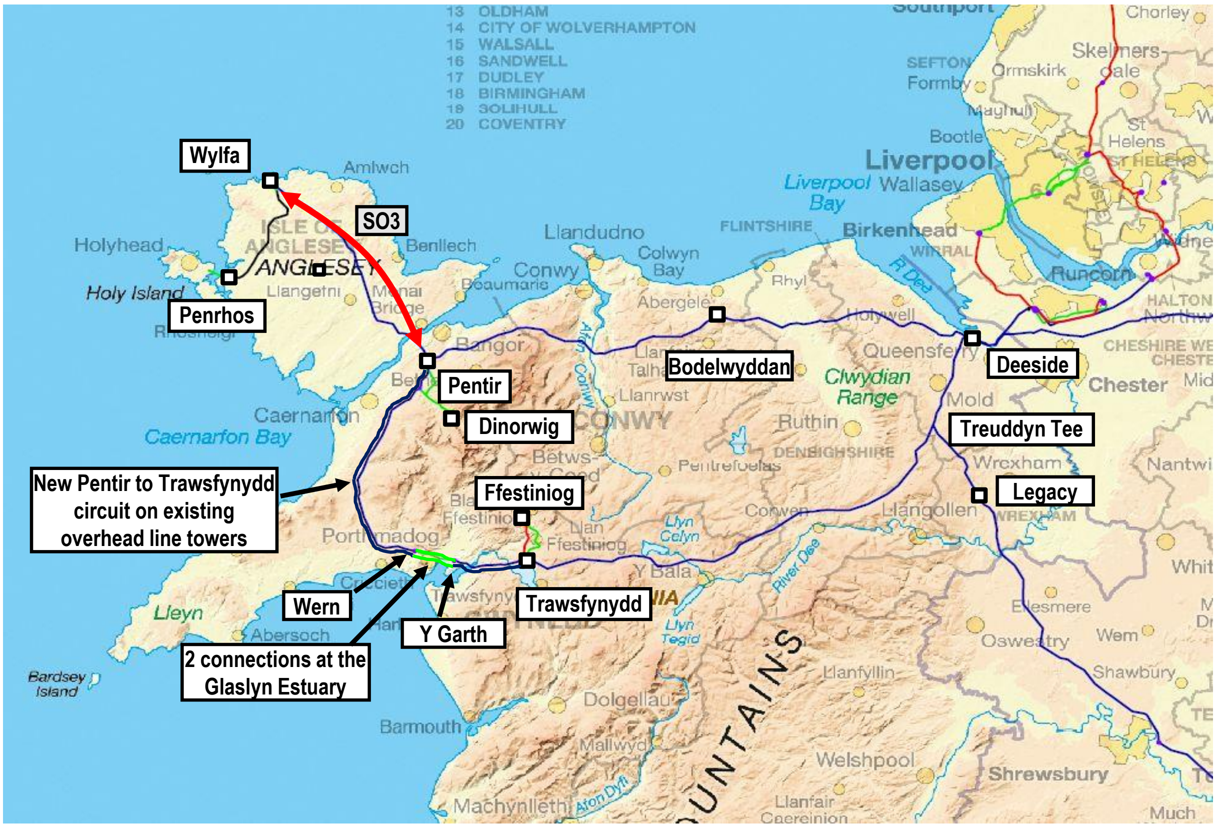


Figure 9.1 – Geographic Illustration of Strategic Option 3

9.3 The main works required for the Anglesey elements of Strategic Option 3, Wylfa to Pentir Onshore, are:

- modification of the existing 400 kV substation at Wylfa
- modification of the existing 400 kV substation at Pentir
- installation of circuits (AC or HVDC) between Wylfa and Pentir, a distance of 40 km
- for HVDC, the installation of two converter stations at Wylfa and two at Pentir.

9.4 The study area for this strategic option, shown in Figure 9.2. It is based on a direct route, which all other things being equal, would give rise to the lowest impacts and costs, with a corridor of 10 km on either side to provide reasonable opportunity to avoid constraints. The study area therefore includes an extensive area that encompasses much of Anglesey and a large area on the mainland.

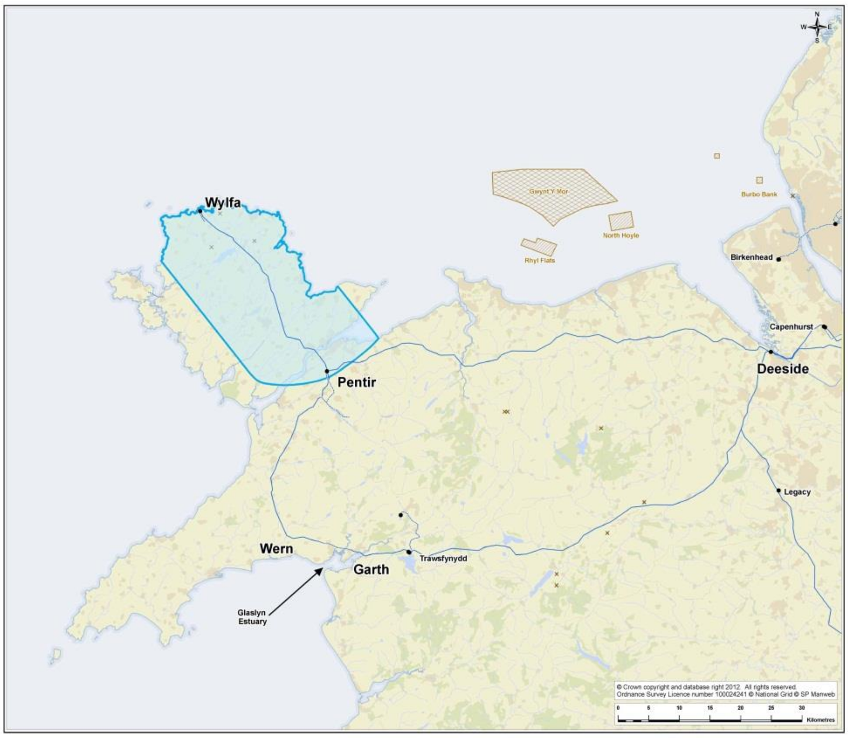


Figure 9.2 – Study Area for Strategic Option 34 – Anglesey Works

9.5 The following paragraphs set out the results of the option appraisal.

Technical and Cost Appraisal

9.6 A NETS SQSS compliant onshore connection between Wylfa and Pentir could be made using any of the following technologies:

- AC Overhead lines (double circuit)
- AC Underground cables (two circuits)
- AC Gas Insulated Line (two circuits), and
- HVDC (two circuits)

AC Overhead Line

9.7 The double circuit overhead line would follow a route across Anglesey, as yet unidentified, and would cross Menai Strait at a suitable location before heading inland to Pentir. AC overhead line is a well proven technology and, although vulnerable in adverse weather conditions, most faults are temporary and self-rectifying. Faults which require remedial work are normally repaired quicker than faults on underground cables.

All Underground Technologies

9.8 The three underground technologies (AC underground, GIL, and HVDC) would also follow a suitable route.

HVDC

9.9 The HVDC option would require two converter stations at Wylfa and two at Pentir, each typically having a footprint of a large warehouse and being around 25 m high. Two HVDC links of 1.5 GW each would be required for Strategic Option 3. This is different to the two 2 GW links required for Strategic Options 1 and 2 due to the fact that those options do not include any reinforcement of the transmission system on the North Wales mainland, and hence the additional HVDC capacity is required to reinforce boundaries NW2 and NW3. For Strategic Option 3, this additional capacity is provided by the mainland common works described in chapters 13 to 16. This also applies to Strategic Options 4, 5, and 6.

9.10 At the time of writing there are no examples of 1.5 GW VSC HVDC converter stations in commercial service anywhere in the world. However, marketing material from some manufacturers does indicate that converter stations at this rating are available. However, as yet no orders have yet been placed for such equipment.

9.11 Although 1.5 GW VSC converters are not a proven technology, it is considered that a converter station of this rating would present a far lower degree of uncertainty and that than the 2 GW VSC converters required for Strategic Options 1 and 2. However, the technical risks associated with connecting large synchronous generators via HVDC circuits (see following paragraphs) apply equally to 1.5 GW and 2 GW VSC HVDC.

9.12 The connection of large synchronous generators (such as the new Wylfa nuclear plant) via HVDC links is not worldwide common practice due to the increased technical complexities of this type of connection. In the event of the existing AC Wylfa to Pentir double circuit overhead line being de-energised (either planned or unplanned), the nuclear power station would be connected to the transmission system solely by HVDC circuits. This can cause significant issues with both the generator and the HVDC circuits; highly complex control and protection schemes would be required to ensure that the transmission system (both locally and nationally) remained stable and secure following such an event.

9.13 To date, no nuclear power station in the world has been connected solely by HVDC circuits. National Grid is currently undertaking a research project titled "Feasibility study of connecting a nuclear power station to the GB transmission system via HVDC technology". This work has indicated that, in theory, a connection via HVDC is feasible. However, this study is likely to recommend that a significant amount of additional research and study work would be required before any connection of this type could actually be progressed.

9.14 As a result of the current uncertainty around the feasibility technical implications of an HVDC connection, the use of HVDC circuits for the nuclear power station connection in this project is considered to represent an unproven technology risk which may result in material additional costs and delays being incurred to develop an acceptable solution. This position is supported by the generator developer, Horizon Nuclear Power, who holds the view that:

9.15 "Horizon is not aware of any precedent for a nuclear power station grid connection being achieved using HVDC technology, either in part or solely connected using that technology. We therefore see such a connection design as introducing significant additional technical risk for both normal and abnormal grid operating scenarios and we would anticipate the need for National Grid to carry out a range of studies to fully understand the nature and extent of those risks. For its part, Horizon would also wish to carry out its own independent studies to assess the technical implications of employing a connection achieved partly using HVDC technology and it is likely that a significant programme of work would need to be undertaken to enable Horizon to make such a judgement."

9.16 National Grid is continuing to monitor closely the development of VSC HVDC converter station technology and how this could be utilised in this and any future projects.

AC Underground Cable

9.17 Installation of this scale of AC cable system presents a number of technical issues which are likely to be surmountable but which must be carefully considered in cable system design and implementation.

GIL

9.18 GIL is similar in capital cost to AC cable. GIL has not been installed anywhere in the world with the capacity or length required for this application.

Costs

9.19 The capital and lifetime cost estimates for this option are shown in tables 9.1 and 9.2.

Item	**Need**	**Cost**			
Wylfa 400 kV substation	Connect Wylfa power station and the new circuits	£38m			
Pentir 400 kV substation	Connect new circuits	£25m			
New Circuits		**OHL**	**AC Cable**	**GIL**	**HVDC**
Wylfa to Pentir ('Lo' Capacity, 40 km)	Connect Wylfa to Pentir creating Wylfa export capability	£101m	£522m	£735m	£713m
Total Capital Cost		**£164m**	**£585m**	**£798m**	**£776m**

Table 9.1 Strategic Option 3 – Anglesey Works – Wylfa - Pentir Onshore: Capital Cost Estimates

	OHL	AC Cable	GIL	HVDC
Capital Cost of New Circuits	£101m	£522m	£735m	£713m
NPV of Cost of Losses over 40 years	£42m	£31m	£15m	£236m
NPV of Operation & Maintenance Costs over 40 years	£2m	£4m	£2m	£98m
Lifetime Cost of New Circuits [31]	**£145m**	**£557m**	**£752m**	**£1,047m**

Table 9.2 Strategic Option 3 – Anglesey Works – Wylfa - Pentir Onshore: New Circuits: Capital and Lifetime Cost Estimates

9.20 In summary, the estimated total capital costs for the Anglesey works of this option vary between £164m for overhead line and £798m for GIL. The estimated lifetime costs for the new circuit elements vary between £145m for overhead line and £1,047m for HVDC.

Environmental - Ecology and Biodiversity

9.21 The principal ecological sites affecting this option are shown in Figure G.6 in Appendix G of this report. There are seven ecological constraints within the study area between Wylfa and Pentir which are considered to be material to the decision:

- Menai Strait and Conwy Bay SAC (not considered material for overhead line)
- Coedydd Afon Menai SSSI
- Anglesey Fens SAC
- Cors Erddreiniog SSSI
- Llyn Alaw SSSI
- Glannau Porthaethwy SSSI
- Malltraeth Marsh SSSI
- Traeth Lafan SSSI.

9.22 It is considered that impacts on these constraints could be avoided through careful routing of overhead lines or, where appropriate, the use of other

[31] The lifetime cost calculation methodology is explained in Appendix D. It is used to compare the cost of connecting transmission substations using various technologies for the new circuits. It does not include the capital or lifetime costs of substation equipment. The lifetime cost is the net present value of capital costs, the costs of transmission losses and maintenance costs over 40 years. A discount rate of 3.5% is used.

mitigation measures such as undergrounds cable sections.

Environmental - Cultural Heritage, Landscape and Visual

9.23 The principal cultural heritage and landscape designations affecting this option are shown in Figure G.6 in Appendix G of this report. Within the study area between Wylfa and Pentir, cultural heritage, landscape and visual constraints considered to be material to the decision across all technology options are the Isle of Anglesey Coastal Path, (a Designated National Trail) and settlements.

9.24 In addition, for overhead line technology other designations and protected sites that are material to the decision are the Anglesey Area of Outstanding Natural Beauty, which while it could be avoided around much of the Anglesey coastline, could not be avoided at Menai Strait. In addition the Registered Park and Gardens of Plas Newydd overlooking Menai Strait and Vaynol on the mainland shore of the Strait are also considered material to the consideration of the use of an overhead line. The AONB and coastal path would experience long term visual impacts from an overhead line, most notably where the route would cross the Menai Strait; however the registered parks and gardens can be directly avoided but may experience indirect long term visual impacts.

9.25 In the case of underground technologies, significant effects upon the AONB may be avoided, and would in any event be largely restricted to the construction phase. Impacts to settlements from underground technologies can be easily avoided through careful routeing.

9.26 It is noted that, for HVDC options, converter stations near Wylfa may indirectly affect the AONB but this will be seen in context with other developments in this area.

9.27 Converter stations located in the vicinity of Pentir substation would be around 5 km from the boundary of Snowdonia National Park, and due to the elevation of the land within the Park and the scale of the converter station buildings, impacts to views from the Park are possible. While Pentir's remote rural location is likely to result in adverse landscape effects (despite the presence of existing transmission infrastructure) visual effects are likely to be localised.

Environmental – Other Sub-topics

9.28 No constraints considered to be material to the decision within the sub-topics noise and vibration, soil and geology and hydrology and flood risk have been identified.

Environmental – Consideration of combined Environmental Sub-topics

9.29 The study areas around Menai Strait and Beaumaris both have a high concentration of cultural heritage, landscape and visual constraints. The Beaumaris area can be easily avoided but the high concentration around Menai Strait limits the available transmission routes across the Strait. This concentration is considered to be material to the decision in the case of overhead line technology.

Socio-Economic - Economic Activity & People and Communities

9.30 No constraints appraised within this sub-topic are considered material to the decision at this level of appraisal. However key socio-economic issues have been identified.

9.31 Socio-economic impacts are considered to be more extensive during construction than during operation. Areas that are considered likely to receive most of the direct socio-economic impacts during construction are Anglesey and Menai Strait. Construction is estimated to take approximately two years for overhead line technology and around four years for buried technology.

9.32 Some localised disruption during construction is expected for road networks across Anglesey, Gwynedd and North Wales. This could temporarily impact local communities, businesses and access to public service infrastructure.

9.33 Regionally, transport disruption could have a low to moderate impact on the tourism industry as tourism is one of the region's largest sources of employment.

9.34 Potential benefits from this option include an increase in economic activity due to a specialised work force being located in the area for approximately four years and the opportunities for local employment.

Feedback from Stage 1 Consultation Events

9.35 Respondents generally expressed a preference for the use of underground technology as opposed to any overhead line connection. Opposition to this strategic option was mainly related to perceived environmental, landscape and visual, economic and health effects, which were suggested as being associated with an overhead line. Respondents suggested that any disruption caused by the construction effects of undergrounding would be offset by the perceived longer term gains of less visual impact. Conversely, a number of respondents raised concerns about the impacts of undergrounding, particularly during the construction phase with respondents citing the detrimental effects that installing underground cables would have on the countryside.

10 Appraisal of Strategic Option 4 – Wylfa - Pentir Works

10.1 Strategic Option 4 would provide the additional transmission capacity required across Anglesey, reinforcing boundary NW1, through the installation of approximately 64 km of offshore circuits between Wylfa and Pentir, located off the east coast of Anglesey.

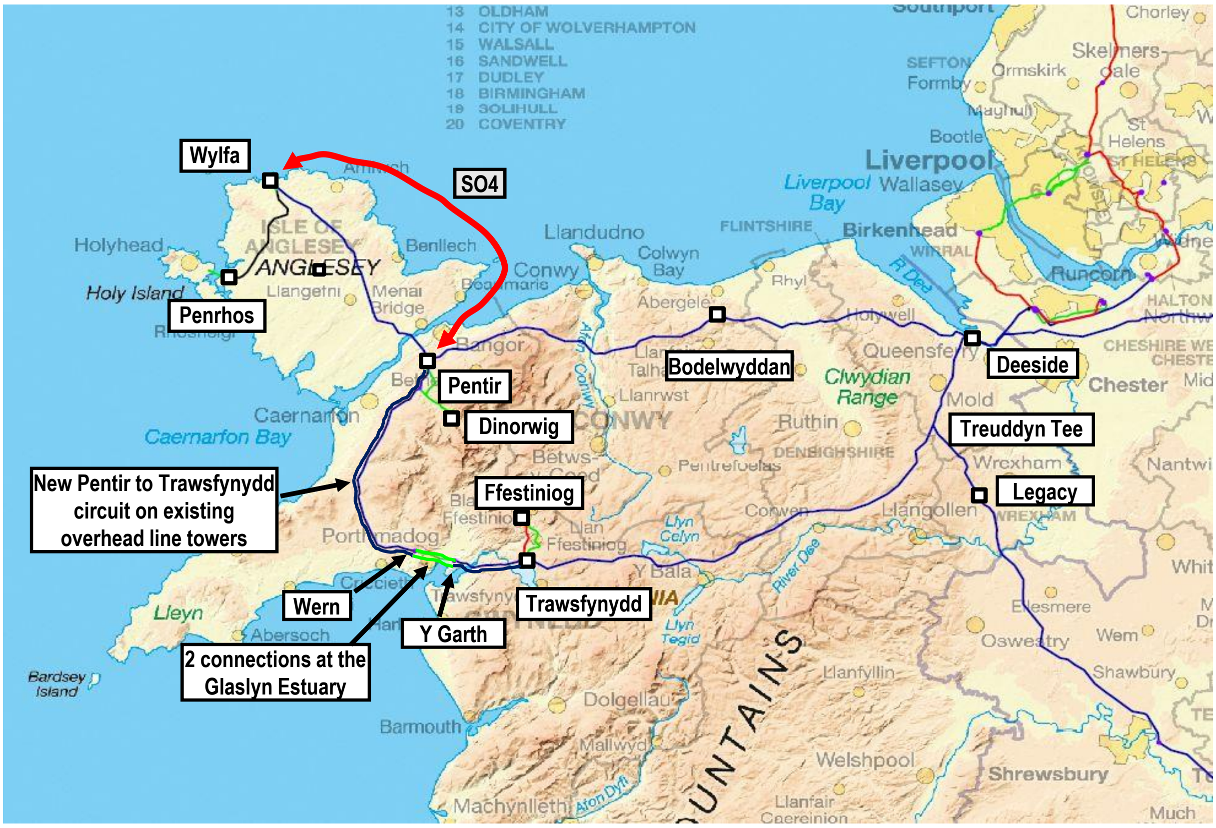


Figure 10.1 – Geographic Illustration of Strategic Option 4

10.2 The main works required for the Anglesey elements of Strategic Option 4, Wylfa to Pentir Offshore East, are:

- modification of the existing 400 kV substation at Wylfa
- modification of the existing 400 kV substation at Pentir
- installation of subsea cable circuits between Wylfa and Pentir, a distance of 64 km around the east of Anglesey
- for HVDC, the installation of two converter stations at Wylfa and two at Pentir.

10.3 The study area for this strategic option is shown in Figure 10.2. It is based on a direct route, which all other things being equal, would give rise to the lowest impacts and costs. It is bounded by the Anglesey coast to the west and a 10 km wide swathe to the east and south to provide reasonable opportunity to avoid constraints.

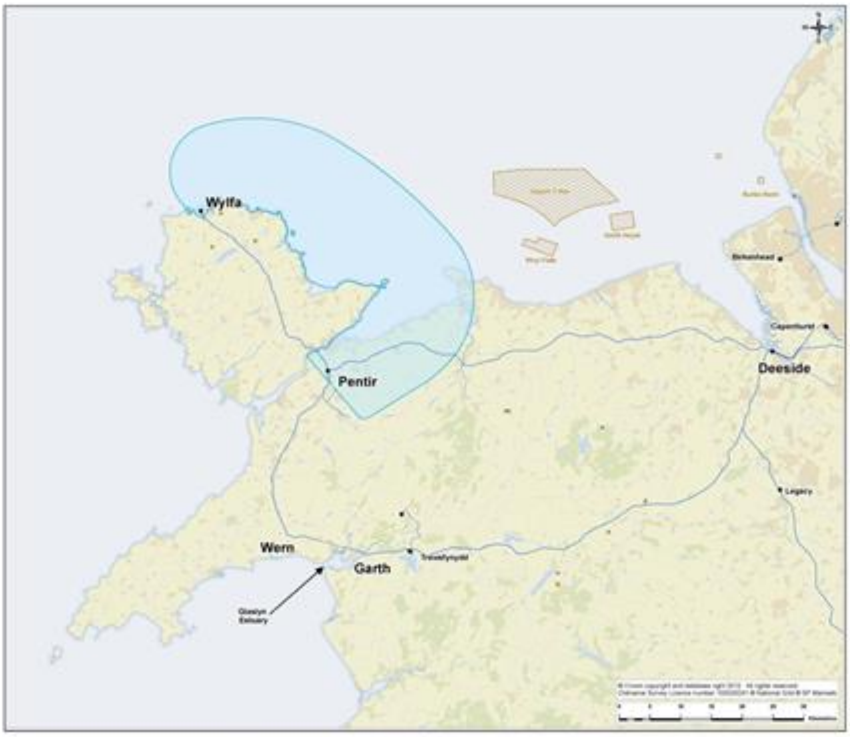


Figure 10.2 – Study Area for Strategic Option 4 – Anglesey Works

10.4 The study area therefore includes an area around the existing Wylfa power station, a large area on the North Wales mainland including Bangor and Llandudno, a large area offshore, east of Anglesey including the Irish Sea and Conwy Bay.

10.5 The following paragraphs set out the results of the option appraisal.

Technical and Cost Appraisal

10.6 The offshore connections between Wylfa and Pentir could be made using either of the following technologies:

- Subsea AC cables (two circuits), and
- HVDC (two circuits)

Subsea AC and HVDC Cables

10.7 The cable installations would have landfall sites at or near Wylfa substation and also somewhere on the North Wales mainland west of Llandudno. They would follow a route from the landfall to Pentir substation.

10.8 There is a security risk relating to subsea cable close into shorelines with tidal movements.

10.9 In the event of faults, cable installations are out of service for longer periods than overhead lines, particularly subsea cable installations.

Subsea AC Cables

10.10 Installation of this scale of AC cable system presents a number of technical issues which are likely to be surmountable but which must be carefully considered in cable system design and implementation. As described previously, AC cables of ~75km or greater in length may require reactive compensation to be installed at points along the cable route. This could result in a cable needing to be brought ashore at least once. In this case it has been assumed that the reactive compensation requirement could be met through equipment installed at either end of the cable and hence no mid-point compensation has been included. However, it should be noted that the reactive compensation requirements of a cable circuit cannot be fully determined until detailed design work is carried out and hence there is a risk that mid-point compensation installations may be needed.

HVDC

10.11 The HVDC option would require two converter stations at Wylfa and two at Pentir, each typically having the footprint of a large warehouse and being around 25 m in height. As with Strategic Option 3, two HVDC circuits of 1.5 GW each would be required.

10.12 At the time of writing there are no examples of 1.5 GW VSC HVDC converter stations in commercial service anywhere in the world. However, marketing material from some manufacturers does indicate that converter stations at this rating are available. However, as yet no orders have yet been placed for such equipment.

10.13 Although 1.5 GW VSC converters are not a proven technology, it is considered that a converter station of this rating would present a far lower degree of uncertainty than the 2 GW VSC converters required for Strategic Options 1 and 2. However, the technical risks associated with connecting large synchronous generators via HVDC circuits (see following paragraphs) apply equally to 1.5 GW and 2 GW VSC HVDC.

10.14 The connection of large synchronous generators (such as the new Wylfa nuclear plant) via HVDC links is not worldwide common practice due to the increased technical complexities of this type of connection. In the event of the existing AC Wylfa to Pentir double circuit overhead line being de-energised (either planned or unplanned), the nuclear power station would be connected to the transmission system solely by HVDC circuits. This can cause significant issues with both the generator and the HVDC circuits; highly complex control and protection schemes would be required to ensure that the transmission system (both locally and nationally) remained stable and secure following such an event.

10.15 To date, no nuclear power station in the world has been connected solely by HVDC circuits. National Grid is currently undertaking a research project titled "Feasibility study of connecting a nuclear power station to the GB transmission system via HVDC technology". This work has indicated that, in theory, a connection via HVDC is feasible. However, this study is likely to recommend that a significant amount of additional research and study work would be required before any connection of this type could actually be progressed.

10.16 As a result of the current uncertainty around the feasibility technical implications of an HVDC connection, the use of HVDC circuits for the nuclear power station connection in this project is considered to represent an unproven technology risk which may result in material additional costs and delays being incurred to develop an acceptable solution. This position is supported by the generator developer, Horizon Nuclear Power, who holds the view that:

"Horizon is not aware of any precedent for a nuclear power station grid connection being achieved using HVDC technology, either in part or solely connected using that technology. We therefore see such a connection design as introducing significant additional technical risk for both normal and abnormal grid operating scenarios and we would anticipate the need for National Grid to carry out a range of studies to fully understand the nature and extent of those risks. For its part, Horizon would also wish to carry out its own independent studies to assess the technical implications of employing a connection achieved partly using HVDC technology and it is likely that a significant programme of work would need to be undertaken to enable Horizon to make such a judgement."

10.17 National Grid is continuing to monitor closely the development of VSC HVDC converter station technology and how this could be utilised in this and any future projects.

<u>Costs</u>

10.18 The capital and lifetime cost estimates for this option are shown in tables 10.1 and 10.2.

Item	**Need**	**Cost**	
Wylfa 400 kV substation	Connect Wylfa power station and the new circuits	£38m	
Pentir 400 kV substation	Connect new circuits	£25m	
New Circuits		**AC Cable**	**HVDC**
Wylfa to Pentir ('Lo' Capacity, 64 km)	Connect Wylfa to Pentir creating Wylfa export capability	£837m	£803m
Total Capital Cost		**£900m**	**£866m**

Table 10.1 Strategic Option 4 – Anglesey Works – Wylfa - Pentir Offshore East: Capital Cost Estimates

	AC Cable	HVDC
Capital Cost of New Circuits	£837m	£803m
NPV of Cost of Losses over 40 years	£53m	£236m
NPV of Operation & Maintenance Costs over 40 years	£7m	£98m
Lifetime Cost of New Circuits [32]	**£898m**	**£1,137m**

Table 10.2 Strategic Option 4 – Anglesey Works – Wylfa - Pentir Offshore East New Circuits: Capital and Lifetime Cost Estimates

10.19 In summary, the estimated total capital costs for connections off the east coast of Anglesey range from £866m for an HVDC system to £900m for AC cables. The estimated lifetime costs of the new circuit elements ranges from £898m for AC cables to £1,137m for an HVDC system.

Environmental - Ecology and Biodiversity

10.20 The principal ecological sites affecting this option are shown in Figure G.7 in Appendix G of this report. There are nine ecological constraints within the study area on the east side of Anglesey which are considered to be material to the decision.

- Menai Strait and Conwy Bay SAC
- Liverpool bay SPA
- Lavan Sands SSSI, Important Bird Area and Lavan Sands Conway Bay SPA
- Coedydd Aber SSSI and SAC
- Aber Afon Conwy SSSI
- Eryi SSSI
- Great Ormes Head SSSI

10.21 All but two can be avoided through careful routeing; Liverpool Bay SPA and Menai Strait and Conwy Bay SAC. The high concentration of ecological constraints near Menai Strait results in available landing points and transmission routes to Pentir being limited, and increases the risk of significant effects upon the integrity of two

[32] The lifetime cost calculation methodology is explained in Appendix D. It is used to compare the cost of connecting transmission substations using various technologies for the new circuits. It does not include the capital or lifetime costs of substation equipment. The lifetime cost is the net present value of capital costs, the costs of transmission losses and maintenance costs over 40 years. A discount rate of 3.5% is used.

Natura 2000 sites as a result of the installation of the submarine cables.

Environmental - Cultural Heritage, Landscape and Visual

10.22 The principal cultural heritage and landscape designations affecting this option are shown in Figure G.7 in Appendix G of this report. The study area including Anglesey and the Gwynedd mainland between the coast and Pentir has four cultural heritage, landscape and visual constraints considered to be material to the decision. All are registered as outstanding Landscapes of Historic Interest in Wales.

- North Arllechwedd, Gwynedd / Conwy
- Ogwen Valley, Gwynedd
- Penmon, Anglesey
- Dinorwig, Gwynedd.

10.23 While Penmon landscape can be easily avoided and North Arllechwedd and the Ogwen Valley can also be avoided. However due to their large geographical spread avoiding both of these would significantly limit available transmission routes to Pentir. The Dinorwig landscape is unavoidable as the existing substation is within this landscape. While the 'Landscape of Outstanding Interest' designation affords no additional statutory protection, they are likely to be areas of greater landscape sensitivity from a heritage perspective, especially susceptible to the greater intrusion that would be associated with HVDC technology and the related converter stations at Pentir.

10.24 It is noted that converter stations near Wylfa may indirectly affect the AONB but this will be seen in context with other developments in this area.

10.25 Converter stations located in the vicinity of Pentir substation would be around 5 km from the boundary of Snowdonia National Park, and due to the elevation of the land within the Park and the scale of the converter station buildings, impacts to views from the Park are possible. While Pentir's remote rural location is likely to result in adverse landscape effects (despite the presence of existing transmission infrastructure) visual effects are likely to be localised.

Environmental – Other Sub-topics

10.26 No constraints considered to be material to the decision within the sub-topics noise and vibration, soil and geology and hydrology and flood risk have been identified. It should be noted that Menai Strait and Wharf Bay are designated Shellfish Waters and are considered material to the decision. Both can be avoided, however Menai Strait shellfish waters would significantly reduce available transmission routes for the offshore cables.

Environmental - Consideration of combined Environmental Sub-topics

10.27 The study areas around Menai have a high concentration of environmental constraints. The concentration of environmental constraints around the east end of Menai Strait (onshore and offshore) is considered material to the decision as it is not possible to bring the cables on land to Pentir without impacting on one or more constraints (offshore constraints and onshore).

Socio-Economic - Economic Activity & People and Communities

10.28 No constraints appraised within this sub-topic are considered material to the decision at this level of appraisal. However key socio-economic issues have been identified.

10.29 Socio-economic impacts are considered to be more extensive during construction than during operation.

10.30 It has been assumed that a high proportion of the workforce required for this project will need to be specialised. This would be expected to result in migration to the respective regions for the duration of the construction works (approximately four years).

10.31 Any localised disruption during construction for road and rail networks between Wylfa and Pentir is expected to be slight as the majority of the works is offshore. However, it is expected to be moderate around the Bangor and Bethesda area due to the installation of underground cables between the coast and Pentir.

10.32 Potential benefits from this strategic option include an increase in economic activity due to a specialised work force being located in the area for approximately four years and the opportunities for local employment.

Feedback from Stage 1 Consultation Events

10.33 No feedback specifically related to Strategic Option 4 was received, this was mainly due to respondents not specifically distinguishing between Strategic Option 4 and Strategic Options 1 and 2. Feedback considered all three of these options to represent an "offshore" option and hence feedback applicable to Strategic Options 1 and 2 can be equally applied to Strategic Option 4. A number of respondents identified "offshore" Strategic Options as their favoured option because they considered them to have the least visual impact and considered that any associated technical difficulties of using HVDC cables could be overcome. Respondents considered that a subsea connection would be affordable in the long term, especially when costs were spread out across GB electricity consumers.

11 Appraisal of Strategic Option 5 – Wylfa - Pentir Works

11.1 Strategic Option 5 would provide the additional transmission capacity required across Anglesey reinforcing boundary NW1, through the installation of approximately 80 km of offshore circuits between Wylfa and Pentir, located off the west coast of Anglesey.

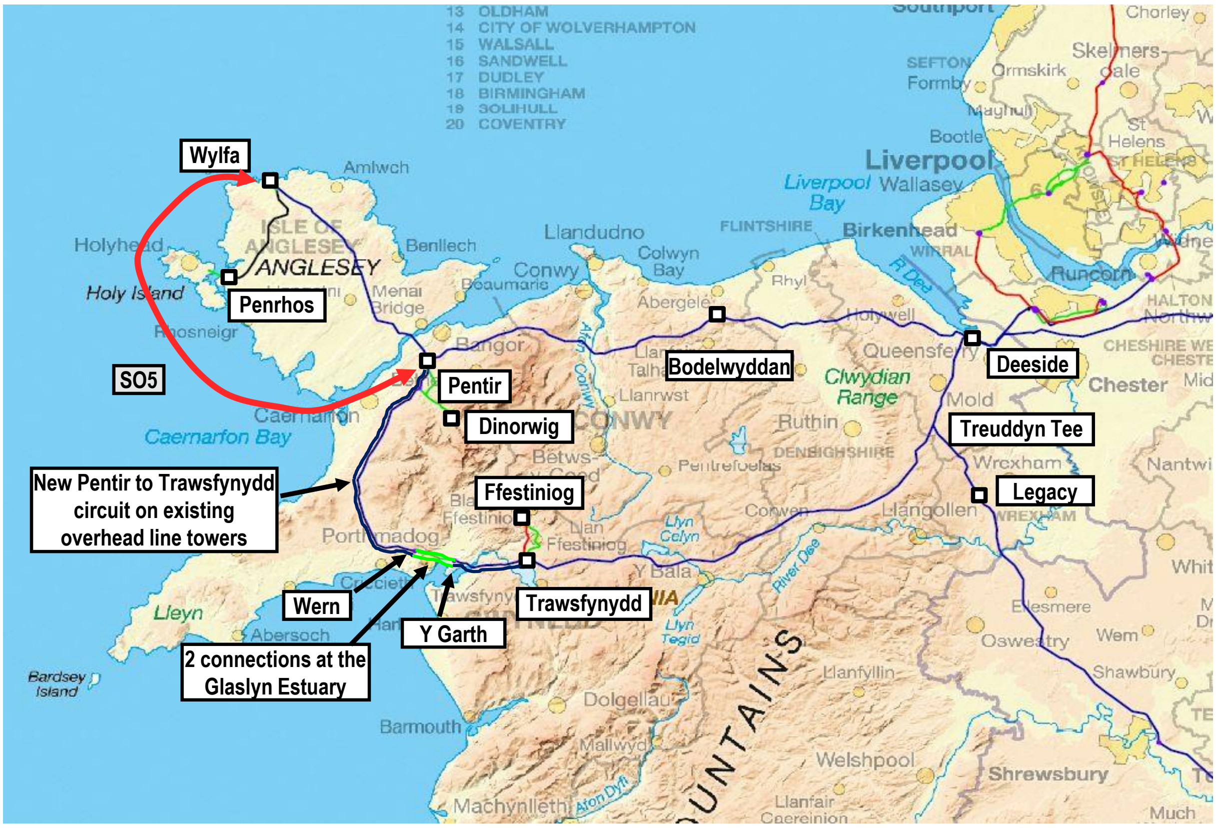


Figure 11.1 – Geographic Illustration of Strategic Option 5

11.2 The main works required for the Anglesey elements of Strategic Option 5, Wylfa to Pentir Offshore West, are:

- modification of the existing 400 kV substation at Wylfa
- modification of the existing 400 kV substation at Pentir
- installation of subsea cable circuits between Wylfa and Pentir, a distance of 80 km around the west of Anglesey
- for HVDC, the installation of two converter stations at Wylfa and two at Pentir.

11.3 The study area for this strategic option is shown in Figure 11.2. It is based on a direct route, which all other things being equal, would give rise to the lowest impacts and costs. It is bounded by the Anglesey coast to the east and a 10 km wide swathe to the west and south to provide reasonable opportunity to avoid constraints, and includes a large tract of the east of Penygroes.

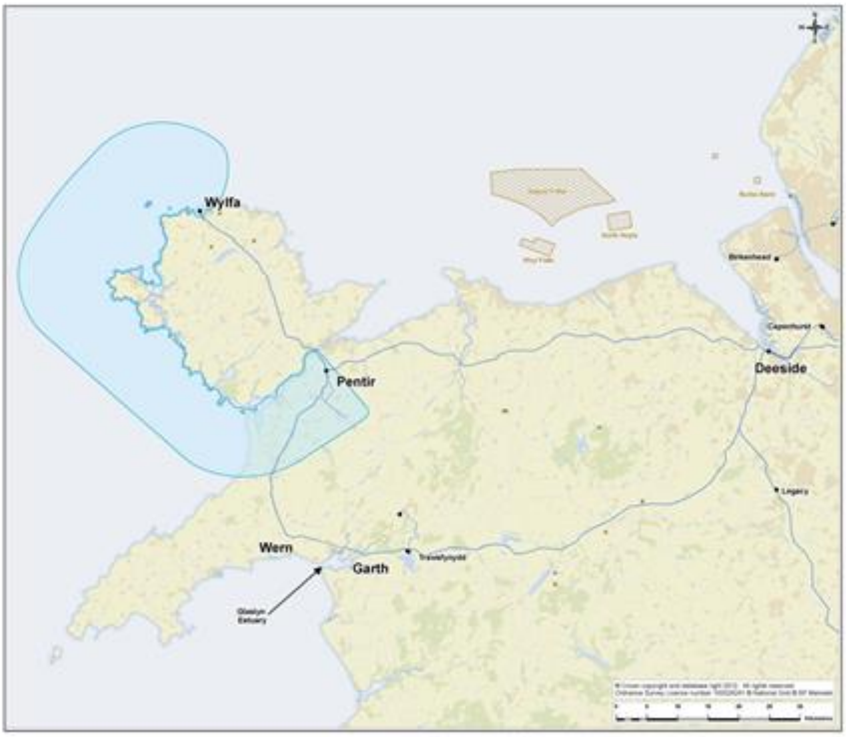


Figure 11.2 – Study Area for Strategic Option 5 – Anglesey Works

11.4 The study area therefore includes an area around the existing Wylfa power station, a large area on the North Wales mainland including Caernarfon and a large area offshore west of Anglesey, including the Irish Sea and Caernarfon Bay.

11.5 The following paragraphs set out the results of the option appraisal.

<u>Technical and Cost Appraisal</u>

11.6 The offshore connections between Wylfa and Pentir could be made using either of the following technologies:

- AC Subsea cables (two circuits), and
- HVDC (two circuits)

Subsea AC and HVDC Cables

11.7 The cable installations would have landfall sites at or near Wylfa substation and also somewhere on the North Wales mainland west of Pentir. They would follow a route from the landfall to Pentir substation.

11.8 There is a security risk relating to subsea cable close into shorelines with tidal movements.

11.9 In the event of faults, cable installations are out of service for longer periods than overhead lines, particularly subsea cable installations.

AC Subsea Cables

11.10 Installation of this scale of AC cable system presents a number of technical issues which are likely to be surmountable but which must be carefully considered in cable system design and implementation. As described previously, AC cables of ~75km or greater in length may require reactive compensation to be installed at points along the cable route. This could result in a cable needing to be brought ashore at least once. In this case it has been assumed that the reactive compensation requirement could be met through equipment installed at either end of the cable and hence no mid-point compensation has been included. However, it should be noted that the reactive compensation requirements of a cable circuit cannot be fully determined until detailed design work is carried out and hence there is a risk that mid-point compensation installations may be needed.

HVDC

11.11 The HVDC option would require two converter stations at Wylfa and two at Pentir, each typically having the footprint of a large warehouse and being around 25 m in height. As with Strategic Option 3, two HVDC circuits of 1.5 GW each would be required.

11.12 At the time of writing there are no examples of 1.5 GW VSC HVDC converter stations in commercial service anywhere in the world. However, marketing material from some manufacturers does indicate that converter stations at this rating are available. However, as yet no orders have yet been placed for such equipment.

11.13 Although 1.5 GW VSC converters are not a proven technology, it is considered that a converter station of this rating would present a far lower degree of uncertainty than the 2 GW VSC converters required for Strategic Options 1 and 2. However, the technical risks associated with connecting large synchronous generators via HVDC circuits (see following paragraphs) apply equally to 1.5 GW and 2 GW VSC HVDC.

11.14 The connection of large synchronous generators (such as the new Wylfa nuclear plant) via HVDC links is not worldwide common practice due to the increased technical complexities of this type of connection. In the event of the existing AC Wylfa to Pentir double circuit overhead line being de-energised (either planned or unplanned), the nuclear power station would be connected to the transmission system solely by HVDC circuits. This can cause significant issues with both the generator and the HVDC circuits; highly complex control and protection schemes would be required to ensure that the transmission system (both locally and nationally) remained stable and secure following such an event.

11.15 To date, no nuclear power station in the world has been connected solely by HVDC circuits. National Grid is currently undertaking a research project titled "Feasibility study of connecting a nuclear power station to the GB transmission system via HVDC technology". This work has indicated that, in theory, a connection via HVDC is feasible. However, this study is likely to recommend that a significant amount of additional research and study work would be required before any connection of this type could actually be progressed.

11.16 As a result of the current uncertainty around the feasibility technical implications of an HVDC connection, the use of HVDC circuits for the nuclear power station connection in this project is considered to represent an unproven technology risk which may result in material additional costs and delays being incurred to develop an acceptable solution. This position is supported by the generator developer, Horizon Nuclear Power, who holds the view that:

"Horizon is not aware of any precedent for a nuclear power station grid connection being achieved using HVDC technology, either in part or solely connected using that technology. We therefore see such a connection design as introducing significant additional technical risk for both normal and abnormal grid operating scenarios and we would anticipate the need for National Grid to carry out a range of studies to fully understand the nature and extent of those risks. For its part, Horizon would also wish to carry out its own independent studies to assess the technical implications of employing a connection achieved partly using HVDC technology and it is likely that a significant programme of work would need to be undertaken to enable Horizon to make such a judgement."

11.17 National Grid is continuing to monitor closely the development of VSC HVDC converter station technology and how this could be utilised in this and any future projects.

Costs

11.18 The capital and lifetime cost estimates for this option are shown in tables 11.1 and 11.2.

Item	**Need**	**Cost**	
Wylfa 400 kV substation	Connect Wylfa power station and the new circuits	£38m	
Pentir 400 kV substation	Connect new circuits	£25m	
New Circuits		**AC Cable**	**HVDC**
Wylfa to Pentir ('Lo' Capacity, 80 km)	Connect Wylfa to Pentir creating Wylfa export capability	£1,050m	£864m
Total Capital Cost		**£1,113m**	**£927m**

Table 11.1 Strategic Option 5 – Anglesey Works – Wylfa - Pentir Offshore West: Capital Cost Estimates

	AC Cable	HVDC
Capital Cost of New Circuits	£1,050m	£864m
NPV of Cost of Losses over 40 years	£72m	£236m
NPV of Operation & Maintenance Costs over 40 years	£9m	£98m
Lifetime Cost of New Circuits [33]	**£1,131m**	**£1,198m**

Table 11.2 Strategic Option 5 – Anglesey Works Wylfa - Pentir Offshore West New Circuits: Capital and Lifetime Cost Estimates

11.19 In summary, the estimated total capital costs for connections off the west coast of Anglesey range from £927m for an HVDC system to £1,113m for AC cables. The estimated lifetime costs for the new circuit elements range from £1,131m for AC cables to £1,198 for an HVDC system.

Environmental - Ecology and Biodiversity

11.20 The principal ecological sites affecting this option are shown in Figure G.8 in Appendix G of this report. There are five ecological constraints within the study area on the west side of Anglesey which are considered to be material to the decision;

- Abermenai to Aberffraw Dunes SAC
- Afon Gwyrfai A Llyn Cwellyn SAC and SSSI
- Y Foryd SSSI
- Morfa Dinlle SSSI.

11.21 All but two sites can be avoided - Afon Gwyrfai A Llyn Cwellyn SAC and SSSI. Given the limited width of this protected river corridor, appropriate construction techniques should be able to mitigate effects to these designations.

Environmental - Cultural Heritage, Landscape and Visual

11.22 The principal cultural heritage and landscape designations affecting this option are shown in Figure G.8 in Appendix G of this report. Within the study area on

[33] The lifetime cost calculation methodology is explained in Appendix D. It is used to compare the cost of connecting transmission substations using various technologies for the new circuits. It does not include the capital or lifetime costs of substation equipment. The lifetime cost is the net present value of capital costs, the costs of transmission losses and maintenance costs over 40 years. A discount rate of 3.5% is used.

Anglesey and the Gwynedd mainland between the coast and Pentir three landscape and visual constraints are considered to be material to the decision:

- Dinorwig Landscape of Historic Interest, Gwynedd (registered as outstanding)
- North Anglesey Coast Heritage Coast
- Isle of Anglesey Coastal Path Designated National Trail.

11.23 Dinorwig landscape and the coastal path cannot be avoided. Caernarfon and Llandwrog have a high concentration of heritage assets. However, both areas can be avoided.

11.24 It is noted that converter stations near Wylfa may indirectly affect the AONB but this will be seen in context with other developments in this area.

11.25 Converter stations located in the vicinity of Pentir substation would be around 5 km from the boundary of Snowdonia National Park, and due to the elevation of the land within the Park and the scale of the converter station buildings, impacts to views from the Park are possible. While Pentir's remote rural location is likely to result in adverse landscape effects (despite the presence of existing transmission infrastructure) visual effects are likely to be localised.

<u>Environmental – Other Sub-topics</u>

11.26 No constraints considered to be material to the decision within the sub-topics noise and vibration, soil and geology and hydrology and flood risk have been identified. It should be noted that Menai Strait and Malltraeth Bay are designated Shellfish Waters and are considered material to the decision. Both can be avoided, however Menai Strait shellfish waters would significantly reduce available transmission routes for the offshore cables.

<u>Environmental - Consideration of combined Environmental Sub-topics</u>

11.27 While there are a number of cultural heritage and ecological constraints within and close to Menai Strait in combination they are not considered to represent a more material consideration than if considered in isolation, as route options to avoid these constraints would not be further restricted in a significant way.

Socio-Economic - Economic Activity & People and Communities

11.28 No constraints appraised within this sub-topic are considered material to the decision at this level of appraisal. However, key socio-economic issues have been identified.

11.29 Socio-economic impacts are considered to be more extensive during construction than during operation.

11.30 It has been assumed that a high proportion of the workforce required for this project will need to be specialised. This would be expected to result in migration to the respective regions for the duration of the construction works (approximately four years).

11.31 Any localised disruption during construction for road and rail networks across Anglesey, Gwynedd and North Wales is expected to be slight as the majority of the works is offshore.

11.32 Potential benefits from this strategic option include an increase in economic activity due to a specialised work force being located in the area for approximately four years and the opportunities for local employment.

Feedback from Stage 1 Consultation Events

11.33 No feedback specifically related to Strategic Option 5 was received, this was mainly due to respondents not specifically distinguishing between Strategic Option 5 and Strategic Options 1 and 2. Feedback considered all three of these options to represent an "offshore" option and hence feedback applicable to Strategic Options 1 and 2 can be equally applied to Strategic Option 5. A number of respondents identified "offshore" Strategic Options as their favoured option because they considered these to have the least visual impact and considered that any associated technical difficulties of using HVDC cables could be overcome. Respondents considered that a subsea connection would be affordable in the long term, especially when costs were spread out across GB electricity consumers.

12 Appraisal of Strategic Option 6 – Wylfa – West Gwynedd Works

12.1 Strategic Option 6 would provide the additional transmission capacity required across Anglesey through the installation of approximately 18 km of onshore circuits between Wylfa and the vicinity of Valley (replacing an existing 132 kV route), approximately 30 km of offshore circuits and 8 km of onshore circuits between Valley and a new substation located in west Gwynedd.

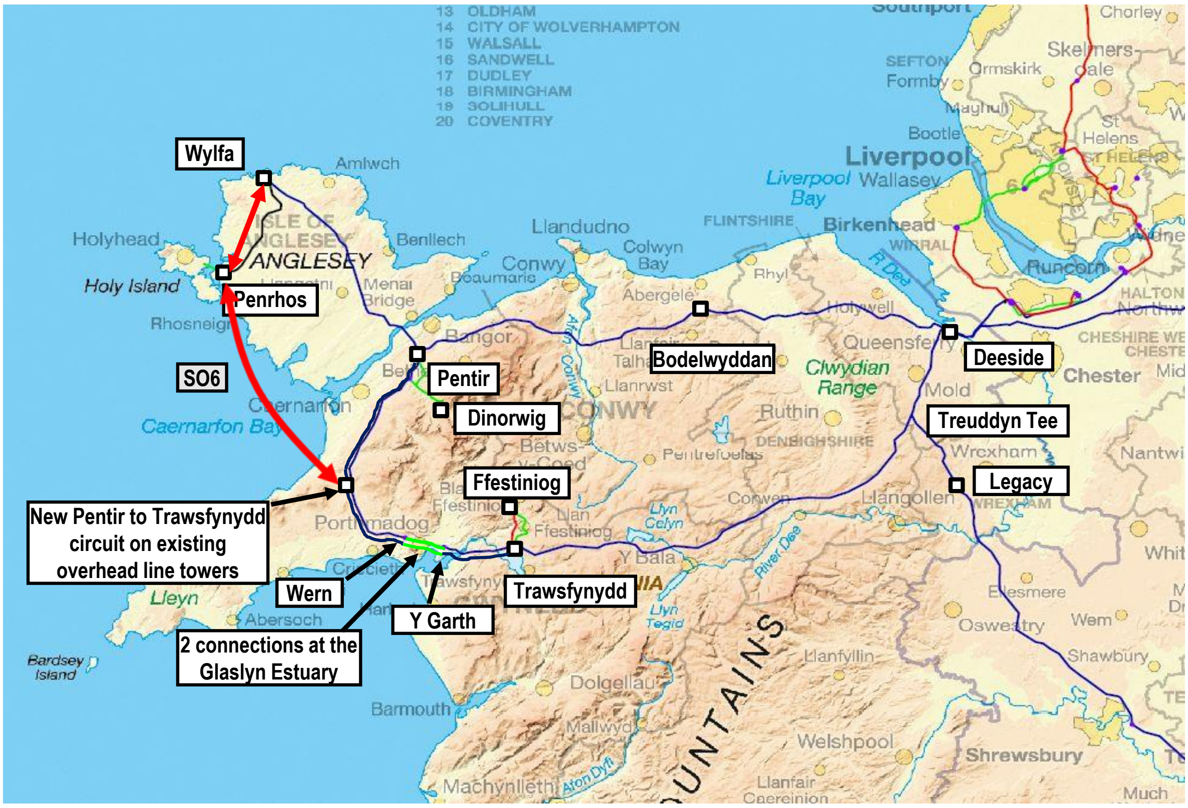


Figure 12.1 – Geographic Illustration of Strategic Option 6

12.2 The main works required for the Anglesey elements of Strategic Option 6, Wylfa to Valley to west Gwynedd, are:

- modification of the existing 400 kV substation at Wylfa
- replacement of the existing 132 kV overhead line between Wylfa and Valley with a new 400 kV connection, approximately 18 km
- installation of a new Grid Supply Point (GSP) in the Valley area
- installation of subsea cable circuits between Valley and west Gwynedd, a distance of approximately 30 km around the west of Anglesey

- installation of 8 km (assumed) of new onshore circuits in west Gwynedd
- installation of a new 400kV substation in west Gwynedd to connect the new circuits to the existing overhead line
- if HVDC, the installation of two converter stations at Valley and two in west Gwynedd.

12.3 The study area for this strategic option is shown in Figure 12.2. It is based on a direct route, which all other things being equal, would give rise to the lowest impacts and costs, with a corridor of 10 km on either side to provide reasonable opportunity to avoid constraints. The appraisal does not assume that the new route would necessarily follow the same alignment as the existing 132kV line that it would replace.

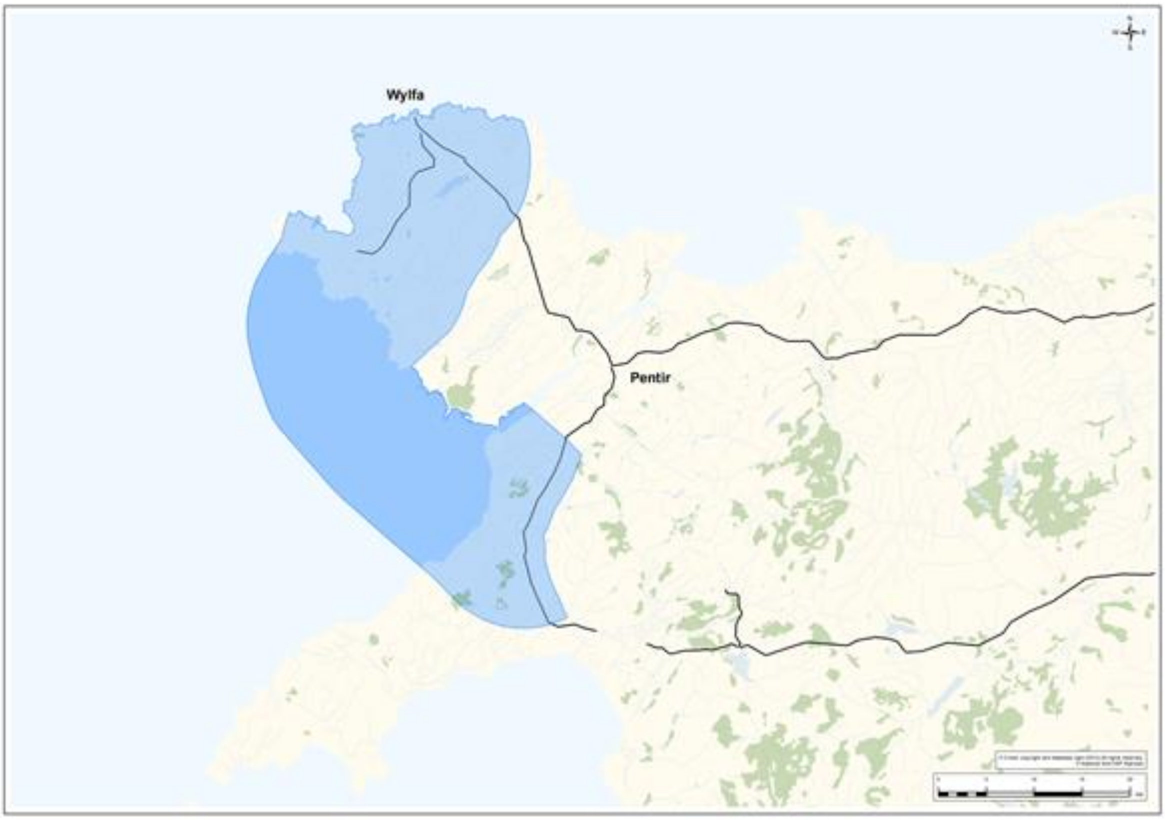


Figure 12.2 – Study Area for Strategic Option 6

12.4 The study area includes: the majority of the northern and western half of Anglesey, between the existing Wylfa power station and west coast near Rhosneigr, a large area of west Gwynedd, on the North Wales mainland, between Caernarfon in the north and north of Llanystumdwy in the south; and finally a large area offshore west of Anglesey, including the Irish Sea and Caernarfon Bay.

12.5 The following paragraphs set out the results of the option appraisal.

Technical and Cost Appraisal

12.6 The offshore connections between Wylfa and the mainland coast could be made using either of the following technologies:

- AC overhead lines (onshore sections only),
- AC cables (onshore and offshore sections),
- HVDC (onshore and offshore sections),
- Gas Insulated Lines (onshore sections only)

AC Overhead Line

12.7 The double circuit overhead line would follow a route across the north west of Anglesey and replace the existing 132kV OHL. Overhead line is a well proven technology and, although vulnerable in adverse weather conditions, most faults are temporary and self-rectifying. Faults which require remedial work are normally repaired quicker than faults on underground cables.

AC Underground Cable

12.8 Installation of this scale of AC cable system presents a number of technical issues that are likely to be surmountable, but which must be carefully considered in the cable system design and implementation.

Subsea AC and HVDC Cables

12.9 The cable installations would have landfall sites in the vicinity of Valley, on Anglesey, and on the west Gwynedd coast south of Caernarfon. The cable on the mainland would follow a route from the landfall point to the new substation in the vicinity of west Gwynedd.

12.10 In the event of faults, cable installations are out of service for longer periods than overhead lines, particularly subsea cable installations.

HVDC

12.11 The HVDC option would require two converter stations at Wylfa and two at West Gywnedd, each typically having the footprint of a large warehouse and being around 25 m in height. As with Strategic Option 3, two HVDC circuits of 1.5 GW each would be required.

12.12 At the time of writing there are no examples of 1.5 GW VSC HVDC converter stations in commercial service anywhere in the world. However, marketing material from some manufacturers does indicate that converter stations at this rating are available. However, as yet no orders have yet been placed for such equipment.

12.13 Although 1.5 GW VSC converters are not a proven technology, it is considered that a converter station of this rating would present a far lower degree of uncertainty than that associated with the 2 GW VSC converters required for Strategic Options 1 and 2. However, the technical risks associated with connecting large synchronous generators via HVDC circuits (see following paragraphs) apply equally to 1.5 GW and 2 GW VSC HVDC.

12.14 The connection of large synchronous generators (such as the new Wylfa nuclear plant) via HVDC links is not worldwide common practice due to the increased technical complexities of this type of connection. In the event of the existing AC Wylfa to Pentir double circuit overhead line being de-energised (either planned or unplanned), the nuclear power station would be connected to the transmission system solely by HVDC circuits. This can cause significant issues with both the generator and the HVDC circuits; highly complex control and protection schemes would be required to ensure that the transmission system (both locally and nationally) remained stable and secure following such an event.

12.15 To date, no nuclear power station in the world has been connected solely by HVDC circuits. National Grid is currently undertaking a research project titled "Feasibility study of connecting a nuclear power station to the GB transmission system via HVDC technology". This work has indicated that, in theory, a connection via HVDC is feasible. However, this study is likely to recommend that a significant amount of additional research and study work would be required before any connection of this type could actually be progressed.

12.16 As a result of the current uncertainty around the feasibility and technical implications of an HVDC connection, the use of HVDC circuits for the nuclear power station connection in this project is considered to represent an unproven technology risk which may result in material additional costs and delays being incurred to develop an acceptable solution. This position is supported by the generator developer, Horizon Nuclear Power, who holds the view that:

12.17 "Horizon is not aware of any precedent for a nuclear power station grid connection being achieved using HVDC technology, either in part or solely connected using that technology. We therefore see such a connection design as introducing significant additional technical risk for both normal and abnormal grid operating scenarios and we would anticipate the need for National Grid to carry out a range of studies to fully understand the nature and extent of those risks. For its part, Horizon would also wish to carry out its own independent studies to assess the technical implications of employing a connection achieved partly using HVDC technology and it is likely that a significant programme of work would need to be undertaken to enable Horizon to make such a judgement."

12.18 National Grid is continuing to monitor closely the development of VSC HVDC converter station technology and how this could be utilised in this and any future projects.

Costs

12.19 The capital and lifetime cost estimates for this option are shown in tables 12.1 and 12.2.

<table>
<tr><th>Item</th><th>Need</th><th colspan="4">Cost</th></tr>
<tr><td>Wylfa 400 kV substation</td><td>Connect Wylfa power station and the new circuits</td><td colspan="4">£38m</td></tr>
<tr><td>New Valley GSP</td><td>Maintain supplies to Penrhos</td><td colspan="4">£22m</td></tr>
<tr><td>West Gwynedd New 400kV substation</td><td>Connect new circuits</td><td colspan="4">£42m</td></tr>
<tr><th>New Circuits</th><th></th><th>OHL</th><th>AC Cable</th><th>GIL</th><th>HVDC</th></tr>
<tr><td>Wylfa to Valley
'Lo' rated
18 km</td><td>Provide additional capacity from Wylfa</td><td>£45m</td><td rowspan="3">£734m*</td><td>£331m</td><td rowspan="3">£774m*</td></tr>
<tr><td>Valley to west Gwynedd landfall
'Lo' rated
30 km</td><td>Subsea element of new Wylfa to West Gwynedd circuits</td><td>OHL N/A
£393m
AC cable</td><td>GIL N/A
£393m
AC cable</td></tr>
<tr><td>West Gwynedd onshore
'Lo' rated
8 km</td><td>Onshore element of new Wylfa to West Gwynedd circuits</td><td>£20m
(£103m
if AC Cable
is used)</td><td>£147m</td></tr>
<tr><td colspan="2">Total Capital Cost</td><td>£560m</td><td>£836m</td><td>£973m</td><td>£876m</td></tr>
</table>

* Assumes a continuous AC Cable or HVDC circuit between Wylfa and West Gwynedd

Table 12.1 Strategic Option 6 – Anglesey Works – Wylfa – Valley – West Gwynedd: Capital Cost Estimates

12.20 As described earlier, this Strategic Option has been included as a result of feedback received during National Grid's consultation process. Table 13.1 shows the capital costs for various technology types. However, the actual feedback received indicated a preference for using AC cable for the assumed 8km onshore section to west Gwynedd. Therefore, once this feedback is reflected, the total capital cost would be £643m (38+22+42+45+393+103).

	OHL*	AC Cable	GIL*	HVDC
Capital Cost of New Circuits	£458m	£734m	£1,275m	£774m
NPV of Cost of Losses over 40 years	£54m	£49m	£44m	£236m
NPV of Operation & Maintenance Costs over 40 years	£4m	£6m	£6	£98
Lifetime Cost of New Circuits	**£516m**	**£789m**	**£1,325**	**£1,108**

* Assumes AC cable for 30km subsea section

Table 12.2 Strategic Option 6 – New Circuits: Capital and Lifetime Cost Estimates

Environmental - Ecology and Biodiversity

12.21 The principal ecological sites affecting this option are shown in Figure G.9 in Appendix G of this report. Within the study area of this strategic option there are 9 SACs, 2 SPAs and 55 SSSIs. Of these, there are 20 ecological constraints within the study area, between Wylfa and the west Gwynedd coast, considered to be material to the decision:

- Afon Gwyrfai a Llyn Cwellyn SAC and SSSI,
- Bae Cemlyn / Cemlyn Bay SAC,
- Corsydd Eifionydd / Eifionydd Fens SAC,
- Glannau Mon: Cors Heli / Anglesey Coast: Saltmarsh SAC,
- Glannau Ynys Gybi / Holy Island Coast SAC and SSSI,
- Glynllifon SAC and SSSI,
- Llyn Dinam SAC and SSSI,
- Y Fenai a Bae Conwy / Menai Strait and Conwy Bay SAC,
- Y Ford SSSI,
- Morfa Dinlle SSSI,
- Dinas Dinlle SSSI,
- Ynys Feurig SSSI,
- Rhosneigr Reefs SSSI,
- Beddmanarch Cymyran SSSI,
- Y Twyni o Abermenai i Aberffraw / Abermenai to Aberffraw Dunes SAC, and

- Ynys Feurig, Cemlyn Bay and The Skerries SPA.

12.22 It is anticipated that all of these sites can be avoided through careful routeing.

12.23 There is only a narrow corridor of opportunity for installation of the transmission cables in the proximity of Rhosneigr on the western coast of Anglesey (prior to going offshore) due to the location of Ynys Feurig, Cemlyn Bay and The Skerries SPA plus three, closely aligned SSSIs - Ynys Feurig, Rhosneigr Reefs and Beddmanarch Cymyran SSSIs. The location of these designations would need to be carefully considered.

12.24 The Menai Strait and Malltraeth Bay are designated Shellfish Waters and are considered material to the decision. Both can be avoided during construction, but Menai Strait shellfish waters would reduce available transmission routes for the offshore cables. This is most relevant to cabling works if seeking a coastal landfall north of Dinas Dinlle.

Environmental - Cultural Heritage, Landscape and Visual

12.25 Within the study area there is one World Heritage Site (Caernarfon Castle and Town Walls), 119 Scheduled Monuments and 952 listed buildings (including 15 Grade I Listed Buildings), three Registered Historic Landscapes (Amlwch and Parys Mountain, Lleyn and Bardsey Island and Nantlle Valley) and five Registered Historic Parks and Gardens (including Glynllifon Grade I Registered Park and Garden). It is anticipated that individually these can be avoided through implementation of careful routeing.

12.26 The principal cultural heritage and landscape designations affecting this option are shown in Figure G.9 in Appendix G of this report. Within the study area on north west Anglesey and the Gwynedd mainland four landscape and visual constraints are considered to be material to the decision:

- Anglesey and Llyn AONBs,
- North Anglesey and Lleyn Peninsula Heritage Coasts,
- Isle of Anglesey Coastal Path Designated National Trail,
- Llyn Coastal Path Designated National Trail, and
- National Cycle Routes 5, 8 and 566.

12.27 Lleyn Peninsula Heritage Coast and both coastal paths would be crossed by the transmission line; it is anticipated that cabling activities would intercept them at both landfall points. In addition, National Cycle Routes will be crossed at several points via OHL and cabling activities on Anglesey.

12.28 For Overhead line technology, other decisions and protected sites that are material to the decision include the Anglesey AONB and views from Snowdonia National Park; however it is anticipated that this could be avoided if overhead line technology is only used inland on Anglesey, avoiding both these designations.

12.29 The Anglesey AONB and the Llyn AONB could be crossed by cabling activities, if unable to route outside the AONBs due to other restrictions (e.g. RAF Valley and Rhosneigr). It is anticipated that any visual impact would be short term and restricted to the construction phase.

12.30 Impacts to settlements from underground technologies can be easily avoided through careful routeing. It is noted that substation installations near Bodedern and West Gwynedd may affect distant views from the AONBs, but these could be screened with vegetation in the long term. Nantlle Valley Landscape of Outstanding Historic Interest and Snowdonia National Park could be avoided, but there is a risk that a new West Gwynedd substation could impact on the setting of and views from these designated areas.

12.31 If HVDC were used offshore, the two converter stations located in west Gwynedd would be less than 5km from the boundary of Snowdonia National Park, and due to the elevation of the land within the Park and the scale of the converter station buildings, impacts to views from the Park are possible. However, converter stations would be avoided if AC technology were employed.

12.32 The remote open landscape around and north of Dinas Dinlle would experience significant landscape impacts if an overhead line were to be used from the coast to the substation connection point. Such long-term effects would largely be avoided if buried cables were employed.

<u>Environmental – Other Sub-topics</u>

12.33 No constraints considered to be material to the decision within the sub-topics noise and vibration, soil and geology and hydrology and flood risk have been identified.

Environmental - Consideration of combined Environmental Sub-topics

12.34 Whilst there are a number of cultural heritage, visual and ecological constraints within the study area in combination they are not considered to represent a more material consideration than if considered in isolation, as route options to avoid these constraints would not be further restricted in a significant way.

Socio-Economic - Economic Activity & People and Communities

12.35 No constraints appraised within this sub-topic are considered material to the decision at this level of appraisal. However key socio-economic issues have been identified.

12.36 Socio-economic impacts are considered to be more extensive during construction than during operation. Areas that are considered likely to receive most of the direct socio-economic impacts during construction are Anglesey and south of the Menai Strait in the vicinity of Dinas Dinlle. Construction is generally estimated to take approximately two years for the overhead line technology and around four years for underground technology.

12.37 It has been assumed that a high proportion of the workforce required for this project will need to be specialised. This would be expected to result in migration to the respective regions for the duration of construction works.

12.38 Some localised disruption during construction is expected for road networks across Anglesey, Gwynedd and North Wales (either directly or indirectly as the result of traffic diversions etc). This could temporarily impact local communities, businesses and access to public service infrastructure.

12.39 Regionally, transport disruption could have a low to moderate impact on the tourism industry as tourism is one of the region's largest sources of employment.

12.40 Strategic Option 6 would need to pass near, and possibly within low flying restriction zones, of RAF Valley to reach the west coast of Anglesey and land on the North Wales mainland near Caernarfon airport. RAF Valley is currently home to Search and Rescue operations, which will move to Caernarfon airport in 2015.

However, these constraints are avoidable and only underground or subsea cabling would be employeed near these sites.

12.41 Potential benefits from this strategic option include an increase in economic activity due to a specialised workforce being located in the area for approximately two to four years and the opportunities for local employment.

Feedback from Stage 1 Consultation Events

12.42 A number of respondents proposed this hybrid option of replacing the existing 132 kV route between Wylfa and Valley coupled with a subsea connection to the mainland. In response to this feedback this option has now been included as part of the appraisal and selection of a preferred strategic option as recorded in this update of the Report.

13 Appraisal of Works Common to Strategic Options 3, 4, 5, and 6

13.1 As described earlier, Strategic Options 3, 4, 5 and 6 can all be separated into two distinct parts: the work required on Anglesey to connect between Wylfa and Pentir substations and reinforce boundary NW1, and the work required on the mainland to reinforce boundaries NW2 and NW3. All work proposed on the mainland to reinforce boundaries NW2 and NW3 is identical for each of these options with only the proposed work on Anglesey being different. The common works are:

(a) addition of a second Pentir to Trawsfynydd circuit on the same pylons as the existing circuit (including reconductoring of existing circuit)

(b) modification of Pentir 400 kV substation to accommodate second Pentir – Trawsfynydd circuit

(c) a new Grid Supply Point (GSP) in west Gwynedd

(d) re-conductoring of existing circuits in North Wales

(e) the installation of series compensation equipment,

(f) installation of enhanced connections between Wern and Y Garth (near Porthmadog and the Glaslyn Estuary)

13.2 The study area for these common works for strategic options 3, 4, 5, and 6 is shown in Figure 10.1, is defined by a 2 km wide area centred upon those overhead lines which are to be re-conductored. This study area includes the area in the vicinity of Bryncir for the siting of the new substation.

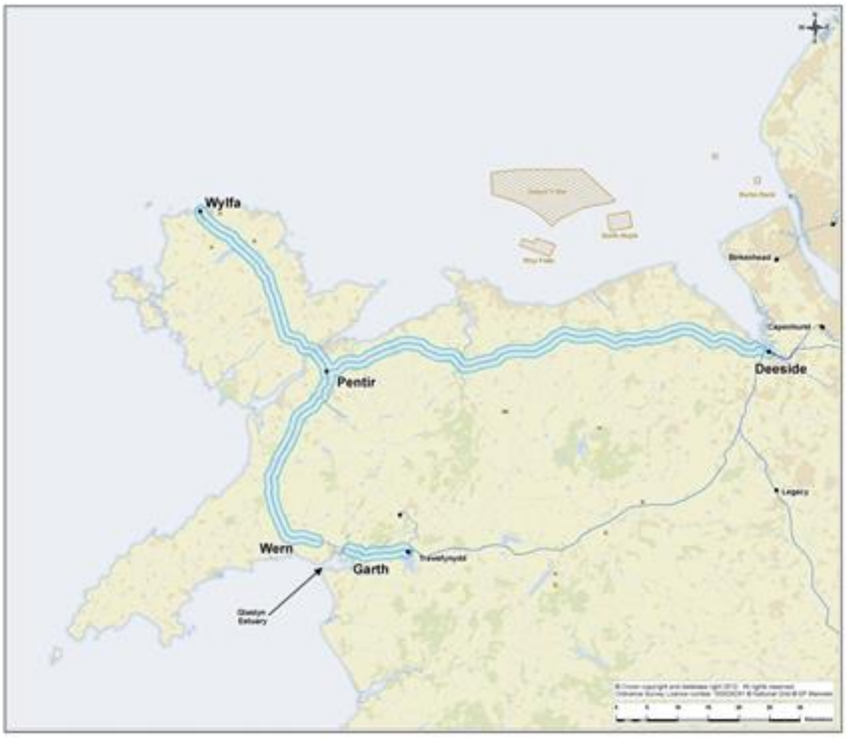


Figure 13.1 – Study Area for Common Works (a) – (e) of Strategic Options 3, 4, 5 and 6

13.3 The following paragraphs set out the appraisal of these common works. Common works (a), (b), (c), (d) and (e) will be appraised together. Common work (f) will then be appraised separately due to the range of technology choice associated with this section of work.

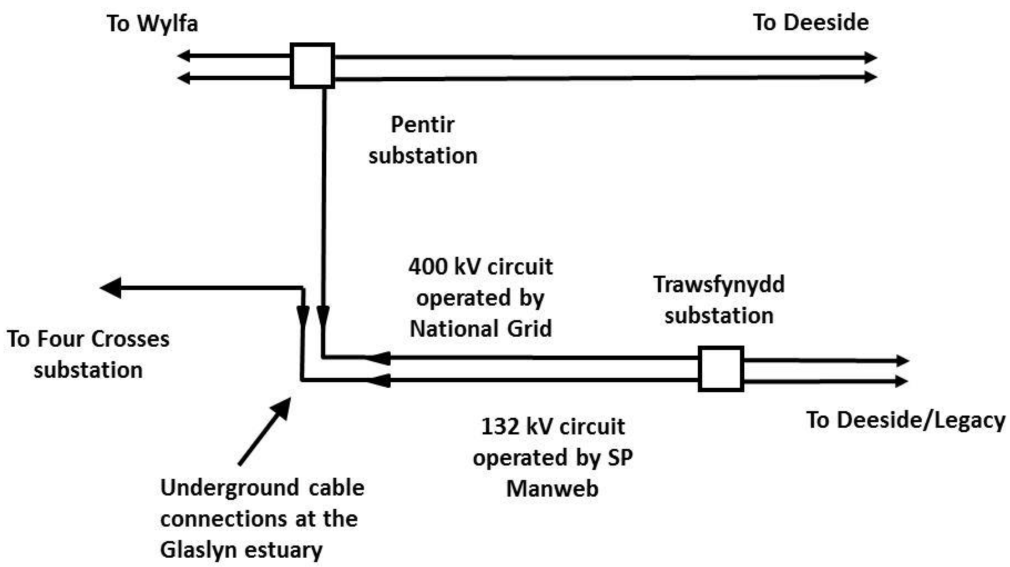
13.4 The conclusions presented in the following sections apply equally to strategic options 3, 4, 5, and 6. A summary table is given in section 18 that shows the total overall cost for these strategic options, including the common works.

14 Appraisal of Common Works (a), (b), (c), (d) and (e)

14.1 There are currently three circuits taking the power out of Pentir going east:

- A 400 kV AC double circuit overhead line between Pentir and Deeside, and
- A 400 kV AC single circuit between Pentir and Trawsfynydd, comprising a 6 km underground cable section between Wern and Y Garth (at Porthmadog and the Glaslyn Estuary) and overhead line for the remainder of the circuit.

14.2 SP Manweb utilises part of one side of the Trawsfynydd to Pentir route. This section of the route operates at 132 kV between Trawsfynydd and Bryncir at which point it leaves the route to run on wood pole structures to Four Crosses substation which provides power to the Llyn Peninsula. This arrangement is



illustrated in Figure 6.4.

Figure 14.1 – Schematic illustration of the existing arrangement on the Pentir to Trawsfynydd route

14.3 It should be noted that the pylons on the Pentir to Trawsfynydd route are a 400 kV design and the side operating at 132 kV can be easily modified to operate at 400 kV.

14.4 In accordance with the Policy, National Grid will only seek to build electricity lines where our existing infrastructure cannot be technically or economically upgraded.

In this case, the required transmission capacity can be established by developing a second circuit between Pentir and Trawsfynydd. This can be achieved by taking over the second side (currently operating at 132kV) of the existing overhead line circuit

14.5 A consequence of establishing the second Pentir to Trawsfynydd circuit is that the local DNO, SP Manweb, requires an alternative means of supplying electricity to the Llyn Peninsula. As a result of work jointly undertaken by National Grid and SP Manweb, it has been assumed for the purposes of this appraisal that a new grid supply point substation is established in west Gwynedd, fed from one of the Pentir to Trawsfynydd 400 kV circuits.

14.6 There is a 6km section of the existing Pentir to Trawsfynydd 400kV circuit that is made up of AC cable. This section is located between Wern and Y Garth (at Porthmadog and the Glaslyn Estuary).

14.7 The existing Pentir to Trawsfynydd overhead line was constructed in the 1960s and at that time a condition of the consent was that the Glaslyn section between Wern and Y Garth was completed using underground cable.

14.8 This cable section will required to be upgraded as part of these works. As there are a number of technology choices available to achieve this, this element of the work (described above as common work (f)) will be appraised separately in section 15.

Technical and Cost Appraisal of Common Works (a), (b), (c), (d) and (e)

14.9 There are no specific technical issues or impacts relating to taking over the existing 132kV circuit, re-conductoring existing circuits, or substation works.

Costs of Common Works (a), (b), (c), (d) and (e)

14.10 The capital cost estimates for these common works are shown in table 14.1.

Item	Need	Cost
(a) New Pentir to Trawfynydd circuit & reconductoring of existing circuit	Increase capacity at boundaries NW2 and NW3	£71m
(b) Modify Pentir and Trawsfynydd 400 kV substations	Connect the new circuits	£40m
(c) West Gwynedd GSP	New supply for SP Manweb	£21m
(d) Re-conductoring of existing North Wales circuits	Increase capacity at boundaries NW2 and NW3	£55m
(e) Install series compensation	Increase stability	£35m
Total Capital Cost		**£222m**

Table 14.1 – Strategic Options 3, 4, 5 and 6 – Common Works (a), (b), (c), (d) and (e): Capital Cost Estimates

14.11 In summary, the estimated total capital cost for common works (a), (b), (c), (d) and (e) for Strategic Options 3, 4 and 5 is £222m.

Environmental and Socio-Economic Appraisal of Common Works (a), (b), (c), (d) and (e)

14.12 The principal environmental designations affecting the common works are shown in Figure G.5 in Appendix G of this report. Within the study areas where re-conductoring will be undertaken, 17 ecological constraints (7 SACs, 1 Ramsar site and 9 SSSIs) have been identified as being material to the decision. None can be avoided; however potential impacts can be mitigated through appropriate access and construction management plans.

14.13 The study area for the re-conductoring of the existing Pentir - Deeside and Pentir - Trawsfynydd lines passes through Snowdonia National Park. The northern route also passes through the Clwydian Range AONB. While the re-conductoring works would result in temporary disruption and visual impacts to these nationally important landscape designations during the engineering phase, the operational impacts would not increase significantly from those currently associated with the line. As such these designations are not considered material to the selection of a preferred strategic option.

14.14 While rural in character there are few constraints in the vicinity of the existing 400 kV line in West Gwynedd that would substantially limit site options for a new substation. Therefore the environmental and socio-economic effects of a new substation are not considered material to the selection of a preferred option at this strategic level of appraisal.

14.15 As previously stated, an alternative means of supplying the Llyn Peninsula would need to be developed if National Grid made use of the side of the Pentir to Trawsfynydd tower route currently used by SP Manweb. This is still being jointly assessed with SP Manweb but for the purposes of the option appraisal it has been assumed that a new grid supply point substation would be constructed in West Gwynedd in the vicinity of where the SP Manweb circuits leave the Pentir to Trawsfynydd route and join the line to Four Crosses substation.

14.16 For the purposes of this appraisal it has been assumed that the series compensation could be located adjacent to or within one or more of the existing substation sites at Pentir, Deeside or Trawsfynydd. While the final design of this electrical equipment is not known, locating it at existing sites would significantly reduce the potential for adverse environmental and socio-economic effects. As such these aspects of the strategic appraisal are not considered material to the selection of a preferred strategic option.

<u>Socio-Economic Appraisal of Common Works (a), (b), (c), (d) and (e) - Economic Activity & People and Communities</u>

14.17 No constraints appraised within this sub-topic are considered material to the decision at this level of appraisal.

15 Appraisal of Common Work (f) – Enhanced Connection between Wern and Y Garth

15.1 As described in section 15, there is a 6 km cable section between Wern and Y Garth sealing end compounds, which forms part of the existing Pentir to Trawsfynydd circuit.

15.2 The existing overhead line was constructed in the 1960s and at that time it was proposed that 4 km was installed underground at the Glaslyn estuary. The Secretary of State refused consent for an adjacent 2 km section of overhead line, largely to protect views of the Snowdon Massif from the coast, and therefore the installed cable length was extended to 6 km.

15.3 The capacity of this cable is insufficient for future needs and, in addition, it is reaching the end of its asset life. This cable will need to be replaced, this work will include:

- increase the capacity of this existing cable section of the existing Pentir to Trawsfynydd 400kV circuit, currently comprising ageing cables of inadequate capacity for future needs
- install a new connection between Wern and Y Garth to form part of the new second Pentir to Trawsfynydd 400kV circuit.
- modify the 400 kV cable sealing ends in the compounds at Wern and Y Garth.

15.4 The study area for this element of common works for strategic options 3, 4, 5 and 6 is shown in Figure 15.1 and is 20 km wide across the Glaslyn estuary near Porthmadog, centred upon a direct line between the two ends of the existing cable at Wern and Y Garth.

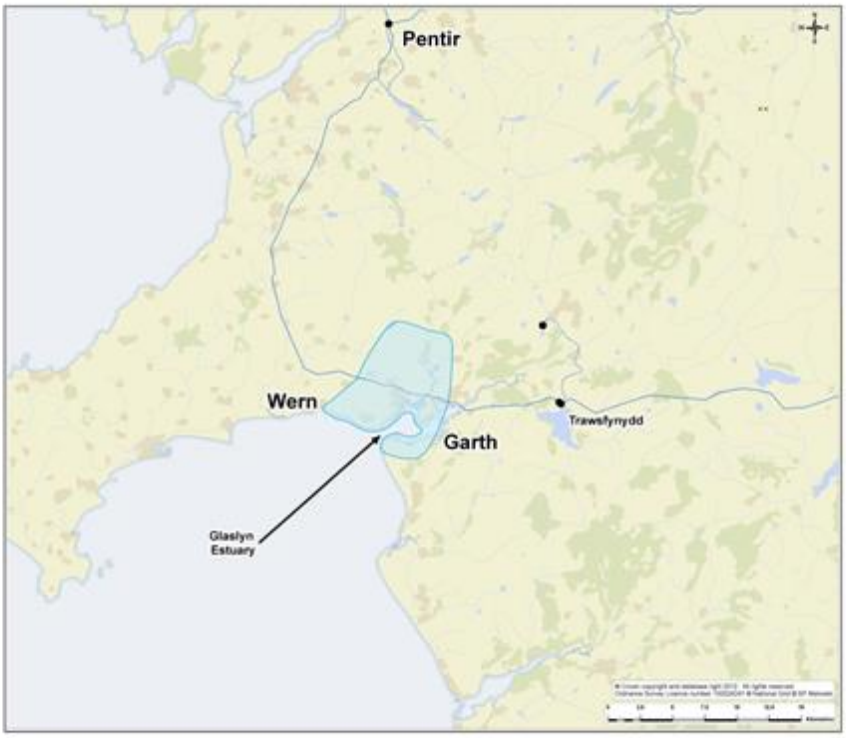


Figure 15.1 – Study area for common work (f) - Wern to Y Garth connection

15.5 The study area therefore includes a large area around the Glaslyn estuary including the settlements of Porthmadog and Tremadog, part of Snowdonia National Park to the north and the coast to the south.

15.6 The following paragraphs set out the results of the appraisal of these works.

<u>Technical and Cost Appraisal of Common Works (f)</u>

15.7 The 6km connection between the cable sealing ends at Wern and Y Garth could be made using any of the following technologies:

- AC Underground cable
- AC Overhead Line, and
- GIL.

15.8 HVDC was not considered for this connection. HVDC has economic advantages over longer distances but, due to the fixed cost of the converter stations, it is very expensive at shorter distances when compared with other technologies. Furthermore, the considerable environmental impact of building converter stations at Wern and at Y Garth means that this technology offers no advantage over AC cables at this location.

15.9 The connections would follow an appropriate route across the estuary and terminate at the existing towers, in the case of overhead line, or at the existing sealing end compounds in the case of the underground technologies.

15.10 Overhead line is a well proven technology and, although vulnerable in adverse weather conditions, most faults are temporary and self-rectifying. Faults which require remedial work are normally repaired quicker than faults on underground cables.

15.11 Installation of AC cable presents a number of technical issues which are likely to be surmountable but which must be carefully considered in cable system design and implementation.

15.12 GIL is similar in capital cost to AC cable. GIL has not been installed anywhere in the world with the capacity or length required for this application.

Costs

15.13 The capital and lifetime cost estimates for this option are shown in tables 15.1 and 15.2.

Item	**Need**	**Capital Cost**		
New Circuits		**OHL**	**AC Cable**	**GIL**
(f) Wern to Y Garth (‘Med’ Capacity, 6 km)	Connect Wern to Y Garth, creating additional capacity	£17m	£133m	£128m
Total Capital Cost		**£17m**	**£133m**	**£128m**

Table 15.1 Strategic Options 3, 4, 5 and 6 – Common Works (f) Wern to Y Garth Technology options: Capital Cost Estimates

	OHL	AC Cable	GIL
Capital Cost of New Circuits	£17m	£133m	£128m
NPV of Cost of Losses over 40 years	£19m	£7m	£9m
NPV of Operation & Maintenance Costs over 40 years	Negligible	£1m	Negligible
Lifetime Cost of New Circuits [34]	**£36m**	**£141m**	**£137m**

Table 15.2 Strategic Options 3, 4, 5 and 6 – Common Works (f) Wern to Y Garth Technology options: Capital and Lifetime Cost Estimates

15.14 In summary, the estimated capital costs for connecting Wern to Y Garth range from £17m for overhead line to £133m for AC Cable. The estimated lifetime costs for the new circuits range from £36m for overhead line to £141m for AC cables.

Environmental - Ecology and Biodiversity

15.15 The principal ecological sites affecting the study area at Glaslyn are shown in Figure G.4 in Appendix G of this report. The study area around the Glaslyn Estuary has four ecological constraints which are considered material to the decision

- Glaslyn SSSI
- Morfa Harlech SSSI
- Meirionnydd Oakwoods and Bat Sites SAC, and
- areas of Ancient and Semi Natural Woodland.

15.16 All can be avoided individually. However, routeing around Glaslyn SSSI and the Meirionnydd Oakwoods SAC would result in Morfa Harlech SSSI being impacted which is considered a significant constraint. One of these SSSIs would therefore be impacted which is considered material to the decision.

15.17 Regardless of the technology utilised between Wern and Y Garth, the existing 132 kV cables owned by SP Manweb and the 400 kV cables owned by National Grid will need to be either removed or made electrically and environmentally

[34] The lifetime cost calculation methodology is explained in Appendix D. It is used to compare the cost of connecting transmission substations using various technologies for the new circuits. It does not include the capital or lifetime costs of substation equipment. The lifetime cost is the net present value of capital costs, the costs of transmission losses and maintenance costs over 40 years. A discount rate of 3.5% is used.

safe. [35]

15.18 The existing underground cables are routed through Glaslyn SSSI and Meirionnydd Oakwoods and Bat Sites SAC. Removing these cables could result in severe ecological impacts, which are considered material to the decision. However leaving the redundant cables in-situ would largely avoid these impacts. Consultation feedback also highlighted local populations of Schedule 1 bird species (Whooper swans and Osprey) the former of which is known to be susceptible to the risk of striking overhead lines.

Environmental - Cultural Heritage, Landscape and Visual

15.19 The principal cultural heritage and landscape designations affecting the study area at Glaslyn option are shown in Figure G.4 in Appendix G of this report. Constraints within the Glaslyn estuary area considered to be material to the decision are:

- settlements (most notably Porthmadog and Tremadog)
- Wern Registered Park and Garden
- Tan-yr-Alt Registered Park and Garden
- Aberglaslyn Registered Historic Landscape
- Snowdonia National Park.

15.20 Settlements, both Registered Park and Gardens and Snowdonia National Park can be avoided; however the high risk of ongoing indirect visual impacts remains in the case of overhead line technology. Aberglaslyn Registered Historic Landscape cannot be avoided. The study area has a high concentration of cultural heritage, landscape and visual constraints which are of significant value.

15.21 There are potential impacts to the visual setting on a high number of cultural heritage assets and to the historic landscape, although this would be largely limited to the construction phase and is therefore not material.

15.22 In the case of overhead line technology it is assumed that the area within the National Park would be avoided. However the risk of significant visual impacts on

[35] The course of action for each set of cables would be agreed between National Grid and SP Manweb and fully discussed with statutory stakeholders.

views into and out of the National Park and to the visual amenity of a number of registered parks and gardens would remain. The close proximity of settlements and high visitor numbers to this area would also increase the visual impacts. Concern over the likely impact of an overhead line on the National Park, even after mitigation and practical offsetting measures, was shared by key statutory bodies during early consultation.

Environmental - Other Sub-topics

15.23 No constraints considered to be material to the decision within the sub-topics noise and vibration, soil and geology and hydrology and flood risk have been identified. The overall risk to these sub-topics is considered to be low. While much of the Glaslyn Estuary lies within the identified flood plain, appropriate design and construction could limit impacts during the operational phase.

Environmental - Consideration of combined Environmental Sub-topics

15.24 In combination the designations and constraints identified would act to significantly restrict the potential routes for a new overhead line or underground cable route. This would be particularly important in the case of overhead technology, where the landscape and visual effects in particular have the potential to adversely affect nearby designations and features beyond the route itself.

Socio-Economic - Economic Activity and People and Communities

15.25 No constraints appraised within this sub-topic are considered material to the decision at this level of appraisal. However key socio-economic issues have been identified.

15.26 Socio-economic impacts are considered to be more extensive during construction than during operation.

15.27 It has been assumed that a small proportion of the workforce required for this project will need to be specialised, however a proportion could be sourced locally for some construction works. Construction is estimated to take approximately four years in the case of underground cable and approximately two years in the case of overhead line.

15.28 Some localised disruption during construction is expected for road networks across Gwynedd and North Wales.

15.29 Disruption to the transport network is unlikely to deter tourists from visiting North Wales. At this strategic level, it is not possible to ascertain whether an overhead line at Glaslyn would have any longer term impact upon the local tourism industry, although it is assumed that the potential for any such long term impacts would be lower for underground technology.

15.30 Potential benefits from this strategic option include an increase in economic activity due to a specialised work force being located in the area for between two years or four years (overhead line and underground cables respectively) and the associated opportunities for local employment.

16 Summary of Common Works for Strategic Options 3, 4, 5 and 6

16.1 As described earlier, Strategic Options 3, 4, 5 and 6 can all be separated into two distinct parts: the work required on Anglesey to connect between Wylfa and Pentir substations and reinforce boundary NW1, and the work required on the mainland to reinforce boundaries NW2 and NW3.

16.2 All work proposed on the mainland to reinforce boundaries NW2 and NW3 is identical for each of these options with only the proposed work on Anglesey being different.

16.3 The appraisal and cost estimation of these common works is given in sections 14 and 15. A summary of the capital cost estimates is shown in Table 16.1 below.

Item	Need		Cost	
(a) New Pentir to Trawfynydd circuit & reconductoring of existing circuit	Increase capacity at boundaries NW2 and NW3		£71m	
(b) Modify Pentir and Trawsfynydd 400 kV substations	Connect the new circuits		£40m	
(c) West Gwynedd GSP	New supply for SP Manweb		£21m	
(d) Re-conductoring of existing North Wales circuits	Increase capacity at boundaries NW2 and NW3		£55m	
(e) Install series compensation	Increase stability		£35m	
	OHL	**AC Cable**	**HVDC**	**GIL**
(f) Wern to Y Garth	£17m	£133m	N/A	£128m
Total Capital Cost	**£239m**	**£355m**	**N/A**	**£350**

Table 16.1 – Strategic Options 3, 4, 5 and 6 – Common Works: Capital Cost Estimates

16.4 The strategic options appraisal and results of early consultation feedback have identified sensitive receptors that could be affected by all or much of any overhead transmission route crossing the Estuary. Furthermore, National Grid has identified that none of the technology options could avoid the Estuary through careful routeing. On this basis, National Grid believes that the higher cost of an underground option (AC Cable or GIL) and the other impacts arising from the installation of circuits under the Estuary are likely to be justified by avoiding the higher landscape and visual impacts associated with an overhead line. This aligns with a previous decision made by the Secretary of State in 1964, which determined that the proposed transmission line between Wern and Y Garth should be underground.

16.5 Although GIL potentially offers some capital cost saving over AC Cable, National Grid considers that AC Cable would be the preferred underground technology for the Wern to Y Garth connection due to the uncertainty and risk that would be associated with the procurement and installation of the unproven GIL technology in what could be challenging ground conditions.

16.6 Therefore, National Grid believes that, on the basis of the appraisal undertaken to date, an underground cable between Wern and Y Garth is likely to achieve the most appropriate balance between its technical, economic, amenity and environmental obligations.

17 Cost Summary of All Strategic Options

17.1 The appraisal and cost estimation for all six Strategic Options has been detailed in sections 6 to 16.

17.2 Table 17.1 summarises the total estimated capital costs for each of the six Strategic Options.

	Description	Total Capital Cost by Technology Type			
		OHL	**AC Cable**	**HVDC**	**GIL**
SO1	2x HVDC Wylfa - Deeside	**N/A**	**N/A**	**£1,134m**	**N/A**
SO2	1x HVDC Wylfa – Deeside 1x HVDC Wylfa - Pembroke	**N/A**	**N/A**	**£1,378m**	**N/A**
SO3	Wylfa to Pentir Onshore	£164m	£585m	£776m	£798m
	Mainland Common Works*	£355m	£355m	£355m	£355m
	Strategic Option 3 Total	**£519m**	**£940m**	**£1,131m**	**£1,153m**
SO4	Wylfa to Pentir Offshore (E)	N/A	£900m	£866m	N/A
	Mainland Common Works*	N/A	£355m	£355m	N/A
	Strategic Option 4 Total	**N/A**	**£1,255m**	**£1,221m**	**N/A**
SO5	Wylfa to Pentir Offshore (W)	N/A	£1,113m	£927m	N/A
	Mainland Common Works*	N/A	£355m	£355m	N/A
	Strategic Option 5 Total	**N/A**	**£1,468m**	**£1,282m**	**N/A**
SO6	Wylfa to Pentir Hybrid	£560m	£836m	£876m	£973m
	Mainland Common Works*	£355m	£355m	£355m	£355m
	Strategic Option 6 Total	**£915m**	**£1,191m**	**£1,231m**	**£1,328m**

* Assumes AC underground cable is used for the Wern to Y Garth Connection

Table 17.1 All Strategic Options: Capital Cost Estimates

17.3 In terms of cost, it is generally true that the more extensive the underground / subsea cable component of an option the higher the cost. The total capital costs of each strategic option (and technology options) are illustrated in Figure 17.1. (Note that for simplification, each option that includes the mainland common works described in sections 13, 14, and 15 assumes underground cable is used for the section between Wern and Y Garth. In order to reflect consultation feedback the cost for SO6 – OHL / AC Cable / AC Cable has also been included here, see paragraph 12.20 for further details).

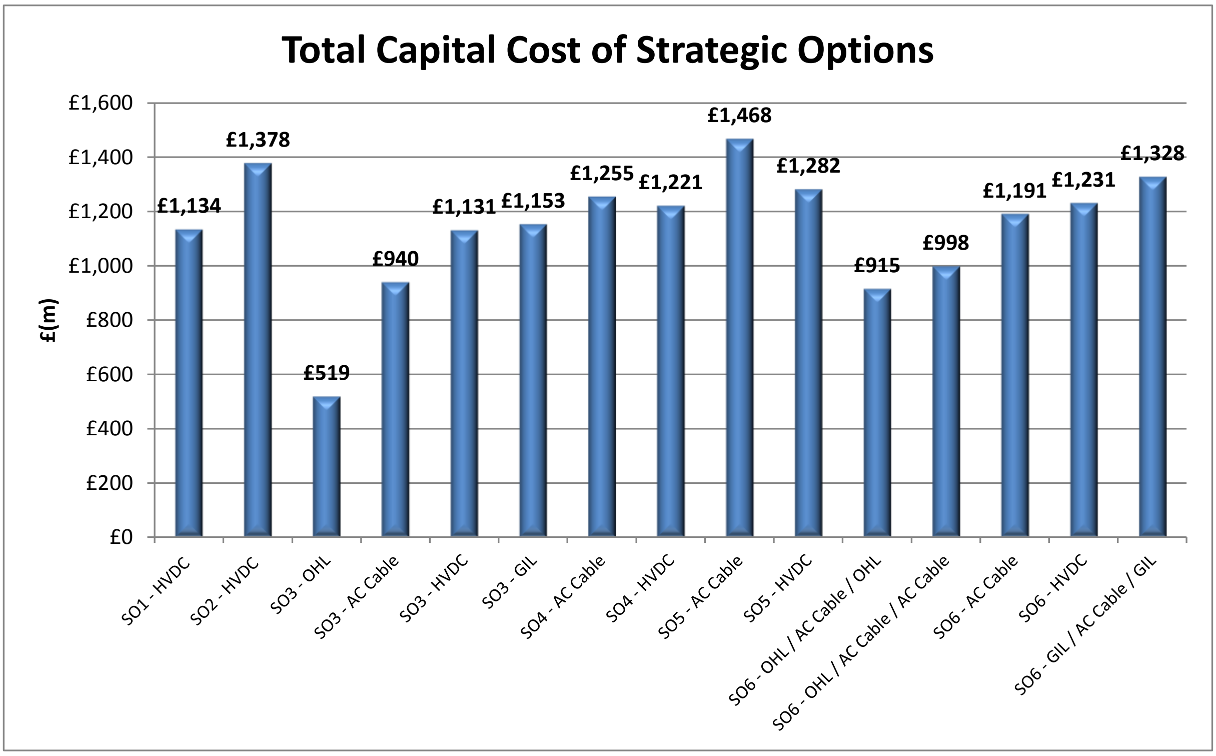


Figure 17.1 – Estimated Total Capital Costs

17.4 SO3 – OHL is the strategic option with the lowest estimated capital cost (£519m).

17.5 It can be seen that the difference in cost between options is significant with the estimated total capital cost of the most expensive option (SO5 – AC cable) being almost three times the estimated total capital cost of the least expensive option (SO3 – OHL).

17.6 It is also evident that the estimate for the lowest cost option with no new overhead line elements, SO3 –AC cable, is approximately £420m more expensive than the cost of SO3 –OHL.

17.7 SO6 – OHL / AC Cable / OHL is comparable in cost to SO3 – AC Cable. While SO6 does include an offshore section there are also two significant onshore sections which would require overhead line development. If AC cable were to be used for these onshore sections the total capital cost estimate would rise to £1,191m (SO6 – AC Cable). Consultation feedback suggested that AC Cable would be preferred for the mainland section of SO6 this would result in a cost of £998m

17.8 The lowest cost fully offshore option is SO1 – HVDC (£1,134m). The estimated cost for this option is approximately £600m more expensive than SO3 – OHL.

18 Conclusions

The factors that most significantly differentiate between the strategic options are: visual and landscape amenity, capital cost, and technical risk. Other material impacts were also identified but these are the most significant differentiating factors.

Strategic Option 1 - Summary

18.1 This option is primarily comprised of:

- Two HVDC subsea circuits connecting Wylfa and Deeside

18.2 With an estimated total capital cost of £1,134m this option is significantly more expensive (by approximately £600m capital cost) than the lowest cost strategic option – SO3 onshore overhead line.

18.3 There is a high concentration of environmental constraints that could be material to this option; offshore, in the Dee Estuary and along both banks of the Dee Estuary. These include the 'Natura 2000' sites of the Dee Estuary SAC and SPA (and Ramsar site) and Liverpool Bay SPA, the latter of which could not be avoided (although it might be possible to avoid significant effects upon the site, which is primarily designated for its overwintering populations of seabirds, through appropriate mitigation). The concentration of other onshore constraints could limit the opportunities for cable routeing in both North Wales and the Wirral. The converter stations at Wylfa would indirectly impact views from the Anglesey AONB, although this would be seen in the context of the potential new nuclear power station. Similarly, the converter stations at Deeside are not anticipated to result in unacceptable landscape or visual impacts given the industrial nature of the landscape in the vicinity.

18.4 As a result of the current uncertainty and technical risk associated with using HVDC circuits to connect synchronous power stations, the use of HVDC circuits for the nuclear power station connection in this project is considered to represent an unproven technology risk which may result in material additional costs and delays being incurred to develop an acceptable solution.

Strategic Option 2 - Summary

18.5 This option is primarily comprised of:

- One HVDC subsea circuit connecting Wylfa and Deeside
- One HVDC subsea circuit connecting Wylfa and Pembroke

18.6 The estimated total capital cost of this option is £1,378m. SO2 has a higher estimated capital cost (£244m more) than the other fully offshore HVDC option - SO1. This is primarily due to the increase route length to Pembroke. SO2 has an estimated capital cost approximately £860m higher than the lowest cost strategic option – SO3 onshore overhead line.

18.7 The principal receptors and risk levels for the HVDC circuit and associated converter stations at Wylfa and Deeside are as described above for Strategic Option 1. The reduction in the number of circuits and converter stations from two to one at Deeside is not considered to alter the assessment of risk associated with these elements at this strategic level.

18.8 The introduction of an HVDC cable route to Pembroke would result in impacts to additional receptors. While the industrial nature of the landscape around Pembroke substation means a significant visual impact is not anticipated, the HVDC cable route would have to pass through two additional ecological sites, the Pembrokeshire Marine SAC being of particular note. The general concentration of other constraints in Pembrokeshire, including Pembrokeshire Coast National Park and Heritage Coasts, would also limit opportunities for cable routeing.

18.9 As with Strategic Option 1, the current uncertainty and technical risk associated with using HVDC circuits to connect synchronous power stations, the use of HVDC circuits for the nuclear power station connection in this project is considered to represent an unproven technology risk which may result in material additional costs and delays being incurred to develop an acceptable solution.

Strategic Option 3 – Summary

18.10 This option is primarily comprised of:

- New onshore circuits connecting Wylfa and Pentir

- One new AC circuit connecting Pentir and Trawsfynydd, to be installed on existing pylons
- A new connection between Wern and Y Garth
- A new substation at west Gwynedd
- Re-conductoring of existing circuits in North Wales
- Modifications at existing substations
- Installation of series compensation equipment

18.11 The capital costs for this option range from £519m for overhead line between Wylfa and Pentir to £1,153m for GIL, both assuming underground AC cables are used between Wern and Y Garth. If overhead line technology is used then SO3 is the lowest cost of all Strategic Options.

18.12 There are a number of technology options relating to this strategic option. The use of AC underground cable, GIL, HVDC and AC overhead line were considered for the Wylfa to Pentir connection. Underground cable, GIL and overhead line were considered for the connection between Wern and Y Garth. The main conclusions of the assessment of this option are discussed in the following paragraphs.

<u>Strategic Option 3 – Wylfa to Pentir connection</u>

18.13 The use of underground cables (AC or HVDC) or GIL between Wylfa and Pentir would avoid significant permanent impact arising from landscape and visual effects in the study area. An underground cable route would necessarily pass through a 'Natura 2000' site, Menai Strait SAC. The high concentration of cultural heritage receptors, especially around Menai Strait, would limit available route options.

18.14 A wholly overhead line between Wylfa and Pentir, including across Menai Strait, would necessarily pass through the Anglesey AONB. Other constraints on the island are scattered and could be more easily avoided by routeing. Various mitigation measures would be possible to reduce or avoid impacts to the AONB and other sensitive receptors. The high concentration of sensitive receptors bordering Menai Strait, both from a landscape and visual and cultural heritage perspective, would limit transmission route options.

18.15 Following further appraisal and consideration of feedback from consultation, National Grid has now announced that mitigation in the form of buried cables is proposed through the AONB and across Menai Strait. The cost of this mitigation has not been included in the costs of the SO3 at the strategic level. However, it is assumed that this would increase the cost of this option by between £35M - £50M to substantially mitigate landscape and visual impacts in this the most sensitive part of the study area by crossing the Menai Strait itself and the AONB.

Strategic Option 3 – Wern to Y Garth connection

18.16 Within the study area at Glaslyn, there are two Registered Parks and Gardens, Snowdonia National Park and a number of settlements, particularly Porthmadog and Tremadog. While it would be possible to route around these areas, an overhead line would result in a very high impact from landscape and visual effects, especially in the case of an overhead line. The route would also have to pass through one of two SSSIs in the area, and close to or though the Meirionnydd Oakwoods and Bat Sites SAC. Impacts to these sites would be less material in the case of an overhead line.

Strategic Option 3 – New substation in West Gwynedd

18.17 Establishing the second Pentir to Trawsfynydd circuit means that the local DNO, SP Manweb, requires an alternative means of supplying electricity to the Llyn Peninsula. The associated works that would be required by SP Manweb have yet to be fully established but the working assumption is that a new substation will be required in west Gwynedd.

Strategic Option 4 – Summary

18.18 This option is primarily comprised of:

- New offshore circuits (AC or HVDC), located east of Anglesey, connecting Wylfa and Pentir
- One new AC circuit connecting Pentir and Trawsfynydd, to be installed on existing pylons
- A new connection between Wern and Y Garth
- A new substation at west Gwynedd

- Re-conductoring of existing circuits in North Wales
- Modifications at existing substations
- Installation of series compensation equipment

18.19 The capital costs for this option range from £1,221m for HVDC between Wylfa and Pentir to £1,255m for subsea AC cables, both assuming underground AC cables are used between Wern and Y Garth. This option is approximately £700m more expensive than the lowest cost Strategic Option.

18.20 There are a number of technology options relating to this strategic option. The use of subsea AC cable and HVDC were considered for the Wylfa to Pentir connection and, as with Strategic Option 3, underground AC cable, GIL and overhead line were considered for the connection between Wern and Y Garth. The main conclusions of the assessment of this option are discussed in the following paragraphs.

18.21 As with Strategic Option 1, the current uncertainty and technical risk associated with using HVDC circuits to connect synchronous power stations, the use of HVDC circuits for the nuclear power station connection in this project is considered to represent an unproven technology risk which may result in material additional costs and delays being incurred to develop an acceptable solution.

<u>Strategic Option 4 – Wylfa to Pentir connection</u>

18.22 The use of subsea cables would largely avoid terrestrial impacts on Anglesey. However, the cables buried in the seabed to the east of the Island would have to pass through both the Liverpool Bay SPA and Menai Strait and Conwy Bay SAC. While the impact to the SPA is likely to be limited due to the nature of its features of interest, the potential impacts to the SAC represent a risk that the works could affect the site's integrity although mitigation measures would be available.

<u>Strategic Option 4 – Wern to Y Garth connection and the new substation in West Gwynedd</u>

18.23 For Strategic Option 4, the assumptions regarding the works between Wern and Y Garth and the new substation in west Gwynedd would be the same as for Strategic Option 3 (see paragraph 18.22 above).

Strategic Option 5 – Summary

18.24 This option is primarily comprised of:

- New offshore circuits (AC or HVDC), located west of Anglesey, connecting Wylfa and Pentir
- One new AC circuit connecting Pentir and Trawsfynydd, to be installed on existing pylons
- A new connection between Wern and Y Garth
- A new substation at west Gwynedd
- Re-conductoring of existing circuits in North Wales
- Modifications at existing substations
- Installation of series compensation equipment

18.25 The capital costs for this option range from £1,282m for HVDC between Wylfa and Pentir to £1,468m for subsea AC cables, both assuming underground AC cables are used between Wern and Y Garth. This option is approximately £760m to £950m more expensive than the lowest cost Strategic Option.

18.26 There are a number of technology options relating to this strategic option. The use of subsea AC cable and HVDC were considered for the Wylfa to Pentir connection and, as with strategic options 3 and 4, underground AC cable, GIL and overhead line were considered for the connection between Wern and Y Garth. The main conclusions of the assessment of this option are discussed in the following paragraphs.

18.27 As with Strategic Option 1, the current uncertainty and technical risk associated with using HVDC circuits to connect synchronous power stations, the use of HVDC circuits for the nuclear power station connection in this project is considered to represent an unproven technology risk which may result in material additional costs and delays being incurred to develop an acceptable solution.

Strategic Option 5 – Wylfa to Pentir connection

18.28 The use of subsea cables would largely avoid terrestrial impacts on Anglesey. Routeing the cables to the west of the Island would avoid the marine 'Natura

2000' sites that the east route would impact. Cable routeing opportunities between the coast and Pentir also appear less constrained for the western marine cable options.

Strategic Option 5 – Wern to Y Garth connection and new substation in West Gwynedd

18.29 For Strategic Option 5, the assumptions regarding the works between Wern and Y Garth and the new substation in west Gwynedd would be the same as for Strategic Option 3 (see paragraph 18.22 above).

Strategic Option 6 – Summary

18.30 Assuming AC technology is used (OHL and Cables), this option is primarily comprised of:

- replacement of the existing 132 kV overhead line between Wylfa and Valley with a new 400 kV connection
- installation of a new GSP in the Valley area
- installation of approximately 30 km subsea cable circuits and 8km of onshore circuits between Valley and a new substation in west Gwynedd
- One new AC circuit connecting Pentir and Trawsfynydd, to be installed on existing pylons
- A new connection between Wern and Y Garth
- A new GSP at west Gwynedd
- Re-conductoring of existing circuits in North Wales
- Modifications at existing substations
- Installation of series compensation equipment

18.31 The total capital costs for this option (assuming the use of AC OHL and Cable technology) are £915m, also assuming underground AC cables are used between Wern and Y Garth. Strategic Option 6 has the next lowest capital cost after Strategic Option 3 – Onshore OHL. However, there still remains a significant cost difference of approximately £400m. It should also be noted that the cost of Strategic Option 6 would rise by an additional £83m if AC Cables were used onshore to connect to west Gwynedd. A preference for that approach was indicated in the consultation feedback received

18.32 There are a number of technology options relating to this strategic option. For the route between Wylfa and Valley OHL, AC Cable, HVDC, or GIL could be used. However, it is considered most likely that OHL or AC Cable would be the most practical option. GIL would offer no material benefit over AC Cable and hence if an OHL route was not possible AC Cable would be the mitigation option.

18.33 Utilising HVDC over such a short distance is not an efficient design as the fixed costs of the converters mean that even short routes are very expensive when compared with other options. However, HVDC could be utilised for the full length of the route (Wylfa – west Gwynedd).

18.34 If an AC option was selected then AC Cable would be used for the subsea section between Valley and the North Wales mainland.

18.35 The onshore route to west Gywnedd could utilise OHL, AC Cable, or GIL. However, the same considerations described for the Wylfa to Valley section apply here, and hence only OHL or AC Cable would be considered practical options.

Strategic Option 6 – New Connection between Wylfa and Valley

18.36 Removing the existing, National Grid owned, 132kV overhead line would help to offset the landscape and visual effects of a new 400kV overhead line in this part of Anglesey by reducing the degree of landscape and visual change. At the individual receptor level the degree of offsetting would be dependent upon the final alignment of the 400kV line. Nevertheless significant effects would remain, including potentially upon views from parts of the AONB. It may not be technically possible to follow exactly the same alignment as the existing line in locations such as the Llyn Alaw wind farm. The construction phase would also give rise to significant temporary environmental effects and community disruption. The use of buried cables would substantially reduce many of these effects but could draw into question the need to mitigate the residual impacts by removing the existing 132kV overhead line at significant additional cost.

Strategic Option 6 – New GSP at Valley

18.37 A new substation GSP in the countryside to the east of Valley would result in significant local landscape and visual effects, which could be mitigated in the medium to long term through careful screen planting. Impact to views from within the AONB would also be limited through distance. Ecological and cultural heritage impacts could be reduced through careful siting of the substation. The construction phase would also result in temporary effects and disruption to local communities.

Strategic Option 6 – Valley to North Wales Mainland Connection

18.38 The installation of AC cables would largely avoid enduring landscape effects and visual effects between the GSP and the coast. Temporary effects and disruption would occur during the installation phase and careful consideration would need to be given to crossing the A55. Detailed discussion would need to be held with the Ministry of Defence so as to avoid impacts upon the operations at RAF Valley. Suitable landfall points on the Anglesey coast are limited by the airfield built development and designated nature conservation sites. Offshore cabling could avoid designated marine sites but consideration would need to be given as to how best to mitigate possible impacts upon commercial shell fisheries. Landfall opportunities on the Gywnedd coast are less constrained than those on Anglesey.

Strategic Option 6 – Connection to New 400 kV Substation in west Gwynedd

18.39 Whilst works within the Snowdonia National Park and Llyn AONB could be avoided, any new overhead line between the coast and the new substation connection point would have significant landscape and visual effects, potentially including effects to views from these sites. Other material considerations include the Glynllifon Estate, which is an important socio-economic receptor and is subject to a number of statutory nature conservation and cultural heritage designations. The use of buried cables would substantially reduce many of these effects but would still give rise to significant temporary effects during the installation phase.

Strategic Option 6 – New 400 kV substation in West Gwynedd

18.40 Whilst this substation could be co-located or even combined with the new GSP required in west Gwynedd, this would do little to reduce the total substation footprint. Careful consideration would need to be given to the whether two separate sites or a single larger site would be preferable from an environmental and socio-economic perspective. In either event the construction of a large new substation would give rise to long-term, but localised visual effects. The significance of the landscape impact would be heavily influenced by final site selection as there is existing built development in the vicinity of the existing 400kV overhead line as it diverges away from the national park boundary. Further mitigation in the form of landscape screening could be effect in the medium to long term. Careful siting would seek to avoid significant effects upon designated cultural heritage and nature conservation sites. The construction phase would result in temporary effects and disruption to local communities.

Strategic Option 6 – Wern to Y Garth connection and new substation in West Gwynedd

18.41 For Strategic Option 6, the assumptions regarding the works between Wern and Y Garth and the new GSP in west Gwynedd would be the same as for Strategic Option 3 (see paragraphs 18.22 above).

Differentiating Factors Between all Options

18.42 Those strategic options with an overhead line component have the highest risk of visual and landscape effects, particularly given the proximity of a number of sensitive areas, such as the Anglesey AONB and Snowdonia National Park, impacts which cannot be completely avoided by careful route selection (although noting these may be mitigated by other means). The strategic option with the most significant overhead line component (in terms of absolute distance) is option 3 with an overhead line from Wylfa to Pentir.

18.43 Strategic Option 6 (with a new overhead line between Wylfa and Valley, and between the Gwynedd coast and a connection point with the existing 400kV overhead line) also includes a substantial element of new overhead line, albeit that the associated effects could be partially offset through the removal of an existing 132kV line across the western part of Anglesey.

Strategic options 1 and 2 (subsea HVDC options) and strategic options 4 and 5, with underground technology between Wern and Y Garth, do not include any new overhead line component. These strategic options, therefore, have the lowest risk of visual and landscape impacts. Strategic options 4 and 5 could include an overhead line component between Wern and Y Garth only. Strategic Option 6 is comprised of a mix of onshore and offshore elements. If OHL was used for the main onshore sections then there would be visual and landscape effects, however it is expected that these would be less than those associated with Strategic Option 3.

Decision Making

18.44 With regard to cost, National Grid has a statutory duty to develop and maintain an efficient, co-ordinated and economical system of electricity transmission under Section 9 the Electricity Act.

18.45 This statutory duty is specifically recognised in paragraph 2.3.5 of the National Policy Statement for Electricity Networks Infrastructure, EN-5, which states that the IPC should take into account that National Grid is required under the Electricity Act to "… *bring forward efficient and economical proposals in terms of network design, taking into account current and reasonably anticipated future generation demand."*

18.46 With regard to visual and landscape impacts, National Grid also has statutory duties including those under the Electricity Act to have regard to amenity and mitigate the impacts of its projects. However, paragraph 2.8.2 of EN-5 states that the Government does not believe that the development of overhead lines is generally incompatible in principle with this statutory duty. While recognising that overhead lines can give rise to adverse landscape and visual impacts it also recognises that for the most part these impacts can be mitigated. It is acknowledged that at particularly sensitive locations the potential adverse landscape and visual impacts of an overhead line proposal may make it unacceptable in planning terms, taking account of the specific local environment and context.

18.47 Paragraph 2.8.9 of EN-5 states that *"the IPC should […] only refuse consent for overhead line proposals in favour of an underground or subsea line if it is satisfied that the benefits from the non-overhead line alternative will clearly outweigh any extra economic, social and environmental impacts and the technical difficulties are surmountable."*

Development Consents Required

18.48 On the basis of the strategic options appraisal, consultation feedback and mitigation likely to be available, National Grid believes that the risks of impacts identified so far are not sufficient for it to conclude that any of the strategic options are likely to be incapable in principle of receiving the necessary development consents when considered in isolation.

18.49 In particular, National Grid believes that appropriate mitigation, potentially including the selective use of underground technologies, would be available to reduce the visual and landscape effects arising from an overhead line between Wylfa and Pentir to acceptable levels in terms of paragraph 2.8.2 of EN-5. National Grid also believes that the benefit of a reduced visual and landscape impact between Wylfa and Pentir would not clearly outweigh, in terms of paragraph 2.8.9 of EN-5, the very significant additional cost of more than £420m to facilitate a wholly underground solution such that the Planning Inspectorate should refuse consent for an overhead line.

Overall Comparison of Strategic Options

18.50 Having concluded on the use of underground cable between Wern and Y Garth (see paragraphs 16.4 – 16.6), only two options, Strategic Options 3 and 6, potentially have major new overhead line elements, i.e. the new route between Wylfa and Pentir or between Wylfa and Valley, and the coast and west Gwynedd respectively.

18.51 It is acknowledged that Strategic Option 6 would involve shorter lengths of overhead line than Strategic Option 3 and would also allow for the removal of an existing overhead line.

18.52 National Grid recognises that appropriately balancing technical requirements, its economic duties, and its duty to have regard to amenity and mitigate impacts means that the lowest cost solution is not necessarily the most appropriate option in every case. However, in this case National Grid considers that any benefits delivered by non-overhead line variants of Strategic Option 3 (e.g. AC Cable, HVDC, or GIL) and Strategic Option 6 (any variant) would not outweigh the very significant additional capital costs (ranging from £396m - £809m) when compared to SO3 - OHL. Therefore, SO3 – OHL is the preferred variant of Strategic Option 3 and Strategic Option 6.

18.53 Strategic Option 3 – OHL is now compared against the remaining offshore based strategic options.

18.54 Strategic Options 1, 2, 4, and 5 would avoid the need to construct major new onshore transmission routes. Strategic Options 1 and 2 would require major new developments (converter stations) in the vicinity of the existing substations at Wylfa and Deeside or Pembroke, but the remainder of the works would comprise largely offshore HVDC cables. Strategic Options 4 and 5 would require development at Wylfa substation and at Pentir substation either within or immediately adjacent to the existing sites (if AC technology was used this development would be of a lesser extent than that required for Strategic development), together with the 'common works' that would also be required for SO3 and SO6.

18.55 National Grid has considered whether the potential benefits of these offshore options would outweigh the very significant additional capital costs (ranging from £615m – £949) when compared to SO3 –OHL (the preferred ‘onshore’ option). In this instance National Grid believes that this is not the case and that SO3 – OHL represents the most appropriate balance between the technical requirements, its economic duties and its duty to have regard to amenity and mitigate impacts.

Preferred Option

18.56 In the light of the options appraisal to date and consultation feedback, the view of National Grid is that Strategic Option 3, with new overhead line circuits connecting Wylfa and Pentir (potentially with appropriate mitigation, including the use of underground technologies) would best achieve an appropriate balance between National Grid's technical, economic, amenity and environmental obligations and is therefore identified as the preferred Strategic Option. This option also includes the identified common works on the North Wales mainland including: one new circuit connecting Pentir and Trawsfynydd (using existing pylons), underground cables connecting Wern and Y Garth, a new substation in west Gwynedd, series compensation, and the re-conductoring of existing circuits.

18.57 Figure 18.1 illustrates the estimated capital costs for the Wylfa to Pentir onshore technology options and illustrates emphatically the very significant cost differences. It excludes all common costs such as Wylfa 400 kV substation and modifications at Pentir 400 kV substation.

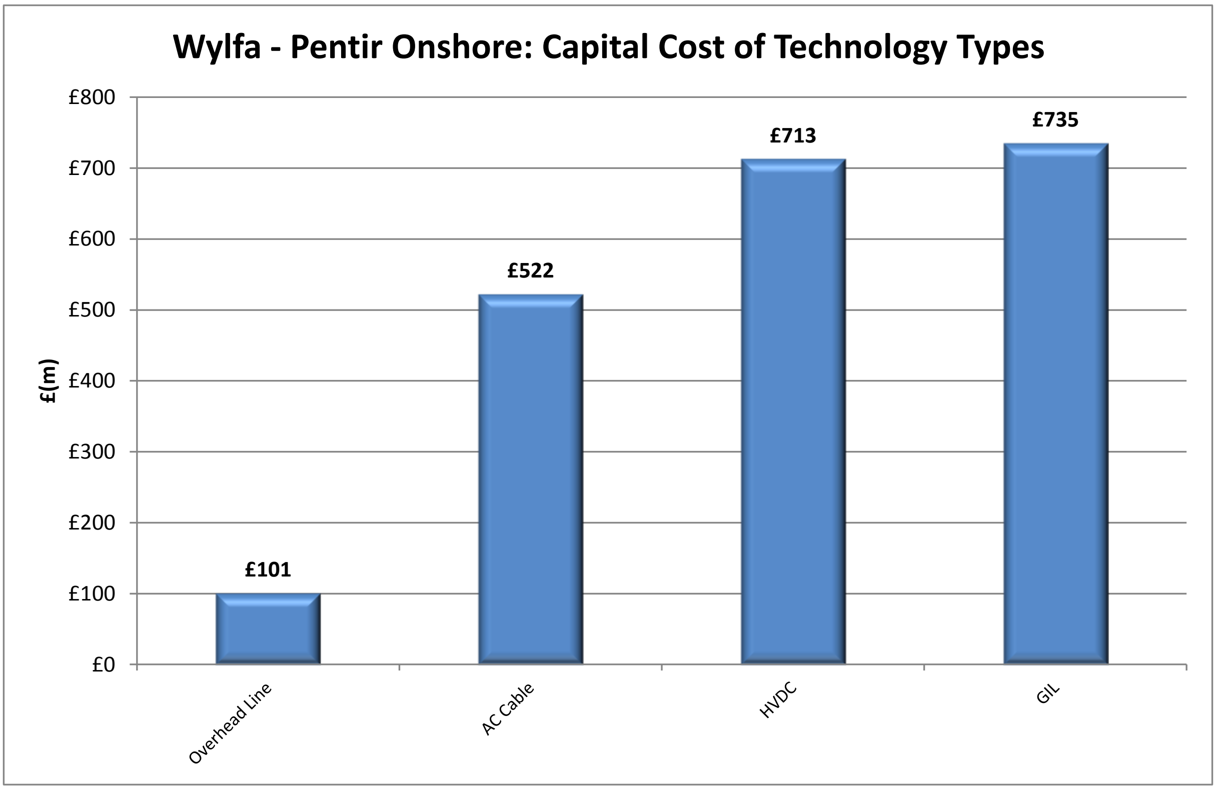


Figure 18.1 – Wylfa to Pentir Onshore Estimated Capital Costs of New Route Technology Types

Additional Benefits of Strategic Option 3

18.58 As described in the options appraisal section Strategic Option 3 can be split into two distinct pieces of work: the works on Anglesey to connect between Wylfa and Pentir to reinforce boundary NW1, and the works on the North Wales mainland to provide additional capacity across boundaries NW2 and NW3. This was also applicable to SO4, SO5, and SO6.

18.59 The primary driver for the works on Anglesey is the connection of the new nuclear power station. The primary driver for the works on the mainland is the connection of new offshore wind generation, as well as the new nuclear power station.

18.60 Being able to plan, resource and deliver these two elements of the overall strategic option with a degree of separation allows National Grid to ensure that the most economic and efficient solution can be delivered for GB consumers. Other strategic options such as SO1 or SO2 would require very large single investments to be made (e.g. purchase of HVDC equipment). This lower level of flexibility means that the risk of having capacity delivered ahead of need or potentially being underutilised (i.e. assets that are delivered but subsequently not required) is far higher.

Conclusion

18.61 Following the strategic options appraisal, National Grid's Preferred Option is Strategic Option 3, with overhead lines (potentially with appropriate mitigation applied) being the preferred technology choice.

18.62 Strategic Option 3 comprises of: an overhead line (with appropriate mitigation, potentially including the use of underground technologies) between Wylfa and Pentir, one new circuit connecting Pentir and Trawsfynydd (using existing pylons), underground cables connecting Wern and Y Garth, a new substation in west Gwynedd, series compensation, and the re-conductoring of existing circuits.

18.63 National Grid believes that Strategic Option 3 - OHL can be designed and is capable of being mitigated in such a way as to ensure compliance with the national planning policies set out in National Policy Statements EN-1 and EN-5 relating to energy developments, against which any application for development consent will be considered by the Secretary of State.

18.64 National Grid concludes that SO3 – Onshore OHL offers the lowest total capital cost whilst also balancing visual, landscape, and environmental concerns, and also offers greater flexibility that will help to ensure the most efficient and economic project is delivered for the GB consumer.

Assumptions

18.65 Certain assumptions have been made in reaching the conclusions set out above. These include an assumption that adequate mitigation of landscape and visual and other impacts will be possible between Wylfa and Pentir. As indicated, such mitigation potentially includes the use of underground technologies for certain parts of the route. The use of underground technologies is likely to be most appropriate in those areas subsequently identified as particularly sensitive. In this context feedback has already raised concerns about the sensitivity of the Anglesey AONB and views around the Menai Strait to overhead line development which would be considered in more detail at the next stage of option appraisal.

18.66 Since the last round of consultation in 2012 National Grid has announced that for any onshore connection between Wylfa and Pentir AC underground cables would be used for the section of the route through the Anglesey AONB and across the Menai Strait. National Grid has concluded that AC cables are the only suitable technology type that can adequately balance the cost and environmental impact considerations for this particular section of the route and fulfil National Grid's statutory duty to have regard to conservation and enhancement of the AONB.

18.67 National Grid recognises that the cost of mitigation measures will increase the capital cost of any strategic option. In the case of the preferred strategic option the cost of employing underground cables through the Anglesey AONB and across the Menai Strait, as announced in January 2015, is assumed to add a further £35-£50 Million to the cost of the option. However, having regard to the outcomes of the strategic option appraisal and consultation, National Grid believes that these additional costs, together with any further mitigation measures that may be identified as the project design continues to evolve, are unlikely to have a significant impact on this preferred Strategic Option decision.

18.68 These assumptions, including those made on available mitigation, will be considered in more detail as the options appraisal process continues. In particular, National Grid acknowledges that the extent of undergrounding which would be appropriate as mitigation remains uncertain. In order to assess whether the conclusion on the Preferred Option remains valid and robust, National Grid's judgment will be back-checked and re-evaluated at each stage of the project's development.

19 Consultation in 2015

19.1 National Grid will be undertaking further public consultation during 2015. These consultation activities will focus on the new circuits between Wylfa and Pentir, which are expected to constitute a nationally significant infrastructure project.

19.2 Consultation will seek feedback from key stakeholders and the public on a number of issues including the announcement of National Grid's selection of a preferred route corridor between Wylfa and Pentir, possible route options within that corridor, and potential mitigation requirements.

19.3 The specifics of the announcement and later consultation events are not covered in this document but will be made available on the project website when appropriate.

http://www.northwalesconnection.com/

Appendix A – Summary of National Grid Legal Obligations [36]

A.1 Transmission of electricity in Great Britain requires permission by a licence granted under Section 6(1)(b) of the Electricity Act 1989 ("the Electricity Act").

A.2 National Grid has been granted a transmission licence and is therefore bound by the legal obligations primarily set out in the Electricity Act and the transmission licence.

A.3 National Grid owns and operates the transmission system in England and Wales and is also responsible for operation of parts of the onshore transmission system that are owned by other transmission licensees (SP Transmission Limited and Scottish Hydro Electricity Transmission Limited).

A.4 National Grid has a statutory duty to develop and maintain an efficient, coordinated and economical system of electricity transmission under Section 9 of the Electricity Act.

A.5 The relevant Standard Licence Conditions [37] are summarised in the following paragraphs.

A.6 Standard Condition C8 [38] (Requirement to offer terms) of National Grid's transmission licence sets out obligations on National Grid regarding provision of offers to provide connections to and/or use of the transmission system. In summary, where a party applies for a connection National Grid shall offer to enter into an agreement(s) [39] to connect, or to modify an existing connection, to the transmission system and the offer shall make detailed provision regarding the:

- carrying out of works required to connect to the transmission system
- carrying out of works (if any) in connection with the extension or reinforcement of the transmission system, and
- date by when any works required permitting access to the transmission system (including any works to reinforce or extend the transmission system) shall be completed.

[36] Summary is not intended as an exhaustive list of National Grid's legal obligations but provides information about the obligations that are particularly relevant to this report.
[37] Standard conditions of the electricity transmission licence http://epr.ofgem.gov.uk/document_fetch.php?documentid=15184
[38] The condition also relates to the use of system and some embedded generating plant.
[39] Paragraph 6 of Licence Condition C8 sets out exceptions where National Grid is not obliged to make an offer e.g. where to do so would put it in breach of certain other contracts or regulations.

A.7 Standard Condition C10 (Connection and Use of System Code) requires National Grid to prepare a connection and use of system code ("CUSC") which sets out, among other things, the terms of the arrangements for connection to and use of the transmission system.

A.8 Standard Condition C14 (Grid Code) requires National Grid to "prepare and at all times have in force and shall implement and comply with the Grid Code". This document (among other things), sets out the technical performance and data provision requirements that need to be met by users connected to or seeking to connect to the transmission system. The document also sets out the process by which demand data from Network Operators and other users of the transmission system should be presented on an annual basis to allow National Grid to plan and operate the transmission system.

A.9 Standard Condition C17 (Transmission system security standard and quality of service) requires National Grid to at all times plan, develop and operate the transmission system in accordance with the National Electricity Transmission System Security and Quality of Supply Standard (NETS SQSS). This condition includes specific arrangements (Connect and Manage Derogation) that permit National Grid to offer to connect a customer to the Transmission System before all reinforcement works to achieve compliance with the NETS SQSS are complete. Such permissions are subject to National Grid publishing Connect and Manage Derogations and reporting to Ofgem.

A.10 Standard Condition C26 (Requirements of a connect and manage connection) supplements the obligations [40] applicable to National Grid when making an offer of connection to the Transmission System. The connect and mange connection regime was introduced in August 2010. One intention of this regime is to facilitate the timely connection of new generation projects.

A.11 As well as the technical obligations described above, Schedule 9 of the Electricity Act 1989 require National Grid, when formulating proposals for new lines and other works, to:

"…have regard to the desirability of preserving natural beauty, of conserving flora, fauna, and geological or physiographical features of special interest and of protecting sites, buildings and objects of architectural, historic or archaeological

[40] Standard condition C8 of the electricity transmission licence.

interest; and shall do what [it] reasonably can to mitigate any effect which the proposals would have on the natural beauty of the countryside or on any such flora, fauna, features, sites, buildings or objects".

A.12 National Grid's Stakeholder, Community and Amenity Policy ("the Policy") sets out how the company will meet the duty to the environment placed upon it. These commitments include:

- only seeking to build new lines and substations where the existing transmission infrastructure cannot be upgraded technically or economically to meet transmission security standards
- where new infrastructure is required seek to avoid areas nationally or internationally designated for their landscape, wildlife or cultural significance, and
- minimising the effects of new infrastructure on other sites valued for their amenity.

A.13 The Policy also refers to the application of best practice methods to assess the environmental impacts of proposals and identify appropriate mitigation and/or offsetting measures. Effective consultation with stakeholders and the public is also promoted by the Policy.

A.14 In addition, the following other statutory duties are relevant to National Grid's development of new infrastructure:

- Section 11A(2) of the National Parks and Access to the Countryside Act 1949 (Duty of certain bodies and persons to have regard to the purposes for which National Parks are designated): "In exercising or performing any functions in relation to, or so as to affect, land in a National Park, any relevant authority shall have regard to the purposes specified in subsection (1) of section five of this Act and, if it appears that there is a conflict between those purposes, shall attach greater weight to the purpose of conserving and enhancing the natural beauty, wildlife and cultural heritage of the area comprised in the National Park."

- Section 85 of the Countryside and Rights of Way Act 2000 (General duty of public bodies etc): "(1) In exercising or performing any functions in relation to, or so as to affect, land in an area of outstanding natural beauty, a relevant authority shall have regard to the purpose of conserving and enhancing the natural beauty of the area of outstanding natural beauty."

- Section 40 of the Natural Environment and Rural Communities Act 2006 states that "Every public body must, in exercising its functions, have regard, so far as is consistent with the proper exercise of those functions, to the purpose of conserving biodiversity."

Appendix B – Requirement for Development Consent

B.1 Developing the transmission system in England and Wales may require one or more statutory consents, depending on the type and scale of the project. These may include planning permission or use of permitted development rights under the Town and Country Planning Act 1990, a marine licence under the Marine and Coastal Access Act 2009 and a Development Consent Order ("DCO") under the Planning Act 2008.

B.2 Certain developments are defined in the Planning Act 2008 as 'Nationally Significant Infrastructure Projects' ("NSIP"). These include the development of new overhead lines operating at a voltage of 132 kV or above and these projects require a DCO granted by the Secretary of State for Energy and Climate Change. Such developments are the subject of six National Policy Statements ("NPS") for energy infrastructure which were published by the Secretary of State for Energy and Climate Change in July 2011. The most relevant NPSs for transmission infrastructure are the Overarching National Policy Statement for Energy (EN-1) and the National Policy Statement for Electricity Networks Infrastructure (EN-5), which must be read in conjunction with EN-1. [41]

B.3 Section 104(3) of the Planning Act 2008 states that the decision maker must determine an application for a DCO in accordance with any relevant NPS, except in certain circumstances. These include where the adverse impact of the proposed development would outweigh its benefits. The energy NPSs provide the primary policy basis for decisions and may also be a material consideration for decisions on other types of development consent in England and Wales (including offshore projects).

Demonstrating the Need for a Project

B.4 Part 3 of EN-1 sets out Government policy on the need for new nationally significant energy infrastructure projects. Paragraph 3.1 confirms that the UK needs all the types of energy infrastructure covered by the NPS to achieve energy security at the same time as dramatically reducing greenhouse gas emissions. It states that "substantial weight" should be given to the contribution which projects would make towards satisfying this need. A need for new transmission infrastructure is set out in EN-1 and EN-5, and a need for new nuclear and

[41] The National Policy Statements can be viewed at http://www.decc.gov.uk/en/content/cms/meeting_energy/consents_planning/nps_en_infra/nps_en_infra.aspx

onshore/offshore wind generation (i.e. the type of generation giving rise to the need for new transmission infrastructure for this project) is set out in EN-1, EN-3 and EN-6. The need for new transmission infrastructure for this project is described in section 3 of this report.

Assessment Principles

B.5 Part 4 of EN-1 sets out the assessment principles to be applied in determining DCO applications for energy NSIPs. Paragraphs 2.3 - 2.5 of EN-5 do the same in the specific context of electricity networks infrastructure.

B.6 Principles of particular importance for transmission infrastructure projects include:

Presumption in Favour of Development

B.7 Section 4.1 of EN-1 provides a presumption in favour of granting consent for energy NSIPs (subject to specific policies in an NPS indicating otherwise or to the specific exceptions in the Planning Act, including where the adverse impacts outweigh the benefits). Adverse impacts include long term and cumulative impacts but take into account mitigation measures. Potential benefits include the contribution to meeting the need for energy infrastructure, job creation and long term wider benefits.

Consideration of Alternatives

B.8 Section 4.4 of EN-1 states that, from a planning policy perspective alone, there is no general requirement to consider alternatives or to establish whether the proposed project represents the best option. However, in relation to transmission projects, paragraph 2.8.4 of EN-5 states that, "wherever the nature or proposed route of an overhead line proposal makes it likely that its visual impact will be particularly significant, the applicant should have given appropriate consideration to the potential costs and benefits of other feasible means of connection or reinforcement, including underground and subsea cables where appropriate."

B.9 Section 4.4 of EN-1 also makes clear that there will be circumstances where a promoter is specifically required to consider alternatives. These may include requirements under the Habitats Directive and the Birds Directive.

Good Design

B.10 Section 4.5 of EN-1 stresses the importance of 'good design' for energy infrastructure and explains this goes beyond aesthetic considerations and is also important for fitness for purpose and sustainability. It is acknowledged that the nature of much energy infrastructure development will often limit the extent to which it can contribute to the enhancement of the quality of the area. Section 2.5 of EN-5 identifies a particular need to demonstrate the principles of good design in the approach to mitigating the potential adverse impacts which can be associated with overhead lines.

Climate Change

B.11 Section 4.8 of EN-1 explains how the effects of climate change should be taken into account and section 2.4 of EN-5 expands on this in the specific context of electricity networks infrastructure. This requires DCO applications to set out the vulnerabilities / resilience of the proposals to flooding, effects of wind on overhead lines, higher average temperatures leading to increased transmission losses and earth movement or subsidence caused by flooding or drought (for underground cables).

Networks DCO Applications Submitted in Isolation

B.12 Section 2.3 of EN-5 confirms that it can be appropriate for DCO applications for new transmission infrastructure to be submitted separately from applications for the generation that this infrastructure will serve. It explains that the need for the transmission project can be assessed on the basis of both contracted and reasonably anticipated generation.

Electricity Act Duties

B.13 Paragraph 2.3.5 of EN-5 recognises National Grid's duties pursuant to Section 9 of the Electricity Act to bring forward efficient and economical proposals in terms of network design, taking into account current and reasonably anticipated future generation demand, and its duty to facilitate competition and so provide a connection whenever and wherever one is required.

Adverse Impacts and Potential Benefits

B.14 Part 5 of EN-1 covers the impacts that are common across all energy NSIPs and sections 2.6-2.9 of EN-5 consider impact in the specific context of electricity networks infrastructure.

B.15 Those impacts identified in EN-1 include air quality and emissions, biodiversity and geological conservation, civil and military aviation and defence interests, coastal change (to the extent in or proximate to a coastal area), dust, odour, artificial light, smoke, steam and insect infestation, flood risk, historic environment, landscape and visual, land use, noise and vibration, socio-economic effects, traffic and transport, waste management and water quality and resources. The extent to which these impacts are relevant to a particular stage of a project, or are a relevant differentiator to a network project, will vary. EN-5 considers specific potential impacts of electricity networks on biodiversity and geological conservation, landscape and visual and noise and vibration.

B.16 Potential impacts of particular importance for transmission infrastructure projects include:

Landscape and Visual

B.17 Paragraph 2.8.2 of EN-5 states that the Government does not believe that development of overhead lines is generally incompatible in principle with National Grid's statutory duty under Section 9 of the Electricity Act 1989 to have regard to amenity and to mitigate impacts but recognises that overhead lines can give rise to adverse landscape and visual impacts, dependent upon their scale, siting, degree of screening and the nature of the landscape and local environment through which they are routed. In relation to alternative technologies for transmission projects, paragraph 2.8.9 states that, "each project should be assessed individually on the basis of its specific circumstances and taking account of the fact that Government has not laid down any general rule about when an overhead line should be considered unacceptable. The Planning Inspectorate should, however, only refuse consent for overhead line proposals in favour of an underground or subsea line if it is satisfied that the benefits from the non-overhead line alternative will clearly outweigh any extra economic, social and environmental impacts and the technical difficulties are surmountable." Paragraph 2.8.7 endorses the Holford Rules which are a set of "common sense" guidelines for routeing new overhead lines.

Biodiversity

B.18 Paragraph 2.7 of EN-5 highlights the potential impacts of overhead lines on large birds.

Appendix C – Technology Overview

C.1 This section provides an overview of the technologies available for the strategic options described in this Report. It provides a high level description of the relevant features of each technology. The costs for each technology are presented in Appendix D.

C.2 The majority of electricity systems throughout the world are AC systems. Consumers have their electricity supplied at different voltages depending upon the amount of power they consume e.g. 230V for domestic customers and 11 kV for large factories and hospitals. The voltage level is relatively easy to change when using AC electricity, which means a more economical electricity network can be developed for customer requirement. This has meant that the electrification of whole countries could be and was delivered quickly and efficiently using AC technology.

C.3 DC electricity did not develop as the means of transmitting large amounts of power from generating stations to customers because DC is difficult to transform to a higher voltage and bulk transmission by low voltage DC is only effective for transporting power over short distances. However, DC is appropriate in certain applications such as the extension of an existing AC system or when providing a connection to the transmission system.

C.4 In terms of voltage, the transmission system in England and Wales operates at both 275 kV and 400 kV. The majority of National Grid's transmission system is now constructed and operated at 400 kV, which facilitates higher power transfers and lower transmission losses.

C.5 There are a number of different technologies that can be used to provide transmission connections. These technologies have different features which affect how, when and where they can be used. The main technology options for electricity transmission are:

- AC Overhead lines
- AC Underground cables
- AC Gas Insulated Lines (GIL) and
- High Voltage Direct Current (HVDC).

C.6 This appendix provides generic information about each of these four technologies. Further information, including a more detailed technical review is available in a series of factsheets that can be found at the project website referenced at the beginning of this Report.

Overhead lines

C.7 Overhead lines form the majority of the existing transmission system circuits in Great Britain and in transmission systems across the world. As such there is established understanding of their construction and use.

C.8 Overhead lines are made up of three main component parts which are; conductors (used to transport the power), pylons (used to support the conductors) and insulators (used to safely connect the conductors to pylons)

C.9 Figure C.1 shows a typical pylon used to support two 275 kV or 400 kV overhead line circuits. This type of pylon has six arms (three either side), each carrying a set (or bundle) of conductors.

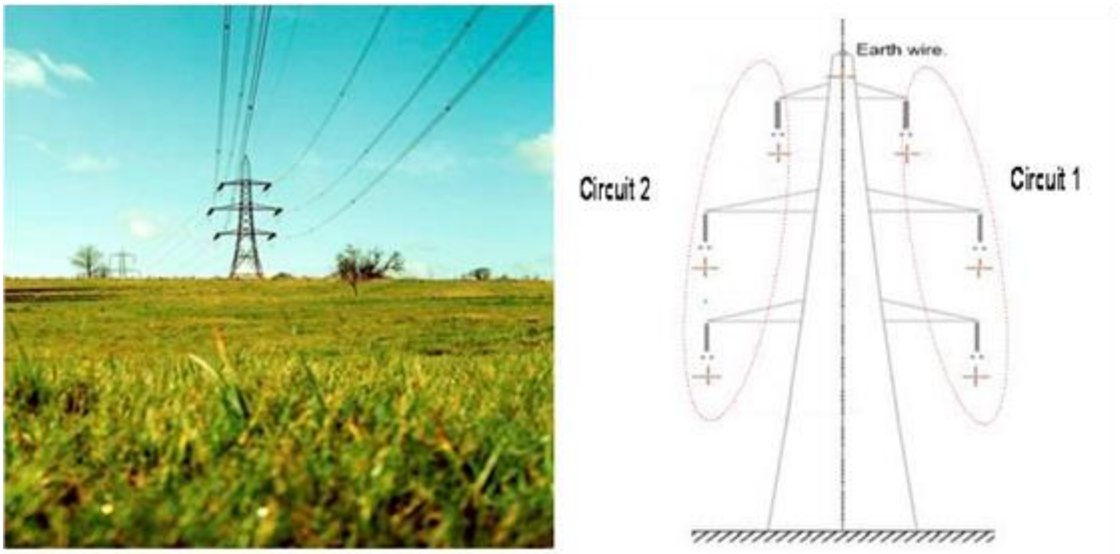


Figure C.1: Example of a 400 kV Double-circuit Tower

C.10 The number of conductors supported by each arm depends on the amount of power to be transmitted and will be either two, three or four conductors per arm. Technology developments have increased the capacity that can be carried by a single conductor and therefore, new overhead lines tend to have two or three conductors per arm.

C.11 With the conclusion of the Royal Institute of British Architects (RIBA) pylon design competition[42] and other recent work with manufacturers to develop alternative pylon designs, National Grid is now able to consider a broader range of pylon types, including steel lattice and monopole designs. The height and width is different for each pylon type, which may help National Grid to manage the impact on landscape and visual amenity better. Figure C.2, below, shows an image on the winning design from the RIBA pylon design competition, a monopole design called the T-pylon (currently being developed by National Grid).

Figure C.2: The T-pylon

C.12 Pylons are designed with sufficient height to ensure that the clearances between each conductor and between the lowest conductor and the ground, buildings or structures are adequate to prevent electricity jumping across. The minimum clearance between the lowest conductor and the ground is normally at the mid-

[42] Press notice issued by DECC on 14 October 2011 http://www.decc.gov.uk/en/content/cms/news/pn11_82/pn11_82.aspx

point between pylons. There must be sufficient clearance[43] between objects and the lowest point of the conductor as shown in Figure C.3.

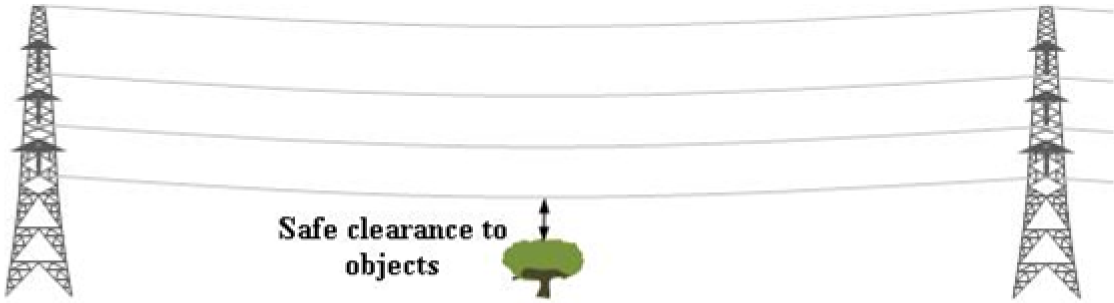


Figure C.3: Safe height between lowest point of conductor and other obstacle ("Safe Clearance")

C.13 The distance between adjacent pylons is termed the '*span length*'. The span length is governed by a number of factors, the principal ones being pylon height, number and size of conductors (i.e. weight), ground contours and changes in route direction. A balance must therefore be struck between the size and physical presence of each tower versus the number of towers; this is a decision based on both visual and economic aspects. The typical 'standard' span length used by National Grid is approximately 360m.

C.14 Lower voltages need less clearance and therefore the pylons needed to support 132 kV lines are not as high as traditional 400 kV and 275 kV pylons. However, lower voltage circuits are unable to transport the same levels of power as higher voltage circuits.

C.15 National Grid has established operational processes and procedures for the design, construction, operation and maintenance of overhead lines. Circuits must be taken out of service from time to time for repair and maintenance. However, short emergency restoration times are achievable on overhead lines as compared, for example, to underground cables. This provides additional operational flexibility if circuits need to be rapidly returned to service to maintain a secure supply of electricity when, for example, another transmission circuit is taken out of service unexpectedly.

[43] More information can be found in the brochure "Development near overhead lines" at http://www.nationalgrid.com/uk/LandandDevelopment/DDC/devnearohl_final/.

C.16 In addition, emergency pylons can be erected in relatively short timescales to bypass damaged sections and restore supplies. Overhead line maintenance and repair therefore does not significantly reduce security of supply risks to end consumers.

C.17 Each of the three main components that make up an overhead line has a different design life, which are:

- Between 40 and 50 years for overhead line conductors
- 80 years for pylons
- Between 20 and 40 years for insulators

C.18 National Grid expects an initial design life of around 40 years, based on the specified design life of the component parts. However, pylons can be easily refurbished and so substantial pylon replacement works are not normally required at the end of the 40 year design life.

C.19 Asset replacement is generally expected at the end of design life. However, National Grid's asset replacement decisions (that are made at the end of design life) will also take account of actual asset condition and may lead to actual life being longer than the design life.

Underground Cables

C.20 Underground cables at 275 kV and 400 kV make up approximately 10% of the existing transmission system in England and Wales, which is typical of the proportion of underground to overhead equipment in transmission systems worldwide. Most of the underground cable is installed in urban areas where achieving an overhead route is not feasible. Examples of other situations where underground cables have been installed, in preference to overhead lines, include crossing rivers, passing close to or through parts of nationally designated landscape areas and preserving important views.

C.21 Underground cable systems are made up of two main components – the cable and connectors. Connectors can be cable joints, which connect a cable to another cable, or overhead line connectors in a substation.

C.22 Cables consist of an electrical conductor in the centre, which is usually copper or aluminium, surrounded by insulating material and sheaths of protective metal and plastic. The insulating material ensures that although the conductor is operating at a high voltage, the outside of the cable is at zero volts (and therefore safe). Figure C.4 shows a cross section of a transmission cable and a joint that is used to connect two underground cables.

Figure C.2: Cable Cross-Section and Joint

C.23 Underground cables can be connected to above-ground electrical equipment at a substation, enclosed within a fenced compound. The connection point is referred to as a cable sealing end. Figure C.5 shows two examples of cable sealing end compounds.

Figure C.5: Cable Sealing End Compounds

C.24 An electrical characteristic of a cable system is capacitance between the conductor and earth. Capacitance causes a continuous 'charging current' to flow, the magnitude of which is dependent on the length of the cable circuit (the longer the cable, the greater the charging current) and the operating voltage (the higher the voltage the greater the current). Charging currents have the effect of reducing the power transfer through the cable.

C.25 High cable capacitance also has the effect of increasing the voltage along the length of the circuit, reaching a peak at the remote end of the cable.

C.26 National Grid can reduce cable capacitance problems by connecting reactive compensation equipment to the cable, either at the ends of the cable, or, in the case of longer cables, at regular intervals along the route. Specific operational arrangements and switching facilities at points along the cable circuit may also be needed to manage charging currents.

C.27 Identifying faults in underground cable circuits often requires multiple excavations to locate the fault and some repairs require removal and installation of new cables, which can take a number of weeks to complete.

C.28 High voltage underground cables must be regularly taken out of service for maintenance and inspection and, should any faults be found and depending on whether cable excavation is required, emergency restoration for security of supply reasons typically takes a lot longer than for overhead lines (days rather than hours).

C.29 The installation of underground cables requires significant civil engineering works. These make the construction times for cables longer than overhead lines.

C.30 The construction swathe required for two AC circuits comprising two cables per phase will be between 35-50 m wide.

C.31 Each of the two main components that make up an underground cable system has a design life of between 40 and 50 years.

C.32 Asset replacement is generally expected at the end of design life. However, National Grid's asset replacement decisions (that are made at the end of design life) will also take account of actual asset condition and may lead to actual life being longer than the design life.

Gas Insulated Lines (GIL)

C.33 GIL is an alternative to underground cable for high voltage transmission. GIL has been developed from the well-established technology of gas-insulated switchgear, which has been installed on the transmission system since the 1960s.

C.34 GIL uses a mixture of nitrogen and sulphur hexafluoride (SF_6) gas to provide the electrical insulation. GIL is constructed from welded or flanged metal tubes with an aluminium conductor in the centre. Three tubes are required per circuit, one tube for each phase. Six tubes are therefore required for two circuits, as illustrated in Figure C.6 below.

C.35 GIL tubes are brought to site in 10 – 20 m lengths and they are joined in situ. It is important that no impurities enter the tubes during construction as impurities can cause the gas insulation to fail. GIL installation methods are therefore more onerous than those used in, for example, natural gas pipeline installations.

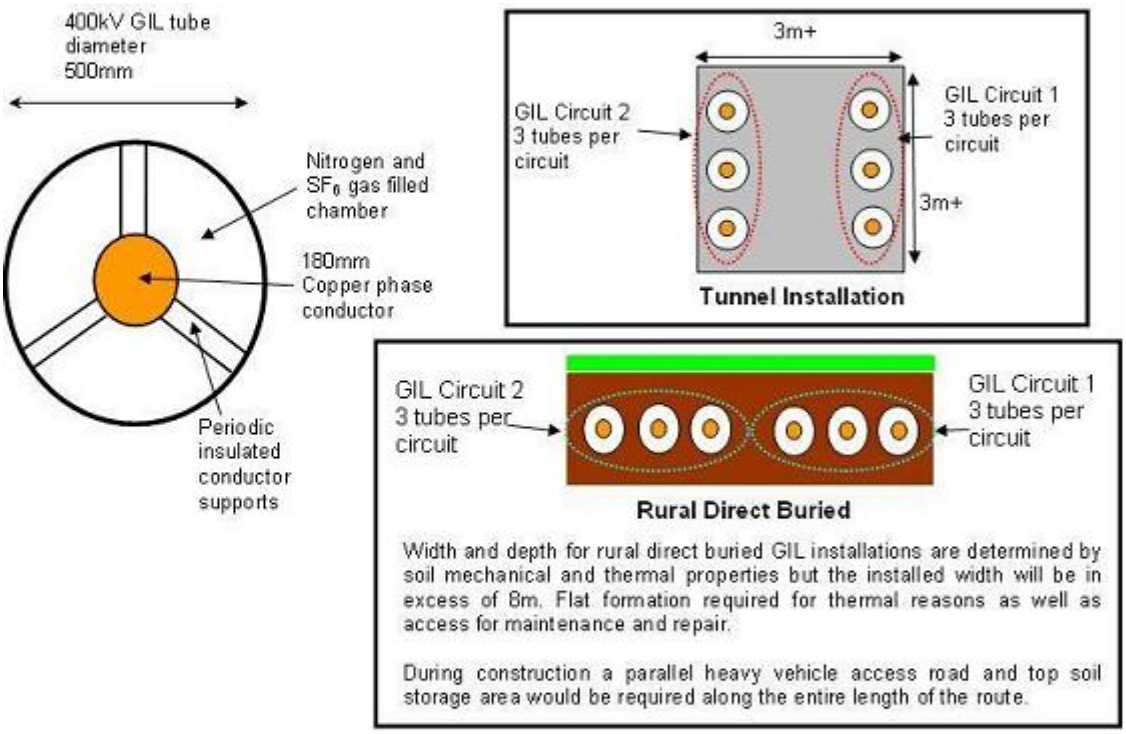


Figure C.6: Key Components of GIL[44]

C.36 A major advantage of GIL compared to underground cable is that it does not require reactive compensation.

C.37 The installation widths over the land can also be narrower than cable installations, especially where more than one cable per phase is required.

C.38 GIL can have a reliability advantage over cable in that it can be re-energised immediately after a fault (similar to overhead lines) whereas a cable requires investigations prior to re-energisation. If the fault was a transient fault it will remain energised and if the fault was permanent the circuit will automatically and safely de-energise again.

C.39 There are environmental concerns with GIL as the SF_6[45] gas used in the insulating gas mixture is a potent 'greenhouse gas'. Since SF_6 is an essential part of the gas mixture GIL installations are designed to ensure that the risk of gas leakage is minimised.

C.40 There are a number of ways in which the risk of gas leakage from GIL can be managed, which include:

(i) use of high-integrity welded joints to connect sections of tube;

(ii) designing the GIL tube to withstand an internal fault; and

(iii) splitting each GIL tube into a number of smaller, discrete gas zones that can be independently monitored and controlled.

C.41 At decommissioning the SF_6 can be separated out from the gas mixture and either recycled or disposed of without any environmental damage.

C.42 GIL is a relatively new technology and therefore has limited historical data, meaning that its operational performance has not been empirically proven.

[44] The distances are based on initial manufacturer estimates of tunnel and buried GIL dimensions which would be subject to full technical appraisal by National Grid and manufacturers to achieve required ratings which may increase the separation required. It should be noted that the diagram does not show the swathe of land required during construction. Any GIL tunnel installations would have to meet the detailed design requirements of National Grid for such installations.

[45] SF_6 is a greenhouse gas with a global warming potential, according to the Intergovernmental Panel on Climate Change, Working Group 1 (Climate Change 2007, Chapter 2.10.2), of 22,800 times that of CO2. www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html

National Grid has two GIL installations on the transmission system which are 545 m and 150 m long[46]. These are both in electricity substations; one is above ground and the other is in a trough. The longest directly buried transmission voltage GIL in the world is approximately one kilometre long and was recently installed on the German transmission system around Frankfurt Airport.

C.43 In the absence of proven design life information, and to promote consistency with assessment of other technology options, National Grid assesses GIL over a design life of up to 40 years.

C.44 Asset replacement is generally expected at the end of design life. However, National Grid's asset replacement decisions (that are made at the end of design life) will also take account of actual asset condition and may lead to actual life being longer than the design life.

High Voltage Direct Current ("HVDC")

C.45 HVDC technology can provide efficient solutions for the bulk transmission of electricity between AC electricity systems (or between points on an electricity system).

C.46 There are circumstances where HVDC has advantages over AC, generally where transmission takes place over very long distances or between different, electrically-separate systems, such as between Great Britain and countries such as France, The Netherlands and Ireland.

C.47 HVDC links may also be used to connect a generating station that is distant from the rest of the electricity system. For example, very remote hydro-electric schemes in China are connected by HVDC technology with overhead lines.

C.48 Proposed offshore wind farms to be located over 60 km from the coast of Great Britain are likely to be connected using HVDC technology as an alternative to an AC subsea cable. This is because AC subsea cables over 60 km long have a number of technical limitations, such as high charging currents and the need for mid-point compensation equipment.

[46] The distances are based on initial manufacturer estimates of tunnel and buried GIL dimensions which would be subject to full technical appraisal by National Grid and manufacturers to achieve required ratings which may increase the separation required. It should be noted that the diagram does not show the swathe of land required during construction. Any GIL tunnel installations would have to meet the detailed design requirements of National Grid for such installations.

C.49 The connection point between AC and DC electrical systems has equipment that can convert AC to DC (and vice versa), known as a converter. The DC electricity is transmitted at high voltage between converter stations.

C.50 HVDC can offer advantages over AC underground cable, such as:

- a minimum of two cables per circuit is required for HVDC whereas a minimum of three cables per circuit is required for AC.

- reactive compensation mid-route is not required for HVDC.

- cables with smaller cross sectional areas can be used (compared to equivalent AC system rating).

C.51 HVDC systems have a design life of about 40 years. This design life period is on the basis that large parts of the converter stations (valves and control systems) would be replaced after 20 years.

C.52 Asset replacement is generally expected at the end of design life. However, National Grid’s asset replacement decisions (that are made at the end of design life) will also take account of actual asset condition and may lead to actual life being longer than the design life.

Appendix D – Economic Appraisal

D.1 This Appendix D provides an overview of the cost information that National Grid uses for economic appraisals to compare feasible transmission system development options which includes:

- a summary of the capital cost allowances for transmission activities that were set out by Ofgem as part of National Grid's current price control[47];
- a summary of National Grid's capital cost estimate information[48] for each technology option included in Appendix C of this Report;
- discussion of additional equipment requirements that are technology specific, and
- an overview of the method National Grid uses to assess the Net Present Value ("NPV") of costs that are expected to be incurred during the lifetime of new transmission assets.

D.2 The IET, PB/CCI Report[49] presents cost information in size of transmission circuit capacity categories for each circuit design that was considered as part of the independent study. To aid comparison between the cost data presented in the IET PB/CCI Report and that used by National Grid for appraisal of Strategic Options, this Appendix D includes cost estimates for circuit designs that are equivalent to those considered as part of the independent study. Examples in this Appendix D are presented using the category size labels of "Lo", "Med" and "Hi" as used in the IET PB/CCI Report for the IET PB/CCI calculations.

Unit Cost Allowances

D.3 For National Grid's current price control, baseline Unit Cost Allowances ("UCA") were agreed between National Grid and Ofgem for transmission activities that include development of overhead lines, AC underground cables and supergrid transformers. UCAs based on 2009/10 cost information and mechanisms to allow

[47] The current National Grid price control commenced on 1 April 2013 and has an eight year price control period.
[48] Capital cost estimate information that was current at the date of this Report.
[49] "Electricity Transmission Costing Study – An Independent Report Endorsed by the Institution of Engineering & Technology" by Parsons Brinckerhoff in association with Cable Consulting International. Page 10 refers to Double circuit capacities. http://www.theiet.org/factfiles/transmission-report.cfm

baseline figures to be adjusted to current day prices have been set out by Ofgem in National Grid's Transmission Licence[50].

D.4 The UCAs defined as part of National Grid's current price control are an all inclusive allowance which incorporates the weighted average of all costs. Prior to the agreement of National Grid's current price control, the basis of cost estimates for National Grid Strategic Options Reports excluded certain costs including overheads and elements of consenting required under the Planning Act 2008. It is noted that such costs were also excluded from the cost estimates within the IET, PB/CCI Report.

D.5 Table D.1 provides a summary of the UCAs defined in National Grids transmission licence:

Category	Description	2009/10 UCA £m	2009/10 Equivalent "double" or two circuit[1] UCA £/km
Overhead Line	Weighted Average of Overhead Line Costs	£1.1m/ circuit km	£2.2m/km
Cable[2] Average of costs above 3km[3]	"Lo" capacity 1 Core Per Phase 2500mm	£5.1m / Circuit km	£10.2m/km
	"Med" capacity 2 Core Per Phase 2500mm	£8.8m / Circuit km	£17.6m/km
	"Hi" capacity 3 Core Per Phase 2500mm	£12.5m / Circuit km	£25mkm
Supergrid Transformers (SGT)	240MVA 400/132 kV or 275/132 kV	£3.9 / SGT	N/A

Table D.1 – Agreed UCAs in 2009/10 prices

Notes:
1. In most cases, National Grid has two circuit routes and therefore the reflective route cost is twice the cost per km.
2. Cable UCAs are set out in Special Condition 6F and 6K of the transmission licence. In Special Condition 6K the table is reflective of the marginal difference between OHL and Cables and are therefore £1.1m per circuit km lower than the table in 6F. Therefore to get the inclusive build cost £1.1m must be added to prices shown in special condition 6k tables to be reflective of total cable costs shown in special condition 6F
3. To gain a single cable cost for comparison an average of UCAs for cables less or equal to 2500mm and greater than 3km has been obtained.

Lifetime Costs for Transmission

D.6 For each technology option appraised within a Strategic Option, National Grid estimates total lifetime costs for the new transmission assets required for that

[50] National Grid Electricity Transmission Plc – Electricity transmission licence Special Conditions https://epr.ofgem.gov.uk//Content/Documents/National%20Grid%20Electricity%20Transmission%20Plc%20-%20Special%20Conditions%20-%20Current%20Version.pdf

Strategic Option. Each total lifetime cost estimate for new transmission assets within a Strategic Option consists of the sum of the estimates of the:

- initial capital cost of developing, consenting, procuring equipment and land, installing and commissioning the new transmission assets (the "Capital Cost Estimate"), and
- net present value of costs that are expected to be incurred during the lifetime of these new transmission assets the "NPV Cost Estimate").

Capital Cost Estimates

D.7 At the initial appraisal stage, National Grid prepares indicative estimates of the capital costs. These indicative estimates are based on the high level scope of works defined for each Strategic Option in respect of each technology option that is considered to be feasible. As these estimates are prepared before detailed design work has been carried out, National Grid takes account of equivalent assumptions for each option.

D.8 This section considers the capital costs in two parts, firstly the AC technology costs are discussed, followed by HVDC technologies. Each of these technologies is described in Appendix C in more detail.

AC Technology Capital Cost Estimates

D.9 Table D.21 shows the category sizes that are relevant for AC technology circuit designs:-

Category	Design	Rating
Lo	Two AC circuits of 1,595 MVA	3,190 MVA
Med	Two AC circuits of 3,190 MVA	6,380 MVA
Hi	Two AC circuits of 3,465 MVA	6,930 MVA

Table D.2 – AC Technology Circuit Designs

D.10 Table D.3 provides a summary of technology configuration and capital cost[51] information:

[51] Each capital cost figure in Table D.3 is the relevant UCA for each transmission activity AC technology option that has been adjusted in accordance with National Grid's transmission licence to financial year prices current at the date of this Report.

IET, PB/CCI Report short-form label	Circuit Ratings by Voltage		Technology Configuration			National Grid Capital Costs			
	275kV	400kV	Overhead Line	AC Underground Cable	Gas Insulated Line	Lattice Overhead Line	T-Pylon Overhead line	AC Underground Cable	Gas Insulated Line
	Total rating for two circuits (2 x rating of each circuit)	Total rating for two circuits (2 x rating of each circuit)	No. of Conductors on each arm (per circuit)	No. of Cables per phase (per circuit)	No of direct buried GIL tubes per phase (per circuit)	Cost for a "double" two circuit pylon route (Cost per circuit, of a double circuit pylon route)	Cost for a "double" two circuit pylon route (Cost per circuit, of a double circuit pylon route)	Cost for a two circuit AC cable route (Cost per circuit, of a two circuit AC cable route)	Cost for a two circuit GIL route (Cost per circuit, of a two circuit GIL route)
Lo	3,190MVA (2 x 1,595MVA) [2,000MVA2 x 1,000MVA for AC cable only]	3,190MVA (2 x 1,595MVA)	Two (Six)	One (Three)	One (Three)	£2.52m/km (1.26m/km)	£4.1m/km (2.05m/km)	£12.86m/km (£6.43m/km)	£18.38m/km (£9.19m/km)
Med	N/A [3,190MVA2 x 1,595MVA for AC cable only]	6,380MVA (2 x 3,190MVA)	Two (Six)	Two (Six)	One (Three "developing" new large GIL tubes)	£2.78m/km (1.39m/km)	£4.1m/km (2.05m/km)	£22.18m/km (£11.09m/km)	£21.34m/km (£10.67m/km)
Hi	N/A	6,930MVA (2 x 3,465MVA)	Three (Nine)	Three (Nine)	Two (Six standard GIL tubes)	£3.02m/km (1.51m/km)	£4.1m/km (2.05m/km)	£31.50 m/km (15.75m/km)	£29.65m/km (£14.83m/km)

Table D.3 - AC Technology Configuration and National Grid Capital Costs by Rating

Notes: -

1. Capital costs for all technologies are based upon rural/arable land installation with no major obstacles (examples of major obstacles would be roads, rivers, railways etc.)
2. All underground AC cable and GIL technology costs are for direct buried installations only. AC cable and GIL tunnel installations would have a higher capital installation cost than direct buried rural installations. However, AC cable or GIL replacement costs following the end of conductor life would benefit from re-use of the tunnel infrastructure.
3. AC cable installation costs exclude the cost of reactors and mid-point switching stations, which are described later in this appendix.
4. 275 kV circuits will often require Super-Grid Transformers (SGT) to allow connection into the 400 kV system, SGT capital costs are not included above but described later in this appendix.
5. 275kV AC cable installations above 1,000 MVA, as indicated in the table above, would require two cables per phase to be installed to achieve ratings of 1,595 MVA per circuit at 275kV.
6. National Grid is aware of changes in cable sizes which are being developed by cable manufacturers that would potentially allow the use of two cables per phase at the "Hi" capacity rating. This would utilise these larger cables, but could facilitate an amendment of cost in the "Hi" capacity rating, currently £31.5m/km, by a reduction of up to £7.8m per kilometre. "Med" and "Lo" costs are unaffected by this potential change, "Hi" rating AC cable costs would be amended when better information becomes available.
7. Costs for Lattice OHL and AC underground cable are based upon UCAs set out in the Special Conditions of National Grids Transmission Licence as described above in this appendix.
8. The "Med" overhead line figure is reflective of the overhead line UCA with "Lo" being 10% below and "Hi" being 10% above.

D.11 Table D.3 provides a summary of the capital costs associated with the key[52] components of transmission circuits for each technology option. Additional equipment is required for technology configurations that include new:

- AC underground cable circuits
- Connections between 400 kV and 275 kV parts of the Transmission System.

D.12 The following sections provide an overview of the additional requirements associated with each of these technology options and indicative capital costs of additional equipment.

Additional equipment requirement - AC Underground Cable

D.13 Appendix C of this Report provides a summary of the electrical characteristics of AC underground cable systems and explains that reactive gain occurs on AC underground cables.

D.14 Table D.4 provides a summary of the typical reactive gain within AC underground cable circuits forming part of the NETS:

Category	Voltage	Design	Reactive Gain per circuit
Lo	275 kV	One 2,500 mm^2 cable per phase	5 Mvar/km
Med	275 kV	Two 2,500 mm^2 cables per phase	10 Mvar/km
Lo	400 kV	One 2,500 mm^2 cable per phase	10 Mvar/km
Med	400 kV	Two 2,500 mm^2 cables per phase	20 Mvar/km
Hi	400 kV	Three 2,500 mm^2 cables per phase	30 Mvar/km

Table D.4 – Reactive Gain Within AC underground cable circuits

D.15 National Grid is required to ensure that reactive gain on any circuit that forms part of the NETS does not exceed 225 Mvar. Above this limit, reactive gain would lead to unacceptable voltages (voltage requirements are defined in the NETS SQSS). In order to manage reactive gain and therefore voltages, reactors are installed on

[52] Components that are not required for all technology options are presented separately in this Appendix D.

AC underground cable circuits to ensure that reactive gain in total is less than 225 Mvar.

D.16 For example a 50 km "Med" double circuit would have an overall reactive gain of 1,000 Mvar per circuit (2,000 Mvar in total for two circuits). The standard shunt reactor size installed at 400 kV on the National Grid System is 200 Mvar. Therefore four 200 Mvar reactors (800 Mvar) need to be installed on each circuit or eight 200 Mvar reactors (1,600 Mvar) reactors for the two circuits. Each of these reactors cost £3.56m adding £28.48m to an overall cable cost for the example double circuit above.

D.17 Mid point switching stations may be required as part of a design to meet the reactive compensation requirements for AC underground cable circuits. The need for switching stations is dependent upon cable design, location and requirements which cannot be fully defined without detailed design.

D.18 For the purposes of economic appraisal of Strategic Options, National Grid includes a cost allowance that reflects typical requirements for switching stations. These allowances shown in table D.5 are:-

Category	Switching Station Requirement
Lo	Reactive Switching Station every 60 km between substations
Med	Reactive Switching Station every 30 km between substations
Hi	Reactive Switching Station every 20 km between substations

Table D.5 – Reactive Gain Within AC underground cable circuits

D.19 It is noted that more detailed design of AC underground cable systems may require a switching station after a shorter or longer distance than the typical values used by National Grid at the initial appraisal stage.

D.20 Table D.6 below shows the capital cost associated with AC underground cable additional equipment.

Category	Cost per mid-point switching station	Cost per 200 Mvar reactor
Lo	£10.68m	£3.56m
Med	£13.05m	
Hi	£13.05m	

Table D.6 – Additional costs associated with AC underground cables

Additional equipment – AC connections between 275 kV and 400 kV circuits

D.21 Equipment that transform voltages between 275 kV and 400 kV (a 400/275 kV supergrid transformer ("SGT")) is required for any new 275 kV circuit that connects to a 400 kV part of the NETS (and vice versa). The number of SGTs needed is dependent on the capacity of the new circuit. National Grid can estimate the number of SGTs required as part of an indicative scope of works that is used for the initial appraisal of Strategic Options.

D.22 Table D.7 below shows capital cost associated with the SGT requirements.

275 kV Equipment	Capital Cost (SGT - including civil engineering work)
400/275 kV SGT 1,100 MVA (excluding switchgear)	£4.91m

Table D.7 – Additional costs associated with 275 kV circuits requiring connection to the 400 kV system

High Voltage Direct Current ("HVDC") Capital Cost Estimates

D.23 Conventional HVDC technology sizes are not easily translated into the "Lo", "Med" and "Hi" ratings suggested in the IET, PB/CCI report. Whilst National Grid information for HVDC is presented for each of these categories, there are differences in the circuit capacity levels. As part of an initial appraisal, National Grid's assessment is based on a standard 2 GW converter size. Higher ratings are achievable using multiple circuits.

D.24 The capital costs of HVDC installations can be much higher than for equivalent AC overhead line transmission routes. Each individual HVDC link, between each converter station, requires its own dedicated set of HVDC cables. HVDC may be more economic than equivalent AC overhead lines where the route length is many hundreds of kilometres.

D.25 Table D.8 provides a summary of technology configuration and capital cost[53] information for each of the HVDC technology options that National Grid considers as part of an appraisal of Strategic Options.

HVDC Converter Type	2 GW Total Converter Capital Costs (Converter Cost at Each End)	2 GW DC Cable Pair Capital Cost
Current Source Technology or "Classic" HVDC	£326m HVDC link cost (£163m at each end)	£1.96m/km
Voltage Source Technology HVDC	£332m HVDC link cost (£166m at each end)	£1.96m/km

Table D.8 - HVDC Technology Capital Costs for 2 GW installations

Notes: -

1. Costs are updated from median of prices published in Appendix E of National Grid's 2013 Electricity Ten Year Statement (ETYS) updated 2014/15 prices. http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/Electricity-ten-year-statement/Current-statement/
2. Sometimes a different HVDC capacity (different from the required AC capacity) can be utilised for a project due to the different way HVDC technology can control power flow. The capacity requirements for HVDC circuits will be specified in any option considering HVDC. The cost shall be based upon table C.4 above.
3. Where a single HVDC Link is proposed as an option, to maintain compliance with the NETS SQSS, there may be a requirement to install an additional "Earth Return" DC cable. For example a 2 GW link must be capable of operating at half its capacity i.e. 1 GW during maintenance or following a cable fault. To allow this operation the additional cable known as an "Earth Return" must be installed, this increases cable costs by a further 50%.
4. Capital Costs for HVDC cable installations are based upon subsea or rural/arable land installation with no major obstacles (examples of major obstacles would be subsea pipelines, roads, rivers, railways etc…)

D.26 Costs can be adjusted from this table to achieve equivalent circuit ratings where required. For example a "Lo" rating 3,190 MW would require two HVDC links of (1.6 GW capacity each), while "Med" and "Hi" rating 6,380 MW - 6,930 MW would require three links of 2.1 - 2.3 GW each.

D.27 Converter costs at each end can also be adjusted, by linear scaling, from the cost information in Table D.8, to reflect the size of the HVDC link being appraised.

[53] Capital cost in financial year 2013/14 prices.

HVDC Cable costs are normally left unaltered, as operating at the higher load does not have a large impact on the cable costs per km.

D.28 The capacity of HVDC circuits assessed for this Report is not always exactly equivalent to capacity of AC circuits assessed. However, Table D.9 illustrates how comparisons may be drawn using the scaling methodology outlined above.

IET, PB/CCI Report short-form label	Converters (Circuit Rating)	Total Cable Costs/km (Cable Cost per link)	CSC "Classic" HVDC Total Converter Capital Cost (Total Converter cost per end)	VSC HVDC Total Converter Capital Cost (Total Converter cost per end)
Lo	2 x 1.6 GW (3,190 MW)	£3.92m/km (2 x £1.96m/km)	£521m (4 x £130.3m [4 converters, 2 each end])	£531m (4 x £132.8m [4 converters, 2 each end])
Med	3 x 2.1 GW (6,380 MW)	£5.88m/km (3 x £1.96m/km)	£1026m (6 x £171m [6 converters, 3 each end])	£1046m (6 x £174.3m [6 converters, 3 each end])
Hi	3 x 2.3 GW (6,930 MW)	£5.88m/km (3 x £1.96m/km)	£1123m (6 x £187.2m [6 converters, 3 each end])	£1146m (6 x £190.9m [6 converters, 3 each end])

Table D.9 – Illustrative example using scaled 2 GW HVDC converter costs to match equivalent AC ratings(only required where HVDC requirements match AC technology circuit capacity requirements)

Notes: -

1. Costs based on 2 GW costs shown in table D.8 and table shows how HVDC costs are estimated based upon HVDC capacity required for each option.
2. Scaling can be used to estimate costs for any size of HVDC link required.

Net Present Value Cost Estimates

D.29 At the initial appraisal stage, National Grid prepares estimates of the costs that are expected to be incurred during the design lifetime of the new assets. National Grid considers costs associated with:

- Operation and maintenance
- Electrical losses

D.30 For both categories, NPV calculations are carried out using annual cost estimates and a generic percentage discount rate over the design life period associated with the technology option being considered.

D.31 The design life for all technology equipment is outlined in the technology description in Appendix C. The majority of expected design lives are of the order of 40 years, which is used to assess the following NPV cost estimates below.

D.32 In general discount rates used in NPV calculations would be expected to reflect the normal rate of return for the investor. However, the Treasury Green Book recommends a rate of 3.5% for the reasons set out below[54]

> *"The discount rate is used to convert all costs and benefits to 'present values', so that they can be compared. The recommended discount rate is 3.5%. Calculating the present value of the differences between the streams of costs and benefits provides the net present value (NPV) of an option. The NPV is the primary criterion for deciding whether government action can be justified."*

D.33 National Grid considered the impact of using the lower Rate of Return (used by UK Government) on lifetime cost of losses assessments for transmission system investment proposals. Using the rate of 3.5% will discount loss costs, at a lower rate than that of 6.25%. This has the overall effect of increasing the 40 year cost of losses giving a more onerous cost of losses for higher loss technologies.

D.34 For the appraisal of Strategic Options, National Grid recognises the value of closer alignment of its NPV calculations with the approach set out by government for critical infrastructure projects.

Annual Operations and Maintenance cost

D.35 The maintenance costs associated with each technology vary significantly depending upon type. Some electrical equipment is maintained regularly to ensure system performance is maintained. More complex equipment like HVDC converters have a significantly higher cost associated with them, due to their high maintenance requirements for replacement parts. Table D.10 shows the cost of

[54] http://www.hm-treasury.gov.uk/d/green_book_complete.pdf Paragraph 5.49 on Page 26 of the Treasury Green Book recommends a discount rate of 3.5%. The mathematical expressions used to calculate the discount factor for a cost in year n is $Dn = 1/(1 + r)^n$ where r is the discount rate. The net present value is the sum of the annual discounted cash flows over the period 0 to n, in this case 40 years.

maintenance for each technology, which unlike capital and losses is not dependent on capacity.

	Overhead Line	AC Underground Cable	Gas Insulated Line (GIL)	High Voltage Direct Current (HVDC)
Circuit Annual maintenance cost per two circuit km (AC) **(Annual cost per circuit Km [AC])**	£2,278/km (£1,139/km)	£4,800/km (£2,400/km)	£2,282/km (£1,141/km)	£114/km Subsea Cables
Associated equipment Annual Maintenance cost per item	N/A	£5,700 per reactor £35,360 per switching station	N/A	£1,104,220 per converter station
Additional costs for 275kV circuits requiring connection to the 400kV system				
275/400 kV SGT 1,100 MVA annual maintenance cost per SGT	£5,704 per SGT	£5,704 per SGT	£5,704 per SGT	N/A

Table D.10 –Annual maintenance costs by Technology

D.36 As an example, annual maintenance costs for 40 km circuits would be assessed as:

- For "Med" capacity overhead line:

  £2,278/km x 40 = £0.09m [£91k]

- For "Med" capacity underground cable (with 6 reactors):

  £4,800/km x 40 + (6 x £5,700) = £0.23m [£226k]

- For "Med" Capacity Gas Insulated line:

  £2,215/km x 40 = £0.09m [£91k]

- For "Med" capacity CSC HVDC '3 x 2.1 GW' (3 sets of HVDC Cable cost) + (6 HVDC converter station costs):

  (3 x £114 x 40) + (6 x £1,104,220) = £6.64m

- For "Med" Capacity VSC HVDC '3 x 2.1 GW' (3 sets of HVDC Cable cost) + (6 HVDC converter station costs):

(3 x £114 x 40) + (6 x £1,104,220) = £6.64m

Indication of Technology end of design life replacement impact

D.37 It is unusual for a part of the NETS to be decommissioned and the site reinstated. In general, assets will be replaced towards the end of the assets design life. Typically, transmission assets will be decommissioned and removed only as part of an upgrade or replacement by different assets.

D.38 National Grid does not take account of replacement costs in the lifetime cost assessment.

D.39 National Grid’s asset replacement decisions take account of actual asset condition. This may lead to actual life of any technology being longer or shorter than the design life, depending on the environment it is installed in, lifetime loading, equipment family failures among other factors for example.

D.40 The following provides a high level summary of common replacement requirements applicable to specific technology options.

a) OHL - Based on the design life of component parts, National Grid assumes an initial design life of around 40 years for overhead line circuits. After the initial 40 year life of an overhead line circuit, substantial pylon replacement works would not normally be required. The cost of pylons is reflected in the initial indicative capital costs, but the cost of replacement at 40 years would not include the pylon cost. As pylons have an 80 year life and can be re-used to carry new replacement conductors. The replacement costs for overhead line circuits at the end of their initial design life are assessed by National Grid as being around 50% of the initial capital cost, through the re-use of pylons.

b) AC underground Cable - At the end of their initial design life, circa 40 years, replacement costs for underground cables are estimated to be equal or potentially slightly greater than the initial capital cost. This is because of works being required to excavate and remove old cables prior to installing new cables in their place in some instances.

c) GIL - At the end of the initial design life, circa 40 years, estimated replacement costs for underground GIL would be equal to or potentially greater than the initial capital cost. This is because of works being required to excavate and remove GIL prior to installing new GIL in their place in some instances.

d) HVDC - It should be noted at the end of the initial design life, circa 40 years, replacement costs for HVDC are significant. This due to the large capital costs for the replacement of converter stations and the cost of replacing underground or subsea DC cables when required.

Annual Electrical Losses and Cost

D.41 Transmission losses occur in all electrical equipment and are related to the operation and design of the equipment. The main losses within a transmission system come from heating losses associated with the resistance of the electrical circuits, often referred to as I^2R losses (the electrical current flowing through the circuit, squared, multiplied by the resistance). As the load (the amount of power each circuit is carrying) increases, the current in the circuit is larger.

D.42 The average load of a transmission circuit which is incorporated into the transmission system is estimated to be 34% (known as a circuit average utilisation). This figure is calculated from the analysis of the load on each circuit forming part of National Grid's transmission system over the course of a year. This takes account of varying generation and demand conditions and is an appropriate assumption for the majority of Strategic Options.

D.43 This level of circuit utilisation is required because if a fault occurs there needs to be an alternative route to carry power to prevent wide scale loss of electricity for homes, business, towns and cities. Such events would represent a very small part of a circuit's 40 year life, but this availability of alternative routes is an essential requirement at all times to provide secure electricity supplies to the nation.

D.44 In all AC technologies the power losses are calculated directly from the electrical resistance properties of each technology and associated equipment. Table D.11 provides a summary of circuit resistance data for each AC technology and capacity options considered in this Report.

IET, PB/CCI Report short-form label	AC Overhead Line Conductor Type (complete single circuit resistance for conductor set)	AC Underground Cable Type (complete single circuit resistance for conductor set)	AC Gas Insulated Line (GIL) Type (complete single circuit resistance for conductor set)
Lo	2 x 570 mm^2 (0.025 Ω/km)	1 x 2,500 mm^2 (0.013 Ω/km)	Single Tube per phase (0.0086 Ω/km)
Med	2 x 850 mm^2 (0.0184 Ω/km)	2 x 2,500 mm^2 (0.0065 Ω/km)	Single Tube per phase (0.0086 Ω/km)
Hi	3 x 700 mm^2 (0.014 Ω/km)	2 x 2500 mm^2 (0.0043 Ω/km)	Two tubes per phase (0.0065 Ω/km)
Losses per 200 Mvar Reactor required for AC underground cables			
Reactor Losses	N/A	0.4MW per reactor	N/A
Additional losses for 275 kV circuits requiring connection to the 400 kV system			
275 kV options only **275/400 kV SGT losses**	0.2576 Ω (plus 83 kW of iron losses) per SGT	0.2576 Ω (plus 83 kW of iron losses) per SGT	0.2576 Ω (plus 83 kW of iron losses) per SGT

Table D.11 –AC circuit technologies and associated resistance.

D.45 The process of converting AC power to DC is not 100% efficient. Power losses occur in all elements of the converter station: the valves, transformers, reactive compensation/filtering and auxiliary plant. Manufacturers typically represent these losses in the form of an overall percentage. Table D.12 shows the typical percentage losses encountered in the conversion process, ignoring losses in the DC cable circuits themselves.

HVDC Converter Type	2 GW Converter Station losses	2 GW DC Cable Pair Losses	2 GW Total Link loss
Current Source (CSC) Technology or "Classic" HVDC	0.5% per converter	Negligible	1% per HVDC Link
Voltage Source (VSC) Technology HVDC	1.0% per converter	Negligible	2% per HVDC Link

Table D.12–HVDC circuit technologies and associated resistance per circuit.

D.46 The example calculation explained in detail below is for "Med" category circuits and has been selected to demonstrate the principles of the mathematics set out in this section. This example does not describe specific options set out within this report. A detailed example explanation of the calculations used to calculate AC losses is included in Appendix E.

D.47 The example calculations (using calculation methodology described in Appendix E) of instantaneous losses for each technology option for an example circuit of 40 km "Med" capacity 6,380 MVA (two x 3190 MVA).

- Overhead Lines = (2 x 3) x $1,565.5^2$ x (40 x 0.0184) = 10.8 MW
- Underground Cable = (2 x 3) x $1,565.5^2$ x (40 x 0.0065) + (6 x 0.4 MW) = 6.2 MW
- Gas Insulated Lines = (2 x 3) x $1,565.5^2$ x (40 x 0.0086) = 5.1 MW
- CSC HVDC = 34% x 6,380 x 1% = 21.7 MW
- VSC HVDC = 34% x 6,380 x 2% = 43.4 MW

D.48 An annual loss figure can be calculated from the instantaneous loss. National Grid multiplies the instantaneous loss figure by the number of hours in a year and also by the cost of energy. National Grid uses £60/MWhr which is the cost of energy derived in the Ofgem "project discovery" document[55].

D.49 The following is a summary of National Grid's example calculations of annual losses and maintenance costs for each technology option for an example circuit of 40 km "Med" capacity 6,380 MVA (two x 3,190 MVA).

(a) Overhead line annual loss = (10.8 x 24 x 365) x £60/MWhr = £5.7m.

(b) Underground cable annual loss = (6.2 x 24 x 365) x £60/MWhr = £3.3m.

(c) Gas insulated lines annual loss = (5.1 x 24 x 365) x £60/MWhr = £2.7m

55 http://www.ofgem.gov.uk/Markets/WhlMkts/monitoring-energy-security/Discovery/Documents1/Discovery_Scenarios_ConDoc_FINAL.pdf 2012 figure from figure 3.19 Wholesale Electricity Prices Graph "Dash for Energy" Cost £60/MWhr including marginal cost of carbon.

(d) CSC HVDC annual loss = (21.7 x 24 x 365) x £60/MWhr = £11.4m

(e) VSC HVDC annual loss = (43.4 x 24 x 365) x £60/MWhr = £22.8m

Example Lifetime costs and NPV Cost Estimate

D.50 The annual operation, maintenance and loss information is assessed against the NPV model at 3.5% over 40 years and added to the capital costs to provide a lifetime cost for each technology.

D.51 Table D.13 shows an example for a "Med" capacity 6,380 MVA (2 x 3190 MVA) 400 kV circuits over 40km distance and 40 years of operation.

Example 400 kV "Med" Capacity over 40 km	Overhead Line (OHL)	AC Underground Cable (AC Cable)	Gas Insulated Line (GIL)	CSC High Voltage Direct Current (HVDC)	VSC High Voltage Direct Current (HVDC)
Capital Cost	£111m	£909m	£854m	£1,274m	£1,295m
NPV Loss Cost over 40 years at 3.5% discount rate	£125m	£72m	£58m	£251m	£501m
NPV Maintenance Cost over 40 years at 3.5% discount rate	£2m	£5m	£2m	£146m	£146m
Lifetime Cost	**£238m**	**£986m**	**£914m**	**£1,671m**	**£1,942m**

Table D.13 –Example Lifetime Cost table (rounded to the nearest £m)

Appendix E – Detailed Mathematical Principles used for AC Loss Calculation

E.1 This Appendix provides a detailed description of the mathematical formulae and principles that National Grid applies when calculating losses on the Transmission System. The calculations use recognised mathematical equations which can be found in power system analysis text books.

E.2 The example calculation explained in detail below is for "Med" category circuits and has been selected to demonstrate the principles of the mathematics set out in this section. This example does not describe specific options set out within this report.

E.3 The circuit category, for options contained within this report, is set out within each option. The example below demonstrates the mathematics and principles, which is equally applicable to "Lo", "Med" and "Hi" category circuits, over any distance.

Example Loss Calculation (1) - 40 km 400 kV "Med" Category Circuits

E.4 The following is an example loss calculation for a 40 km 400 kV "Med" category (capacity of 6,380 MVA made up of two 3,190 MVA circuits).

E.5 Firstly, the current flowing in each of the two circuits is calculated from the three phase power equation of,

$$P = \sqrt{3} \times V_{LL} \times I_{LL} \times cos\theta$$

Assuming a unity power factor (cos θ = 1), the current in each circuit can be calculated using a rearranged form of the three phase power equation of:

In a star (Y) configuration electrical system,

$$I = I_{LL} = I_{LN}$$

$$I = \frac{P}{\sqrt{3} \times V_{LL}}$$

where, P is the circuit utilisation power, which is 34% of circuit rating as set out in D.40 of Appendix D, which for the each of the two circuits in the "Med" category example is calculated as:

$$P = 34\% \times 3190\ MVA = 1{,}084.6\ MVA$$

And, V_{LL} is the line to line voltage, which for this example is 400 kV.

For this example, the average current flowing in each of the two circuits is

$$I = \frac{1{,}084.6 \times 10^6}{\sqrt{3} \times 400 \times 10^3} = 1{,}565.5\ A$$

E.6 The current calculated above will flow in each of the phases of the three phase circuit. Therefore from this value it is possible to calculate the instantaneous loss which occurs at the 34% utilisation loading factor against circuit rating for any AC technology.

E.7 For this "Med" category example, the total resistance for each technology option is calculated (from information in Appendix D, Table D.10) as follows:

$$Overhead\ Line = 0.0184\Omega/km \times 40km = 0.736\ \Omega$$

$$Cable\ Circuit\ = \frac{0.0065\Omega}{km} \times 40km = 0.26\ \Omega$$

$$Gas\ Insulated\ Line = \frac{0.0086\Omega}{km} \times 40km = 0.344\ \Omega$$

These circuit resistance values are the total resistance seen in each phase of that particular technology taking account the number of conductors needed for each technology option.

E.8 The following is a total instantaneous loss calculation for the underground cable technology option for the "Med" category example:

Losses per phase are calculated by,

$$P = I^2R$$

$$= 1{,}565.5^2 \times 0.26 = 0.64\ MW$$

Losses per circuit are calculated using by,

$$P = 3 \times I^2 \times R$$

$$= 3 \times 1{,}565.5^2 \times 0.26 = 1.91\ MW$$

Losses for "Med" category are calculated by multiplying losses per circuit by number of circuits in the category

$$Losses\ for\ two\ circuits = 2 \times 1.91 = 3.8\ MW$$

E.9 For underground cable circuits, three reactors per circuit are required (six in total for the two circuits in the "Med" category). Each of these reactors has a loss of 0.4 MW. The total instantaneous losses for this "Med" category example with the underground cable technology option are assessed as:

$$3.8 + (6 \times 0.4) = 6.2\ MW$$

E.10 The same methodology is applied for the other AC technology option types for the "Med" category example considered in this Appendix. The following is a summary of the instantaneous total losses that were assessed for each technology option:

$$Overhead\ Line = (2 \times 3) \times 1{,}565.5^2 \times 0.736 = 10.8\ MW$$

$$Cable\ Circuit = (2 \times 3) \times 1{,}565.5^2 \times 0.26 + (6 \times 0.4) = 6.2\ MW$$

$$Gas\ Insulated\ Line = (2 \times 3) \times 1{,}565.5^2 \times 0.344 = 5.1\ MW$$

<u>Example Loss Calculation (2) - 40 km 275 kV "Lo" Category Circuits Connecting to a 400 kV part of the Transmission System</u>

E.11 The following is an example loss calculation for a 40 km 275 kV "Lo" category (capacity of 3,190 MVA made up of two 1,595 MVA circuits) and includes details of how losses of the supergrid transformer ("SGT") connections to 400 kV circuits are assessed. This example assesses the losses associated with the GIL technology option up to a connection point to the 400 kV system.

The circuit utilisation power (P) which for the each of the two circuits in the "Lo" category example is calculated as:

$$P = 34\% \times 1.595.5 = 542.3\ MVA$$

For this example, the average current flowing in each of the two circuits is:

$$I = \frac{542.3 \times 10^6}{\sqrt{3} \times 275 \times 10^3} = 1{,}138.5\ A$$

E.12 For this "Lo" category example, the total resistance for the GIL technology option is calculated (from information in Appendix D, Table D.10) as follows:

$$0.0086\,\Omega/km \times 40\ km\ = 0.344\ \Omega$$

E.13 The following is a total instantaneous loss calculation for the GIL technology option for this "Lo" category example:

Losses per circuit are calculated using $P=3I^2R$

$$P = 3 \times 1{,}138.5 \times 0.344 = 1.35\ MW$$

Losses for "Lo" category 275 kV circuits are calculated by multiplying losses per circuit by number of circuits in the category

$$P = 2 \times 1.35\ MW = 2.7\ MW$$

E.14 SGT losses also need to be included as part of the assessment for this "Lo" category example which includes connection to 400 kV circuits. SGT resistance [56] is calculated (from information in Appendix D, Table D.10) as 0.2576 Ω.

E.15 The following is a total instantaneous loss calculation for the SGT connection part of this "Lo" category example:

The average current flowing in each of the two SGT 400 kV windings is calculated as:

$$I_{HV} = \frac{542.3 \times 10^6}{\sqrt{3} \times 400 \times 10^3} = 782.7\ A$$

Losses per SGT are calculated using $P=3I^2R$

$$SGT\ Losses = 3 \times 782.7 \times 0.2576 = 0.475\ MW$$

56 Resistance value referred to is the 400 kV side of the transformer.

Iron Losses in each SGT = 84 kW

Total SGT instantaneous loss (one SGT per GIL circuit) = (2 x 0.475) + (2 x 0.084) = 1.1 MW

E.16 For this example, the total "Lo" category loss is the sum of the calculated GIL and SGT total loss figures:

$$\text{"Lo"} category\ loss = 2.7 + 1.1 = 3.8\ MW$$

Appendix F – Environmental and Socio-Economic Appraisal

F.1 At this strategic level of appraisal, where consideration is being given to options for network reinforcement, constraints or features largely of international and national importance in environmental and socio-economic terms are used as differentiators. A summary of these potential constraints and their data sources, derived from desk-based assessment at this stage, is presented in Table F.1 at the end of this Appendix.

F.2 Prior to conducting the environmental and socio-economic appraisals for this project, discussions were held with key stakeholders about the options to be appraised and the scope of those appraisals. The following sections explain the resultant scope of the environmental and socio-economic topic appraisals and the method by which they have been undertaken.

F.3 In certain circumstances, and through consultation with key stakeholders, consideration will be given to the inclusion of additional constraints or features which are not necessarily of international or national importance in environmental and socio-economic terms.

F.4 In general terms, consultants gather baseline environmental and socio-economic information about receptors, constraints and features for the various sub-topics and then assess the likely significant effects of options on those receptors, constraints and features. The findings of that appraisal are then used to inform further consultation with key statutory stakeholders about the options.

F.5 Thereafter, in considering which one or more preferred strategic option(s) to take forward to the next stage of development, National Grid will have regard to the issues identified through the appraisal, key stakeholder feedback, the Company's statutory duties and licence obligations, the standards to which the Company is required to design and operate the network (the NETS SQSS) and the relevant National Policy Statements.

Environmental Appraisal

F.6 There are a number of sub-topics within the environmental appraisal, which are set out in the paragraphs below.

Ecology

F.7 The guiding principles pertaining to the consideration of likely ecology and biodiversity effects, is to seek to avoid or minimise the effects of new infrastructure on valuable species, habitats, ecological networks and ecosystem functionality.

F.8 While not an exhaustive list of considerations, the strategic options appraisal has paid particular attention to the objectives of the following international and national ecological and biodiversity designations:

(a) Ramsar sites, listed under the Convention on Wetlands of International Importance, 1971

(b) Special Protection Areas (SPAs), classified under the EC Directive on the Conservation of Wild Birds, 1979

(c) Special Areas of Conservation (SACs), classified under the EC Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora, 1992 (the Habitats Directive)

(d) National Nature Reserves (NNRs), declared under Section 19 of the National Parks and Access to the Countryside Act 1949 & Section 35 of the Wildlife and Countryside Act 1981

(e) Sites of Special Scientific Interest (SSSI), notified under Section 28 of the Wildlife and Countryside Act 1981 (as amended)

(f) Marine Nature Reserves under the Wildlife and Countryside Act 1981, and

(g) Marine Conservation Zones under the Marine and Coastal Access Act 2009 (MACA)

F.9 The strategic options appraisal has also considered the wider habitat resource and ecological functionality at a strategic level. This has included consideration of sites designated as having national or international value as well as some particular habitats which may fall outside these designated areas or which are not designated as having such value.

F.10 Given the scale of habitats designated at less than a national level, it was considered appropriate through consultation with key stakeholders that some such sites should also be considered in the strategic options appraisal for the North Wales Connections Project. The list of interests includes:

(a) areas of, ancient and semi-natural woodland;

(b) Local Nature Reserves (LNRs)

(c) RSPB Reserves, and

(d) Important Bird Areas.

F.11 Under Article 6(4) of the Habitats Directive 92/43/EEC, an appropriate assessment by a competent authority is required where a plan or project is likely to have a significant effect upon a Natura 2000 site (also known as 'European wildlife sites'), alone or in combination with other planned projects. Natura 2000 is a network of sites that includes SACs and SPAs. In addition, it is UK policy that sites designated under the Ramsar convention are included in this process.

F.12 Given the importance of these sites, consideration has been given to the potential for each of the strategic options to affect the integrity of European wildlife sites, including effects in combination with other plans or projects. Information regarding associated energy projects has been included in this appraisal together with other third party projects advised by CCW. However, the list of projects considered is not exhaustive and will need to be subject to review as the project develops. A screening assessment under the Habitat Regulations would be undertaken for the strategic option finally selected, and an appropriate assessment completed if necessary, prior to submission of any consent application.

Historic Environment

F.13 The guiding principles pertaining to the consideration of likely effects upon the historic environment is to seek to avoid or minimise the effects of new infrastructure on cultural heritage features, including historic buildings and archaeological features.

F.14 While not an exhaustive list of considerations, the strategic options appraisal has paid particular attention to areas subject to international and national archaeological and cultural heritage designations as follows:

(a) World Heritage Sites- as designated by UNESCO's World Heritage Committee to be of Outstanding Universal Value for their contribution to universal cultural heritage

(b) Scheduled Monuments as designated under the Ancient Monuments and Archaeological Areas Act 1979

(c) Protected Wreck Sites as designated under the Protection of Wrecks Act 1973

(d) Historic Battlefields- as defined in the English Heritage register of historic battlefields (England only)

(e) Historic Parks and Gardens- at Grade I and Grade II* as defined by English Heritage's 'Register of Parks and Gardens of Special Historic Interest in England' and by Cadw in the 'Register of Parks and Gardens of Special Historic Interest in Wales', and

(f) Historic Landscape Areas as recorded in Cadw's 'Register of Landscapes of Historic Interest in Wales'.

F.15 Although Listed Buildings are designated at national level they have not been considered at the Level 1 strategic options appraisal stage due to their small site area and the difficulty of assessing the potential for impacts to occur to the setting of the building or feature at this strategic level.

Landscape and Visual

F.16 The guiding principles pertaining to the consideration of likely landscape and visual effects is to seek to avoid or minimise the effects of new infrastructure on the landscape/townscape and visual amenity.

F.17 The strategic options appraisal has paid particular attention to national landscape, and world heritage site designations, and their settings, as follows:

(a) National Parks and any future extension areas which are currently under consideration

(b) Areas of Outstanding Natural Beauty

(c) Designated and proposed World Heritage sites

(d) Areas defined as Heritage Coast

(e) Recreational Trails and Sustrans routes

(f) The value of the visual and sensory aspect of the landscape as assessed by CCW and reported in LandMap

(g) Principal settlement areas, and

(h) The designated cultural heritage features referred to above.

Local Air Quality

F.18 At this strategic level of appraisal the effects of any of the options upon local air quality is not likely to be material to the selection of a preferred option and therefore this aspect was scoped out for this level of appraisal.

Noise and Vibration

F.19 At this strategic level of appraisal the noise and vibration effects associated with any of the options was not considered likely to be material in the selection of a preferred option. It was therefore proposed that this topic be scoped out of the appraisal. However, a number of core statutory consultees suggested that it may differentiate between options, and while not material in itself, may be material in combination with other topic areas. It was therefore considered as part of the appraisal but was found not to be material at this strategic level.

Water

F.20 The guiding principles pertaining to the consideration of likely hydrological effects is to seek to avoid or minimise the effects of new infrastructure on water quality and to minimise flood risk and erosion.

Soils and Geology

F.21 The guiding principles pertaining to the consideration of likely effects on soils and geology is to seek to avoid or minimise the effects of new infrastructure on important geological features or on soils of the highest quality.

F.22 The strategic options appraisal has paid particular attention to:

(a) Nationally important sites of geological or geomorphological interest classified as Sites of Special Scientific Interest (SSSI), and

(b) Areas of extensive geological interest designated as European Geoparks by UNESCO.

(c) Land classified as 'best and most versatile' (i.e. Agricultural land classification Grades 1, 2 and 3a).

Resource Use and Waste

F.23 The guiding principles pertaining to the consideration of likely effects in terms of resource use and waste is to optimise the use of material resources in construction and minimise waste sent to landfill.

Socio-Economic Appraisal

F.24 There are three sub-topics within the socio-economic appraisal, which are set out in the paragraphs below.

Local Economic Activity

F.25 The guiding principles pertaining to the consideration of effects on local economic activity are to seek to avoid or minimise the effects of new infrastructure on economic activities and, so far as reasonably practicable, provide economic benefits at a strategic level.

F.26 Existing areas of strategic economic activity have been identified, including key tourist attractions, ports and airports.

People and Communities

F.27 The guiding principles pertaining to the consideration of likely effects on people and communities is to seek to avoid or minimise the negative economic impacts of new infrastructure on people and communities and, so far as reasonably practicable, provide wider economic benefits for the local community.

F.28 At Level 1 Options Appraisal, major centres of population and community facilities of strategic importance are identified. Such community facilities include major healthcare, educational, sports/leisure and transport facilities.

Traffic and Transport

F.29 The guiding principles pertaining to the consideration of likely traffic and transport effects is to seek to avoid or minimise disruption to local communities during construction.

Aviation and Defence

F.30 The guiding principles pertaining to the consideration of likely effects on aviation and defence is to seek to avoid or minimise the effects of new infrastructure on civil aviation or defence interests.

Topic / Sub-topic	Potential Constraints and Data Sets	Value	Data Source	Extent of Inclusion
Environment Ecology and Biodiversity	Special Areas of Conservation (SAC)	International	Countryside Council for Wales / Natural England	Included
	Special Protection Areas (SPA)	International	Countryside Council for Wales / Natural England	Included
	Ramsar Site	International	Countryside Council for Wales / Natural England	Included
	Sites of Special Scientific Interest (SSSI)	National	Countryside Council for Wales / Natural England	Included
	National Nature Reserve (NNR)	National	Countryside Council for Wales / Natural England	Included
	Biospheres Reserves	International	Countryside Council for Wales / Natural England	Included
	Marine Nature Reserves	National	Countryside Council for Wales / Natural England	Marine Reserves are identified as either a SSSI, SPA or SACs
	Local Nature Reserve (LNR)	Local up to Regional	Countryside Council for Wales / Natural England	Included
	RSPB Reserve	National	RSPB	Included
	Important Bird areas (IBA)	International	BirdLife International RSPB	Included
	National Inventory of Woodland	National	gis.naturalengland.org.uk /Forestry Commission	Included
	Ancient and semi natural woodland (ASNW)	Local to National	Countryside Council for Wales / Natural England	Included

Topic / Sub-topic	Potential Constraints and Data Sets	Value	Data Source	Extent of Inclusion
	Plantation on Ancient Woodland (PAW) site	Local to National	Countryside Council for Wales	Included
Environment Cultural Heritage	World Heritage Sites	International	CADW/English Heritage	Included
	Scheduled Monuments	National	CADW/English Heritage	Included
	Designated landscapes or their regional equivalent	National	CADW/English Heritage	Included
	Historic landscape of international value, whether designated or not.	International	CADW/English Heritage	Included
	Scheduled Monuments with standing remains	National	CADW/English Heritage	Included
	Registered Parks and Gardens	National	CADW/English Heritage	Included
	Protected Wreck Sites	National	CADW/English Heritage	Included
	Heritage Coasts	National	Countryside Council for Wales / Natural England	Included
	Historic Landscape Areas (Wales Only)	National	CADW	Included
Environment Landscape and Visual	National Parks	National	Countryside Council for Wales / Natural England	Included
	Areas of Outstanding Natural Beauty (AONB)	National	Countryside Council for Wales / Natural England	Included
	National Character Areas (NCAs)	National	Natural England	Included
	Principal settlement areas	Regional	DCLG	Included
	Woodland Inventory	Regional	Forestry Commission Wales/ Forestry Commission England	Included

Topic / Sub-topic	Potential Constraints and Data Sets	Value	Data Source	Extent of Inclusion
	Registered Parks and Gardens	Regional	CADW/English Heritage	Included
	Visual and Sensory Aspect Areas (LandMap)	Regional	Countryside Council for Wales	Included
	Sustrans Cycle Routes	Regional	SUSTRANS	Included –National and Regional Cycle Routes Only
	Geoparks	International	Countryside Council for Wales/Geoparks/ Natural England	Included
	Recreational Railway	Regional	OS Mapping	Included
Environment Noise	-	-	-	Included
Environment Soil and Geology	Land classified as Best and Most Versatile (BMV; i.e. ALC grades 1, 2 and 3a);	National	Welsh Assembly Government/ Natural England	Included
	Land of lower ALC grades (i.e. 3b, 4 or 5) where other sustainability considerations need to be taken into account.	National	Welsh Assembly Government/ Natural England	Included
Environment Hydrology and Environment	Water courses (rivers) and still waters (lakes, ponds and reservoirs)	Regional	Environment-agency.gov.uk	Aspects relating to Biodiversity, Recreation, Value to economy, Impacts to river courses and water quality and to fishing have been considered

Topic / Sub-topic	Potential Constraints and Data Sets	Value	Data Source	Extent of Inclusion
	Floodplain (EA flood zones 3 and 2)	Regional	Environment-agency.gov.uk	Included
	Marine and estuaries	Regional	Environment-agency.gov.uk	Aspects relating to Biodiversity, Recreation and Value to economy, have been considered
Socio-Economic Aviation and Defence	Military airfield	National	Defence Estates Safeguarding -	Included
	Passenger airport	National	OS Mapping	Included
	Licensed civil airfield	National	OS Mapping / DECC	Included
Socio-Economic Economic Activity	Tourism and Major visitor attractions and destinations	Regional / National	OS Mapping	Included
	National Trust land	Regional / National	National Trust	Included
	Transport infrastructure	National	OS Mapping	Included
Socio-Economic People and Communities	National Planning Policies	National /Regional		Planning Policy Statements and Technical Advice Notes Regional Spatial Strategies and Regional Development Strategies.
	Local settlements / Population Density	Regional	OS Boundary line & Office of National Statistics	Included

Topic / Sub-topic	Potential Constraints and Data Sets	Value	Data Source	Extent of Inclusion
	Welsh Language	Local / Regional	Welsh Government	Appraisal of whether Strategic Options would have a disproportionate effect on welsh-speaking individuals or communities and / or impact negatively on successful achievement of stated Welsh Government and Local Authority legislative and policy aims
	Community land	Regional	OS Mapping	Included
	Land Access (Wales) - Common land	Regional	Countryside Council for Wales / Natural England	Included
	Land Access (Wales) - Open country	National	Countryside Council for Wales / Natural England	Included
	Community facilities(Health, sports and education facilities)	Local	OS Mapping	Included
	National cycle paths	National	SUSTRANS	Included
	Regional cycle paths	Regional / national	SUSTRANS	Included
Socio-Economic Traffic and Transport	Public rights of way	National	Local Authorities	National and long distance routes only
	Rail network	National	OS Mapping	Included
	Primary roads	National	OS Mapping	Included
	Class A roads (including Trunk road network)	National	OS Mapping	Included
	Class B roads	National	OS Mapping	Included

Topic / Sub-topic	Potential Constraints and Data Sets	Value	Data Source	Extent of Inclusion
	Minor roads	Regional	OS Mapping	Included

Appendix G – Constraint Maps

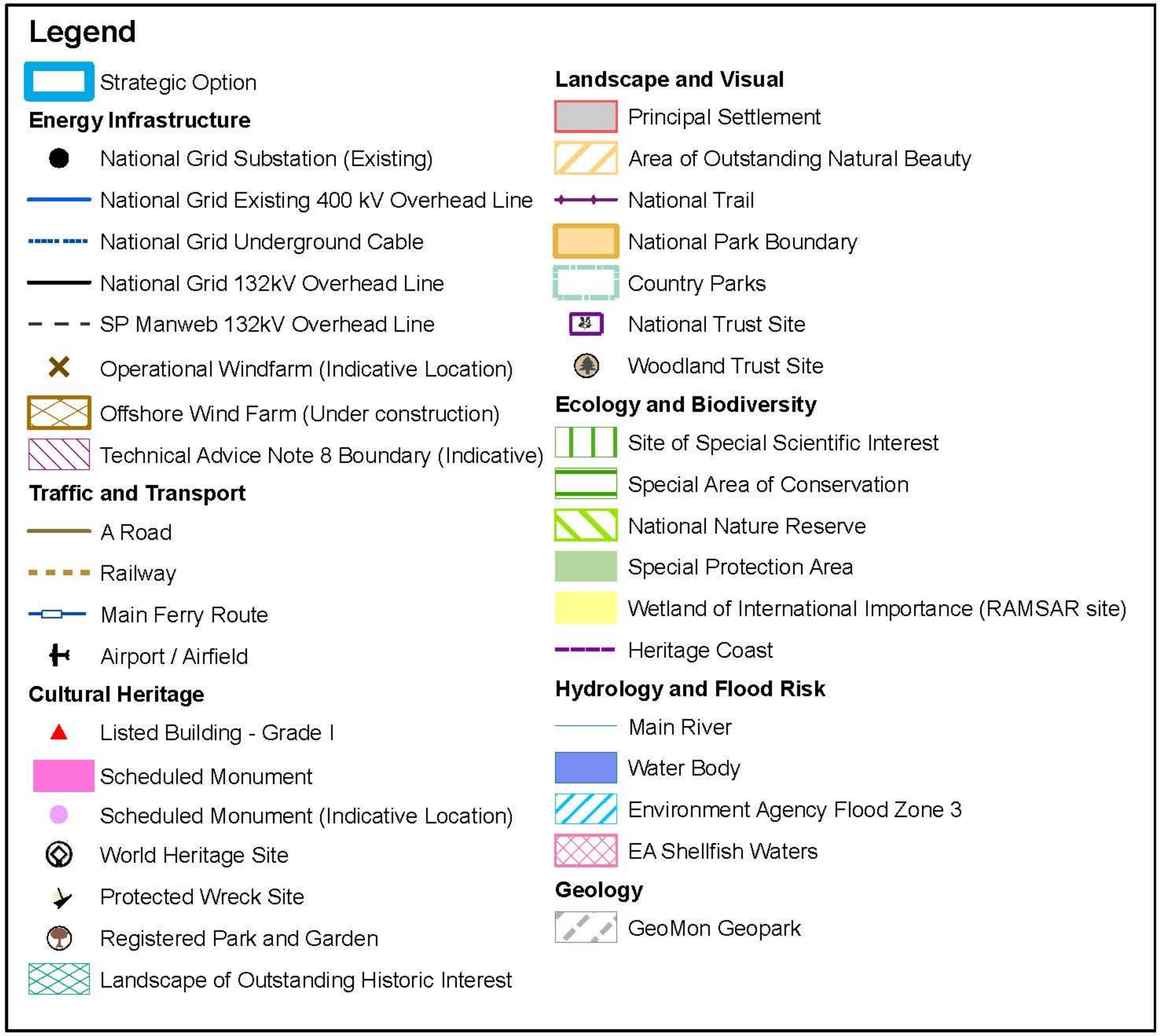


Figure G.1 – Legend for Constraint Maps

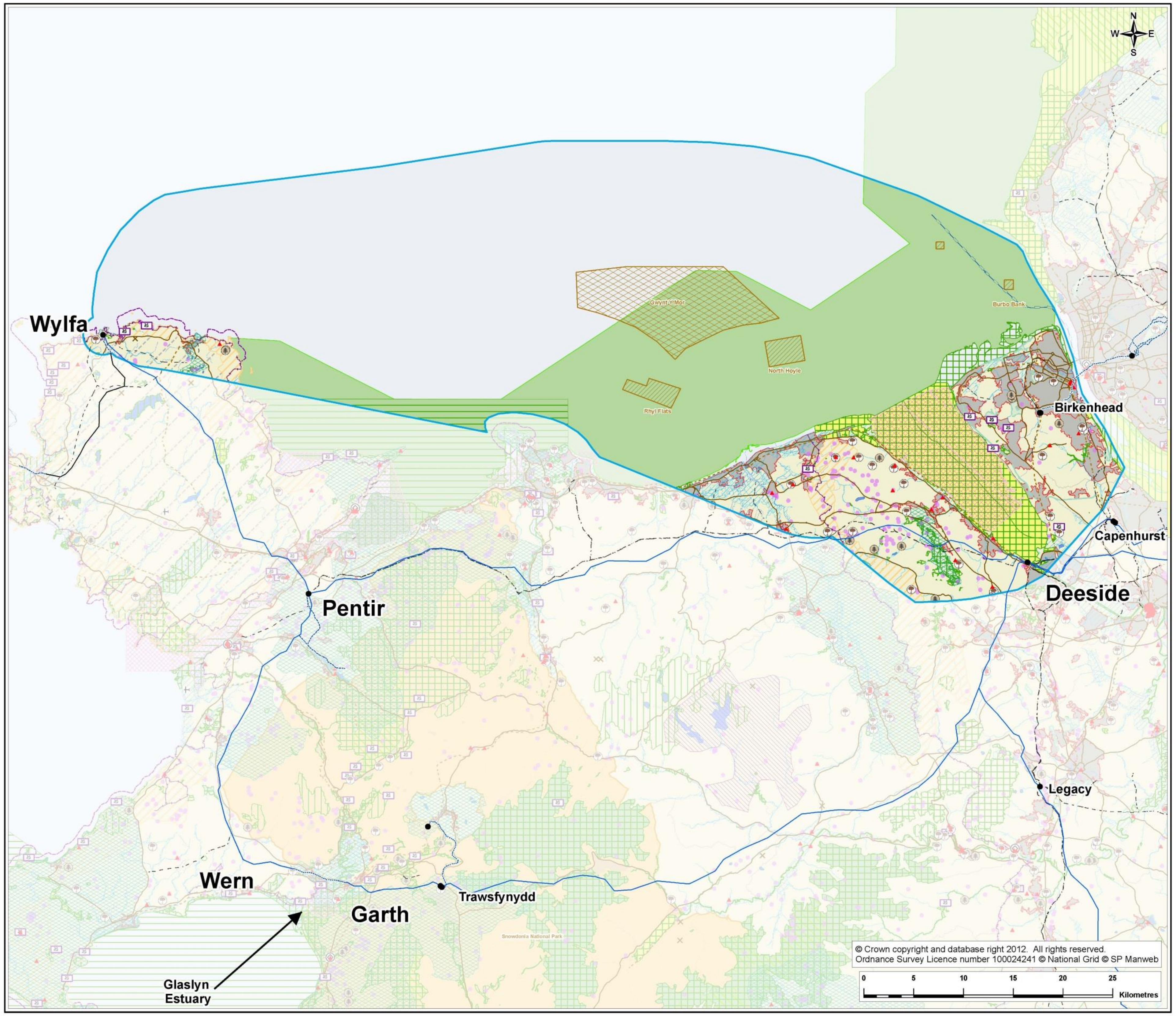


Figure G.2 – The Principal Ecological, Cultural Heritage and Landscape Constraints Affecting Strategic Option 1

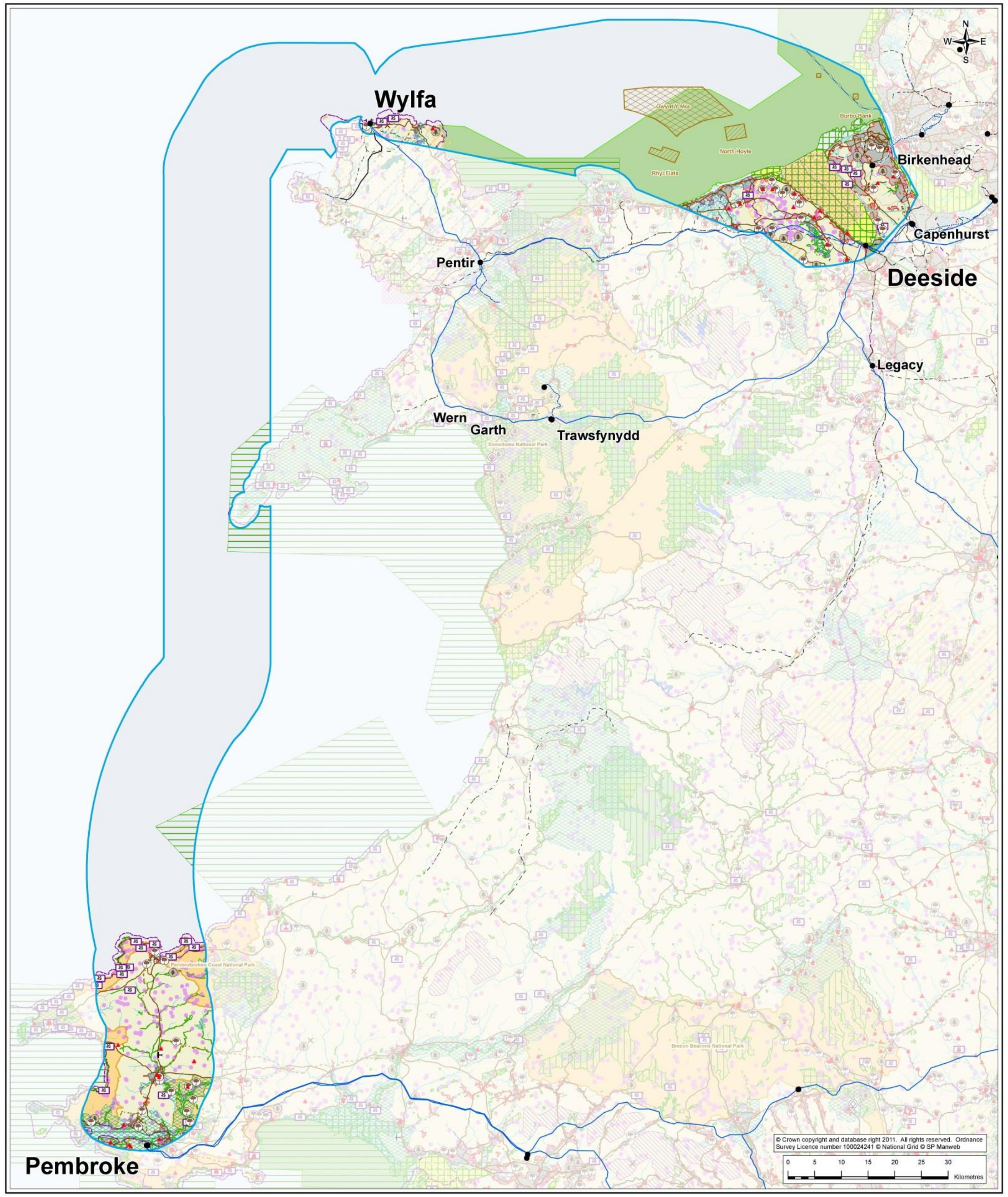


Figure G.3 – The Principal Ecological, Cultural Heritage and Landscape Constraints Affecting Strategic Option 2

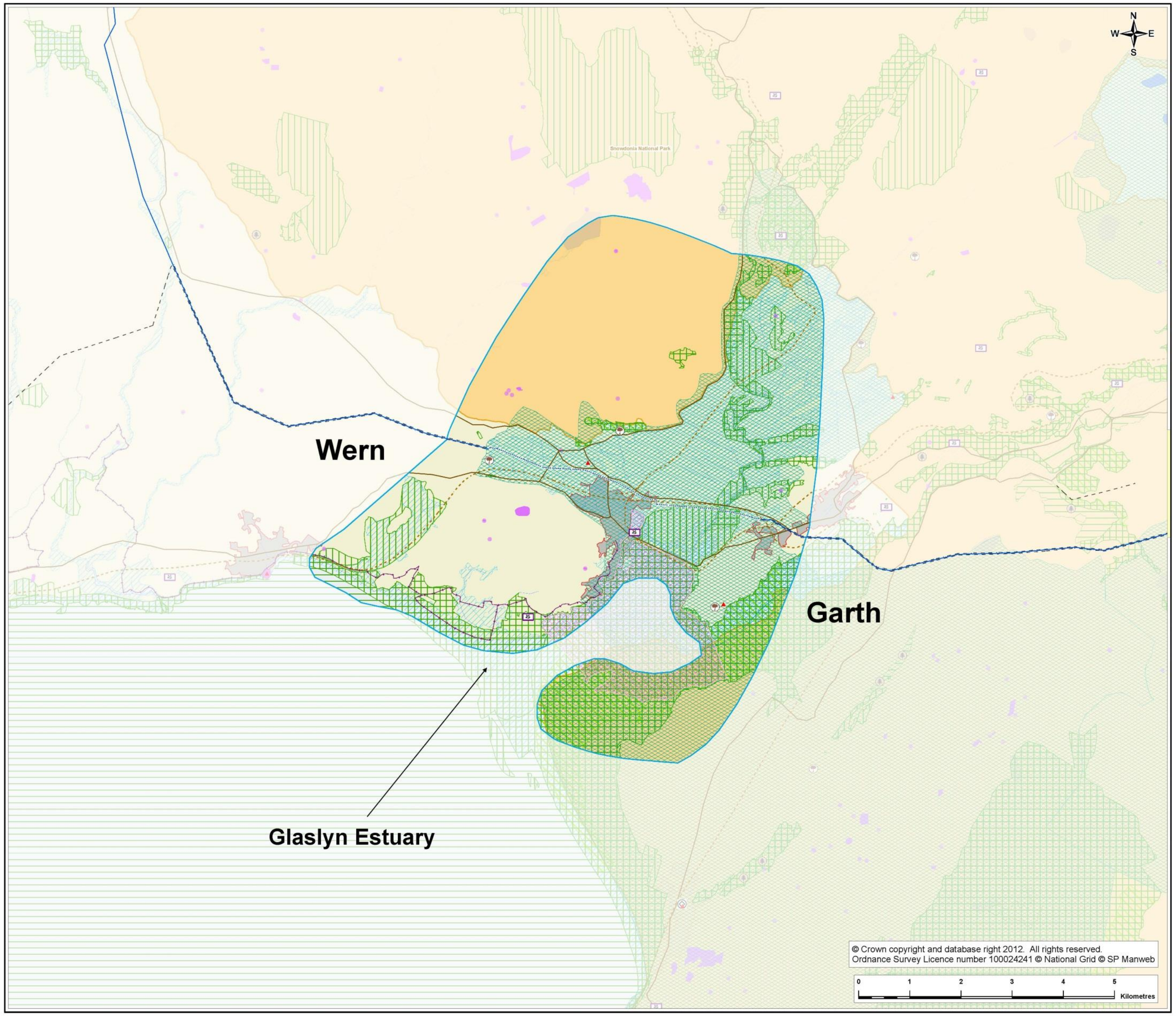


Figure G.4 – The Principal Ecological, Cultural Heritage and Landscape Constraints Affecting Strategic Options 3, 4 and 5 at Glaslyn

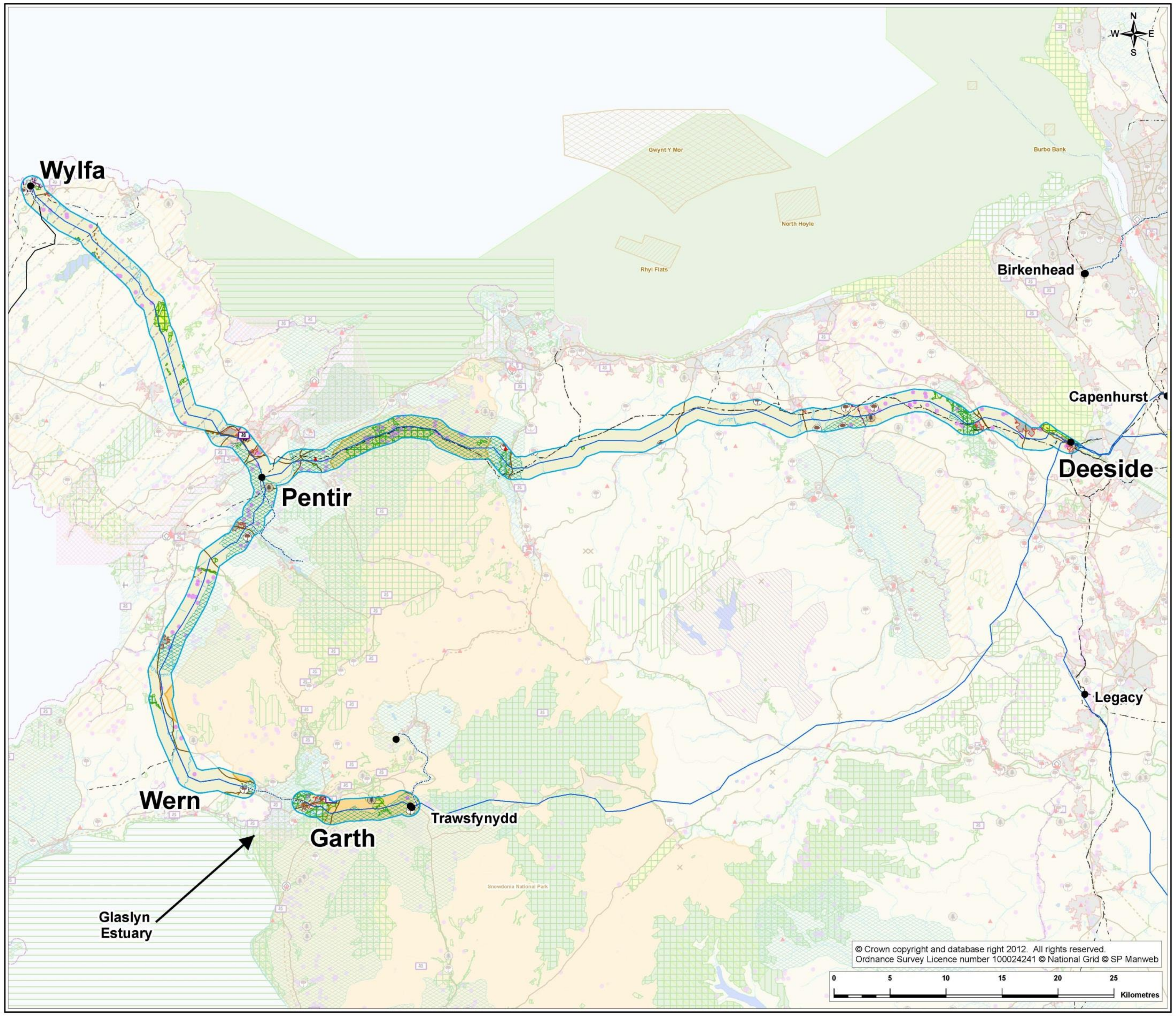


Figure G.5 – The Principal Ecological, Cultural Heritage and Landscape Constraints Affecting the Common Works for Strategic Options 3, 4 and 5

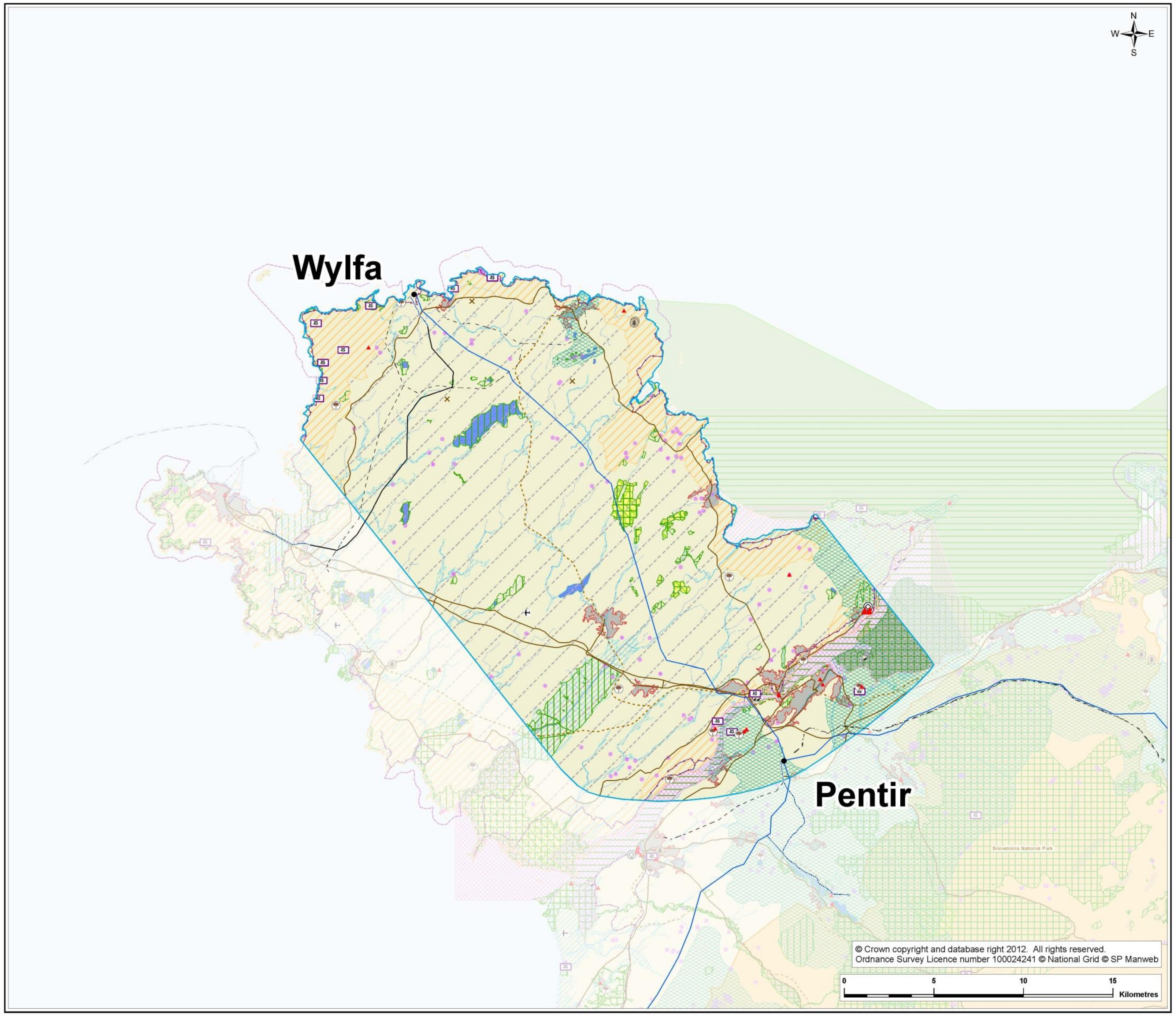


Figure G.6 – The Principal Ecological, Cultural Heritage and Landscape Constraints Between Wylfa and Pentir Affecting Strategic Option 3

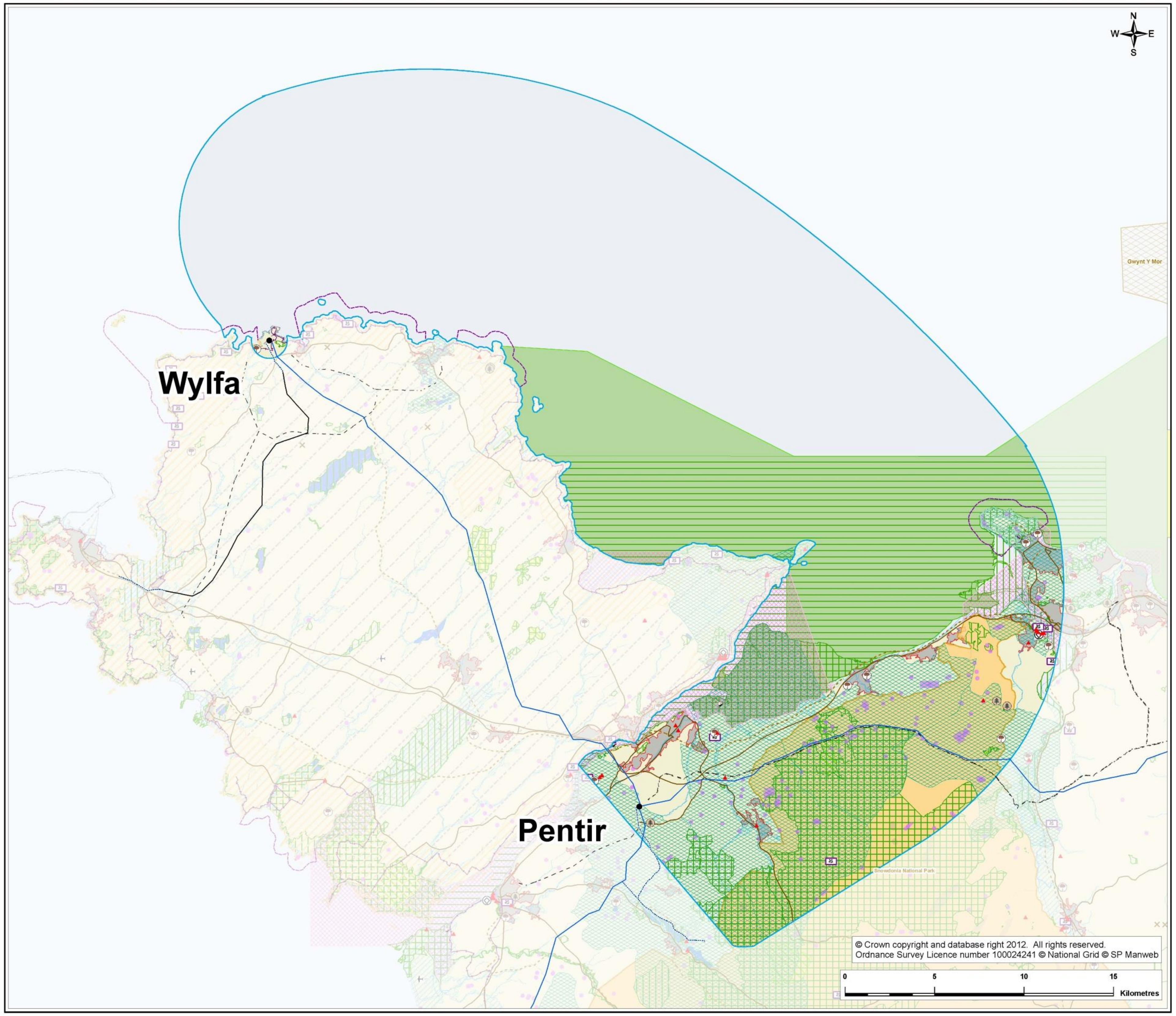


Figure G.7 – The Principal Ecological, Cultural Heritage and Landscape Constraints Between Wylfa and Pentir Affecting Strategic Option 4

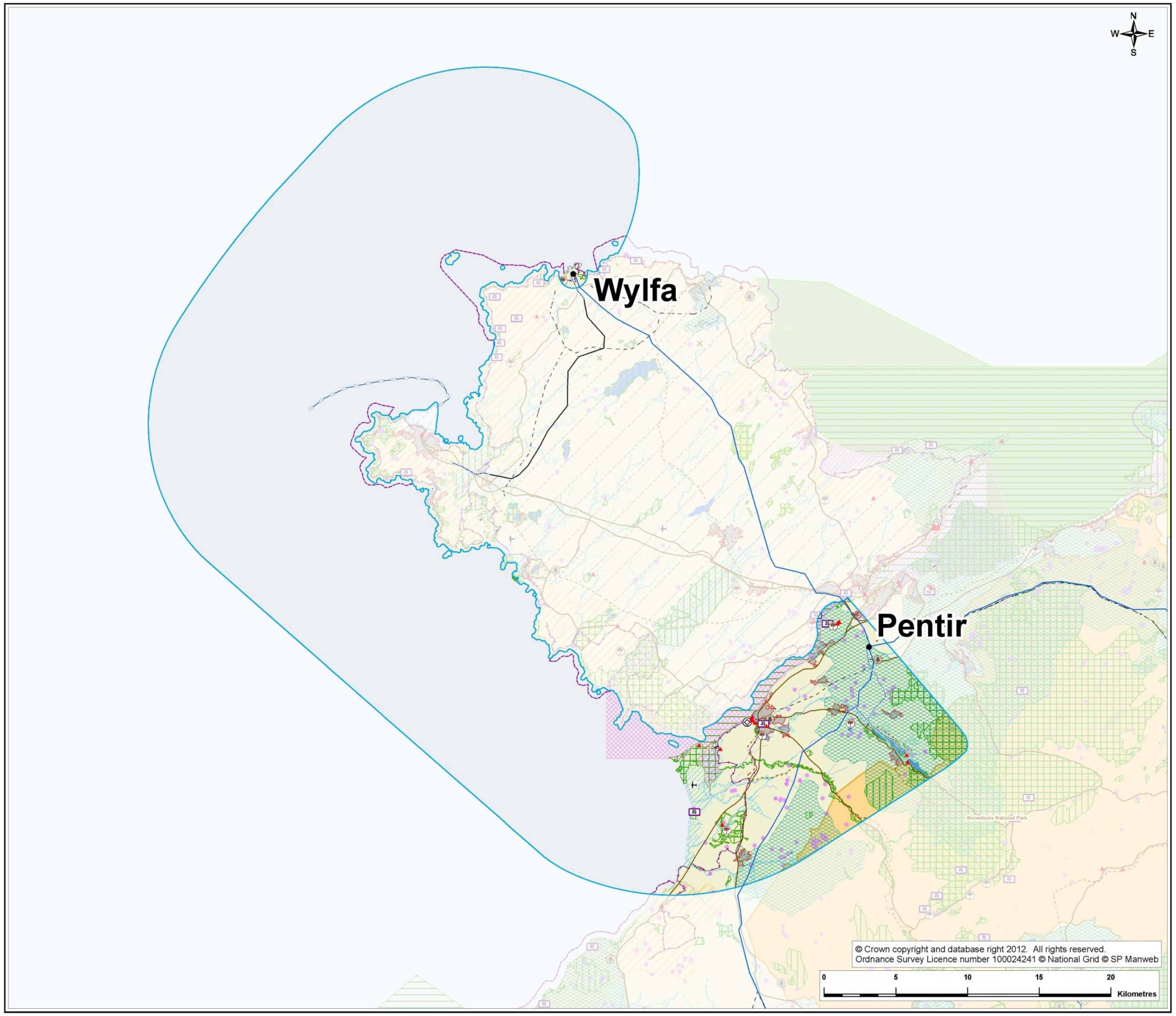


Figure G.8 – The Principal Ecological, Cultural Heritage and Landscape Between Wylfa and Pentir Affecting Strategic Option 5

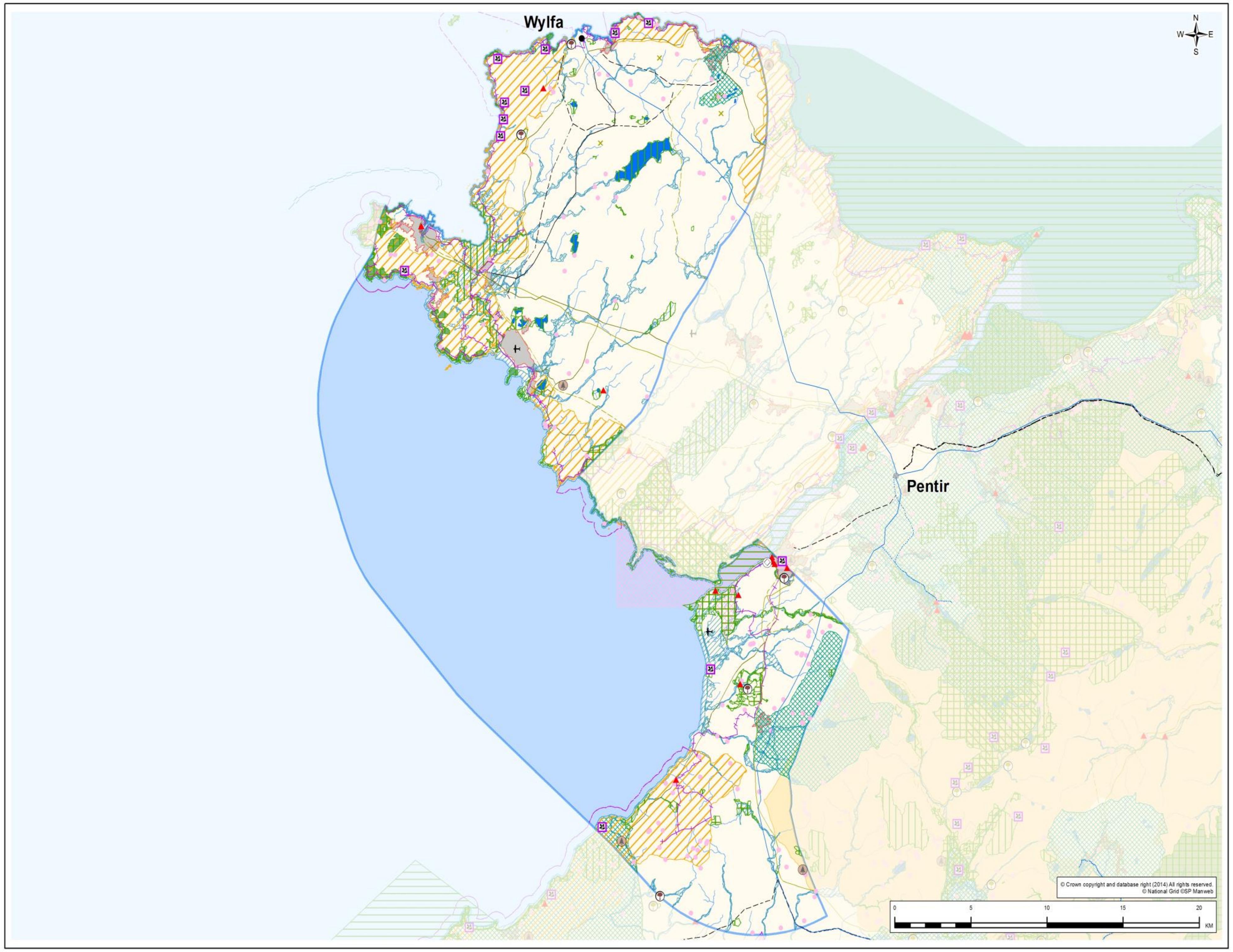


Figure G.9 – The Principal Ecological, Cultural Heritage and Landscape Between Wylfa and Pentir Affecting Strategic Option 6

Glossary of Terms and Acronyms

AC	Alternating Current
AIS	Air Insulated Switchgear - traditional substations with air insulated equipment, usually located away from coastal areas
AONB	Area of Outstanding Natural Beauty
Boundary	Boundaries represent the main weaknesses on the transmission system. Such weaknesses lead to the need to restrict power flows across the system
Converter Station	A converter station connects an AC system to a DC system. It contains electrical equipment that can convert AC to DC (and vice versa)
CSC	Current Source Converter
DC	Direct Current
DCO	Development Consent Order
DNO	Distribution Network Operator
Double Circuit	An overhead line design where two circuits are mounted on a single set of towers.
GIL	Gas Insulated Line
GIS	Gas Insulated Switchgear – compact substations with gas insulated equipment, utilised particularly in coastal areas
HV	High Voltage

HVDC	High Voltage Direct Current HVDC is used where power transmission is necessary over long distances (e.g. greater than 100 km). At such distances, this technology is both highly technically effective and economic. The solution requires the development of at least two converter installations (one at each end) and either a cable or overhead line link between the two. The converter installations are typically the size of a large warehouse.
km	Kilometre
NETS SQSS	National Electricity Transmission System Security and Quality of Supply Standard. [57] The NETS SQSS is a document that defines a set of criterion that specifies the robustness of the transmission system, in terms of the transmission faults and combinations of faults that it must be able to withstand without any interruption of electrical supplies, and the maximum interruption to supplies which is permitted under certain more onerous combination of faults. The SQSS is subject updates through industry and regulatory working groups, this periodic review and consultation changes to the NETS SQSS are implemented by changes to the electricity transmission licence Standard Conditions approved by the industry regulator, Ofgem. The NETS SQSS requires that National Grid must plan for all demand and generation conditions (or "backgrounds") "which ought reasonably to be foreseen to arise in the course of a year of operation … [and] shall include forecast demand cycles, typical power station operating regimes and typical planned outage patterns."
OFGEM	Office of Gas and Electricity Markets The regulatory body that is responsible for electricity and gas supply markets and networks.
OHL	Overhead line

[57] The NETS SQSS can be viewed at https://www.nationalgrid.com/uk/Electricity/Codes/gbsqsscode/

Ramsar	A designation covering all aspects of wetland conservation and wise use, recognising wetlands as ecosystems that are extremely important for biodiversity conservation in general and for the well-being of human communities.
SAC	Special Area of Conservation
SF_6	Sulphur Hexafluoride Gas The electrical insulator in GIL and SF_6 switchgear
SOR	Strategic Options Report
SPA	Special Protection Area Gives protection under the Birds Directive to rare and vulnerable birds, and for regularly occurring migratory species.
SSSI	Site of Special Scientific Interest Protect the country's best wildlife and geological sites.
volt (V)	The electrical unit of potential difference. 1 kilovolt (kV) = 1,000 volts
VSC	Voltage Source Converter
Watt (W)	The SI unit of power 1 kilowatt (kW) = 1,000 watts 1 megawatt (MW) = 1,000 kW 1 gigawatt (GW) = 1,000 MW