July 2022

Pathway to 2030

A holistic network design to support offshore wind deployment for net zero

nationalgridESO

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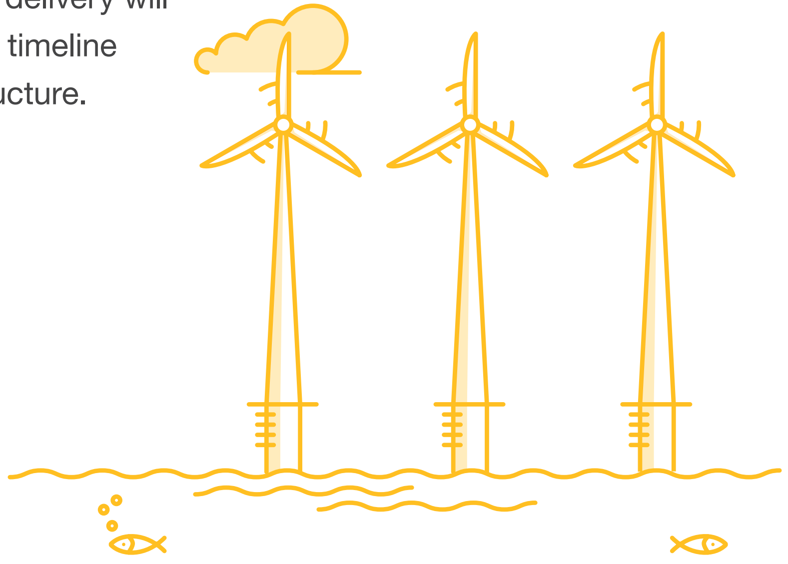
Executive Summary

The Department for Business, Energy and Industrial Strategy (BEIS) launched the Offshore Transmission Network Review (OTNR) in July 2020. It is playing a key part in enabling the vital role offshore wind has in meeting the UK Government's target for net zero. The objective of the OTNR is to "ensure that the transmission connections for offshore wind generation are delivered in the most appropriate way, considering the increased ambition for offshore wind to achieve net zero. This will be done with a view to finding the appropriate balance between environmental, social and economic costs".[1]

The rising cost of energy is having a significant impact on the cost of living in Great Britain. This is largely because of rising global gas prices. The UK Government recognised this in the *British Energy Security Strategy* (*BESS*), published in April 2022.[2] It set out a plan to increase the supply of electricity from zero-carbon British sources to deliver affordable, clean and secure power in the long term. Offshore wind has an important role to play in delivering this plan, with the ambition for 2030 increased to 50 GW in the UK, with 11 GW of that located in Scotland. The Holistic Network Design (HND) is a fundamental component of the *BESS* as it provides the design basis upon which other actions to accelerate delivery will build in order to reduce the end-to-end timeline for delivering strategic network infrastructure.



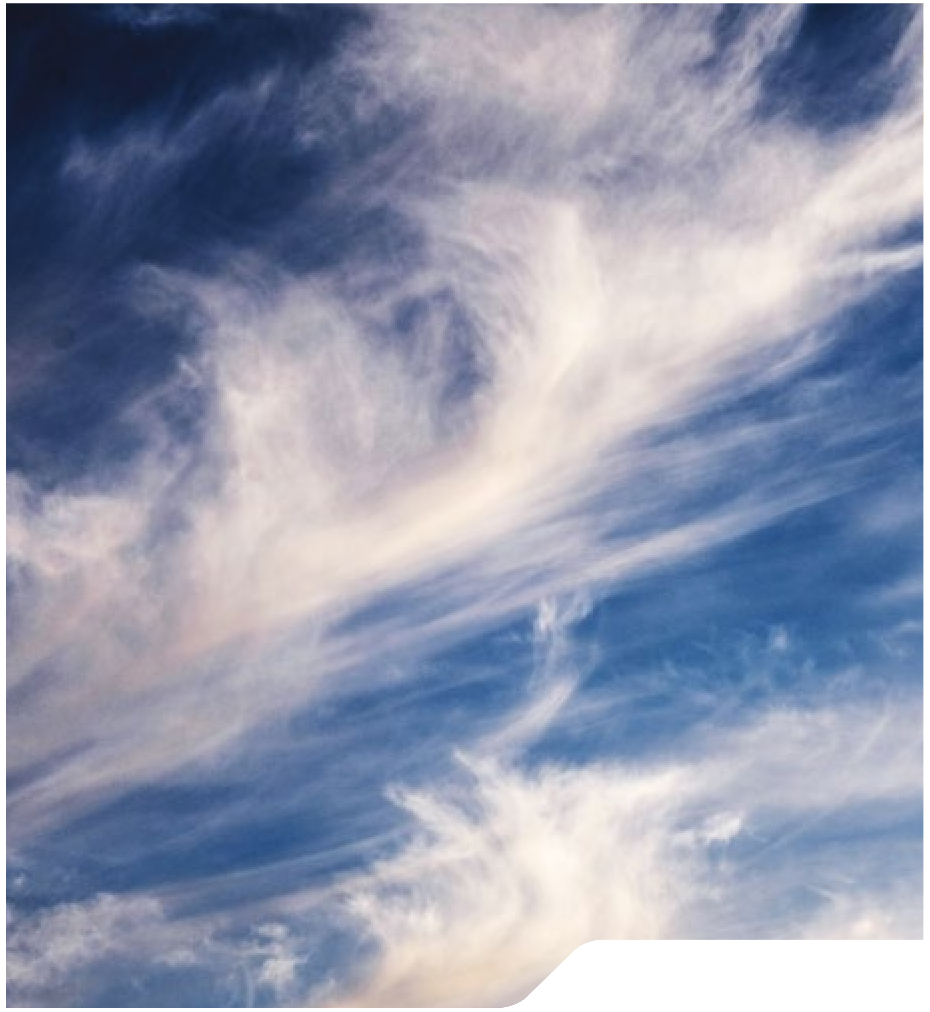
1 gov.uk/government/publications/offshore-transmission-network-review/offshore-transmission-network-review-terms-of-reference
2 gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy

Executive Summary

As the scale of offshore wind deployment increases, so does the need for additional transmission network infrastructure to deliver the electricity generated to consumers. This infrastructure needs to be designed and built in a way that balances the impact on the environment and local communities with providing the greatest value for consumers across the country. A significant step change is required to move from the current capacity of 11.3 GW to 50 GW by 2030, both in the roll out of the additional offshore wind farms themselves and the network required to connect and transport the electricity to where it can be used. Therefore, innovative thinking in network design has never been more important to ensure delivery of affordable, clean and secure power and meet the UK Government's ambitions.

The original radial approach to designing, building, and connecting offshore wind farms involved limited coordination. The approach was developed when the technologies involved were at the early stages of deployment and it was appropriate for the levels of offshore wind at that time. Regulation was designed to de-risk the delivery of offshore wind, with project developers provided with the option of building the associated network to bring the energy onshore. It incentivised developers to connect individually to shore to reduce their costs and minimise risks, which did not encourage coordination. The wind farms have also tended to be connected to the closest point on the onshore network and the network required to transport the electricity to where it is needed was thought about separately. With expectations of future offshore wind capacity now significantly higher, the original model is no longer fit for purpose without potentially risking avoidable impacts on consumers, the environment and communities. A more centralised and strategic approach to network planning is needed to deliver better outcomes, by integrating the connection of offshore wind farms to shore with the capability to transport electricity around Great Britain.

Three workstreams were created in the OTNR to cover offshore wind projects at different stages of development, namely Early Opportunities, Pathway to 2030 and Enduring Regime. Multi-purpose interconnectors are also considered across the three workstreams.



Executive Summary

The Early Opportunities workstream encourages developers of offshore wind and interconnector projects that are working to achieve planning consent to explore opportunities to coordinate their connections. Projects in scope are primarily based off the coast of East Anglia, have confirmed network connection arrangements in place and are more advanced in their development compared to those in the Pathway to 2030 workstream. The Early Opportunities workstream seeks to balance reducing the impact of network infrastructure on communities and the environment with not disrupting the projects' ongoing development, which could increase costs and put the ambition for 50 GW of offshore wind by 2030 at risk. BEIS has now announced four initial pathfinder projects. These are well-advanced projects that are leading the way in utilising the regulatory and policy changes being developed through the OTNR to increase transmission network coordination and deliver the OTNR's objectives.[3] RenewableUK[4] has also been playing a facilitative role in this workstream, through engaging with the relevant developers in the East Anglia Region and seeking options to take coordination opportunities forward and identify additional pathfinder projects. The projects engaged in this RenewableUK workstream have published an update on the progress of this work alongside the HND.[5]

The Office of Gas and Electricity Markets (Ofgem) and the Electricity System Operator (ESO) have also been working hard to remove barriers to coordination opportunities within the Early Opportunities workstream. Ofgem published a minded-to decision on anticipatory investment and implementation of policy changes for Early Opportunities projects in April[6] and we published our Early opportunities update in May.[7] Both publications set out actions and changes to enable early coordination opportunities to take place.

The HND, described in this document, is part of the Pathway to 2030 workstream and goes hand in hand with Ofgem's minded-to decision on the delivery model for the offshore network.[8] Offshore wind projects in scope of the Pathway to 2030 workstream are at a fairly early stage of development and are located around Scotland, Wales, the east coast of England north of the Wash, and south west England. For the first time, the HND enables delivery of a network that simultaneously handles connection of offshore wind farms to shore as well as transporting the power to where it will be used. Led by the ESO, in close consultation with the onshore Transmission Owners (TOs) through the Central Design Group (CDG), the HND has looked holistically across four objectives when considering the connection arrangements for offshore wind farms:

- **Cost to consumers.**
- **Deliverability and operability.**
- **Impact on the environment.**
- **Impact on local communities.**

3 gov.uk/government/publications/offshore-transmission-network-review/offshore-transmission-network-review-terms-of-reference
4 renewableuk.com
5 https://www.gov.uk/government/groups/offshore-transmission-network-review
6 ofgem.gov.uk/publications/offshore-coordination-early-opportunities-consultation-our-minded-decision-anticipatory-investment-and-implementation-policy-changes
7 nationalgrideso.com/document/259686/download
8 ofgem.gov.uk/publications/minded-decision-and-further-consultation-pathway-2030

Executive Summary

By assessing environmental and community impact to a greater extent earlier in the project development process, the HND is expected to reduce the overall impact of transmission network infrastructure for projects within its scope and help expedite their delivery. We have kept the concerns of our varied stakeholders at the forefront of our mind while balancing these objectives. However, the nature of the infrastructure required means the design cannot be without impact. In developing the design though, careful consideration has been given to the location of interface points to minimise community and environmental impacts. Where the recommended design has a greater environmental impact than the radial design, this has been weighed against the benefit of maximising the design's contribution to meeting net zero targets.

Along with wind farms already connected and those that are fairly well advanced in their development, including within scope of the Early Opportunities workstream, the HND facilitates the *BESS* ambition for connecting 50 GW of offshore wind by 2030. This integrated design also provides the opportunity to get the full benefit of offshore wind as soon as possible by providing significant additional transmission capacity to transport renewable power to consumers across Great Britain. In this regard, the HND is a first and significant step towards centralised strategic network planning. The Centralised Strategic Network Plan (CSNP) proposed by Ofgem in their Electricity Transmission Network Planning Review (ETNPR)[9] envisages an integrated approach to network design and delivery across the onshore and offshore networks. Offshore-specific arrangements will be established through the Enduring Regime workstream of the OTNR in alignment with the ETNPR. This includes deployment planning for future offshore wind leasing rounds and the rules associated with multi-purpose interconnectors.

9 ofgem.gov.uk/publications/consultation-initial-findings-our-electricity-transmission-network-planning-review

Executive Summary

Publication of the innovative *HND* is just the start of the delivery of the transmission network required to facilitate 50 GW offshore wind by 2030. It will need to be followed by further innovation by the UK Government, Ofgem, the onshore TOs and other industry players to ensure delivery of the commitments in the *BESS*. Specifically, the time taken to build onshore transmission network infrastructure will need to be significantly reduced in order to meet the offshore wind ambitions and net zero targets. This particularly applies to 11 of the onshore transmission network reinforcements recommended in the HND, where delivery of the commitments in the *BESS*, and resulting commitments from the relevant TOs to earlier delivery dates, will be vital to meeting the 2030 ambition.[10] However, reinforcements with 2030 and earlier delivery dates will also need to be accelerated to help manage supply chain availability. Particularly important will be to deliver a more efficient consenting process and provide earlier regulatory approval to key onshore transmission network projects.

The majority of the onshore reinforcement projects needed to enable the 2030 ambition have already been assessed by the TOs against similar design objectives as part of their project development options appraisal process. Some projects have yet to be appraised beyond a high-level assessment. More detailed environmental and community impact analysis will now be carried out by the TOs on these particular options to build on the initial assessment.

Beyond the *BESS* commitments, it is vitally important the supply chain for onshore and offshore transmission network is also in place. The offshore network design recommended in this document is ambitious but realistic, being based on known and well understood technology. Our aim is to leverage technology that is currently in development in future network plans, to enable an even greater level of integration.

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10 More information on the 11 projects can be found in the System-wide view section, page 62.

Executive Summary

Our key messages

1

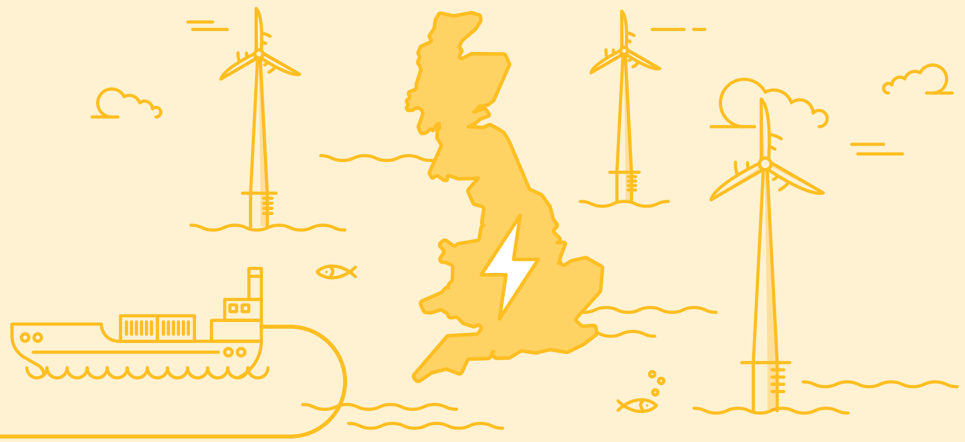
The HND is a first and significant step towards a more centralised and strategic approach to network planning: it integrates connecting offshore wind farms to shore with the capability to transport electricity around Great Britain.

- The HND provides a high-level view of the required onshore and offshore network. For the offshore network, it defines a network topology, capacities and interface sites. For the onshore network, it outlines the necessary upgrades to the existing network and new transmission network infrastructure requirements to facilitate the connection of offshore wind and the increase in power flow transfer requirements that result.
- It provides connection recommendations for 23 GW of offshore wind and the associated transmission network infrastructure to get the power to where it is needed. When combined with existing offshore wind projects and those already further advanced in their development, the HND will enable the connection of 50 GW of offshore wind in Great Britain by 2030.

2

The HND balances deliverability, economic, environmental and community impact criteria and will deliver significant benefits when compared to an optimised radial design, including:

- Overall net consumer savings of approximately £5.5 billion. The recommended design leads to an additional £7.6 billion of capital costs due to the additional offshore infrastructure, but this is outweighed by the £13.1 billion savings in constraint costs[11] that are expected to result from the additional network capacity this infrastructure provides.[12] This equates to a saving of £2.18 per year on the average customer electricity bill.
- A reduction in the impact on the environment with up to a third smaller footprint from offshore cables connecting to shore as a result of the increased use of high voltage direct current (HVDC) technology, reducing the impact on the seabed.
- Increasing the availability of offshore wind on the system by 32 TWh over a ten year period from 2030, equivalent to powering 10 million homes for an entire year.[13]
- Reducing cumulative CO_2 emissions from gas powered generation between 2030 and 2032 by 2 million tones of CO_2 – equivalent to grounding all UK domestic flights for a year – through transporting power produced by offshore wind to where it will be used more of the time, reducing the need for fossil fuel generation to be used in its place.



11 The cost of taking balancing actions to redispatch generation to prevent unacceptable network flows across parts of the network that have limited capacity. These consist of actions to decrease generation output in one part of the country, and actions to increase generation output in a different part of the country.
12 All cost savings are calculated over a 40 year asset life period, starting in 2030, using 2021 prices, unless otherwise stated.
13 This is based on today's average household electricity consumption figures.

Executive Summary

3

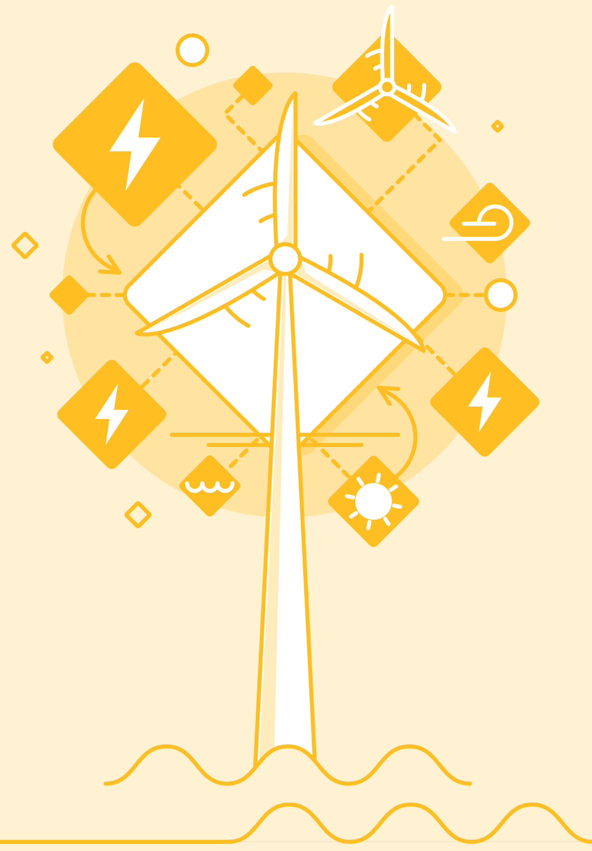
The HND requires significant investment in our existing onshore system to transport electricity to where it will be used. It recommends 94 reinforcements totalling £21.7 billion, to be delivered by the end of the decade.

- 11 reinforcements require acceleration in their delivery to meet 2030 targets and are reliant on the commitments outlined in the *BESS*.
- Many of the remaining 83 projects will need to be delivered before 2030 to smooth the requirements on the supply chain and allow coordination of access to the main transmission network during construction.

4

For the 2030 ambitions to be achieved, the ESO, Government (UK, Scottish and Welsh), Ofgem and the TOs will work innovatively and collectively to deliver the level of ambition set out in the HND, and as committed to in the *BESS*. This includes:

- Significantly reducing the time take from development to construction of strategic infrastructure projects, including expediting the consenting and regulatory approval processes.
- A regulatory framework to allow for strategic and anticipatory investment within the Pathway to 2030 workstream.
- The designation of transmission network infrastructure required for 2030 as strategic.[14]
- Commitments from the TOs to accelerate delivery of their reinforcement projects once detail of the changes set out in the *BESS* are confirmed, with the aim of delivering all necessary infrastructure by 2030.
- Supply chain availability to deliver the recommended network.
- The consideration of mitigation and strategic environmental compensation where needed.



14 The definition of strategic investment in this context will be outlined in Ofgem's ETNPR consultation decision document.

Executive Summary

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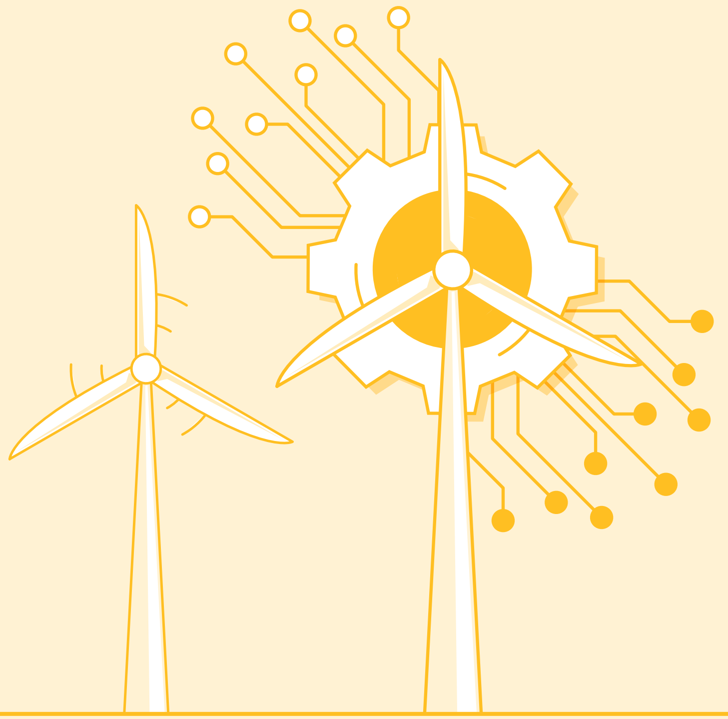
Coordinated connections will also require significant changes to industry codes and standards, which we will further progress during the second half of 2022. We will work with developers in the HND with the aim of updating connection contracts in the autumn.



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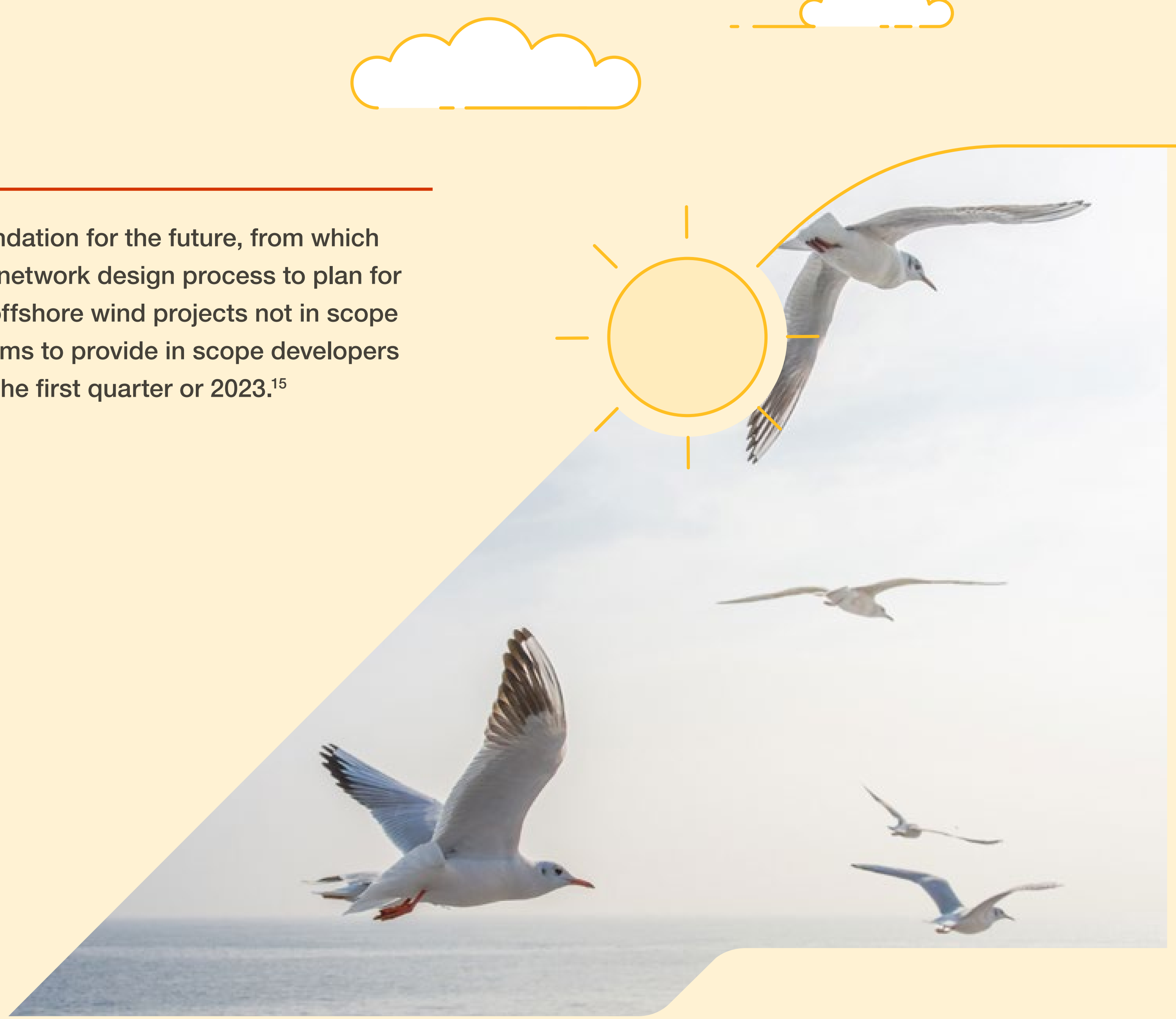
The HND provides the foundation for the future, from which we will deliver a follow-up network design process to plan for the connection of further offshore wind projects not in scope of the current HND. This aims to provide in scope developers with recommendations in the first quarter or 2023.[15]



15 This will include the remaining ScotWind leaseholders and any capacity made available through the ScotWind clearing process. It is also expected to include approximately 4 GW of Celtic Sea capacity. The details of the follow up process, including confirmation of scope and other key aspects, such as the methodology to be used for the process, will be communicated in summer 2022.

Executive Summary

Next steps

The HND will be followed by a Detailed Network Design (DND) and consenting process that will develop the HND recommendations further to determine technology choices, transmission routes and where substations and converter stations will be located. The DND and consenting process will be conducted by the party responsible for developing each asset. It is during this process that statutory consultations and relevant environmental assessments take place. It is also worth noting that the capital cost differentials quoted are based on high-level cost assumptions. The costs of each part of the design are expected to change as the design is developed in more detail during the DND stage.

Ahead of the start of the DND and consenting process, an exercise will need to be undertaken by Ofgem to determine which of the transmission assets in the HND will be regulated and developed as 'onshore transmission' and which will be 'offshore transmission'. This will be determined from both a legal and a technical perspective based on their function within the transmission network, rather than where those assets are spatially. For example, there can be 'onshore transmission' in the sea and 'offshore transmission' on land. This exercise will identify who will be responsible for the DND and consenting process for each of the recommended transmission assets within the HND. Furthermore, for any 'offshore transmission', it will then be necessary to establish which of those assets are radial and which of those assets are non-radial in line with Ofgem's recent minded-to decision on offshore delivery models.[16] This is because there are expected to be different arrangements for the delivery of radial offshore transmission assets within the HND than there are for non-radial offshore transmission assets within the HND.[17]

16 ofgem.gov.uk/publications/minded-decision-and-further-consultation-pathway-2030 - for Ofgem's definitions of radial and non-radial see 1.14 -1.16 of the Minded-to Decision.

17 Ofgem's minded-to decision on offshore delivery models for Pathway to 2030 does not apply to the Celtic Sea and the organisation carrying out the DND onwards in the Celtic Sea will be determined at a later date.

Introduction

In July 2020 the Energy Minister launched the Offshore Transmission Network Review (OTNR). The objective of the OTNR is “to ensure that the transmission connections for offshore wind generation are delivered in the most appropriate way, considering the increased ambition for offshore wind to achieve net zero. This is with a view to finding the appropriate balance between environmental, social and economic costs.” The OTNR is led by the Department for Business, Energy and Industrial Strategy (BEIS) with support from a range of UK Government and industry bodies. The ESO and a number of other organisations are project partners. More information on the OTNR and the project partners can be found on BEIS’s website.[18]

In November 2020 the UK Government published its *Ten Point Plan for a Green Industrial Revolution*[19], which makes clear that offshore wind is a critical source of renewable energy for the UK’s growing economy. In this plan the UK Government expressed its ambition to quadruple its offshore wind capacity by 2030 to 40 GW and achieve net zero greenhouse gas emissions by 2050. In the *British Energy Security Strategy* (*BESS*)[20], published April 2022, the UK Government increased its ambition for offshore wind to 50 GW by 2030. Alongside this the Scottish Government has an ambition for 11 GW offshore wind by 2030 and net zero greenhouse gas emissions by 2045.

To help realise these targets, a step change in both the speed and scale of deployment of offshore wind is required. The onshore and offshore transmission networks play a crucial role in making this happen. They need to change and grow in a way that is efficient for consumers and considers impacts on communities and the environment. Since the beginning of the OTNR, we have been playing a key role in actively assessing whether there is a better approach to planning offshore networks. We are committed to delivering better outcomes for consumers and communities and supporting delivery of the UK Government’s net zero ambitions.

18 https://www.gov.uk/government/groups/offshore-transmission-network-review
19 gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution
20 gov.uk/government/publications/british-energy-security-strategy

Introduction

In December 2020 we concluded there is significant benefit to coordination

In December 2020 we published a report[21] on the costs and benefits of a more coordinated approach to connecting offshore wind and interconnectors compared to the current radial connection approach. With a radial approach, wind farms have individual connections to the main transmission network. These individual connections are designed independently from the onshore network, which transports electricity around the country. We confirmed there is significant benefit in moving quickly to an integrated network in which the onshore and offshore networks are coordinated to optimise the investment across the two and balance the design objectives. The analysis also suggested it is important to consider what flexibility there is for coordination between 2025 and 2030.

21 nationalgrideso.com/document/183031/download

Introduction

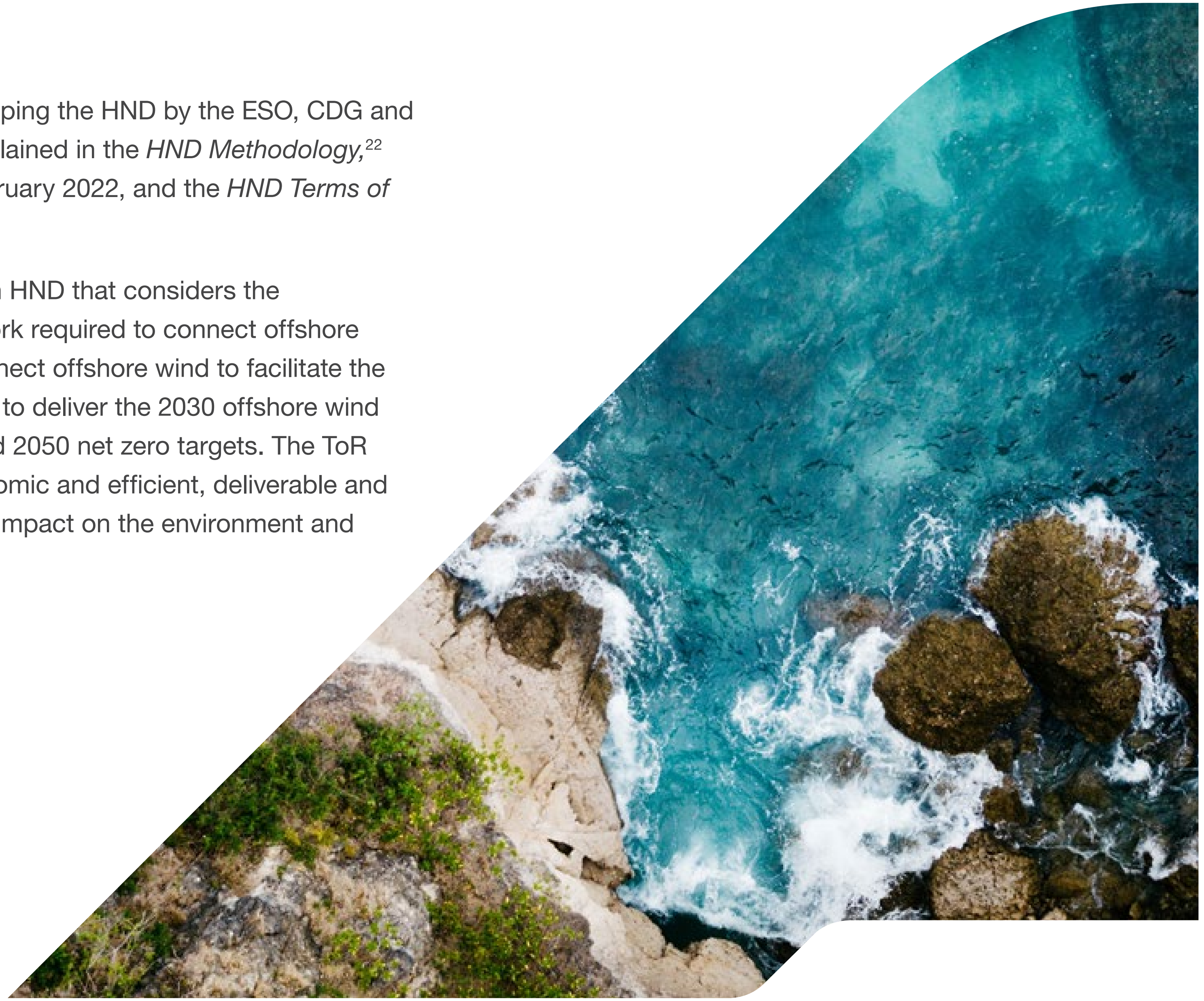
The Holistic Network Design is delivered in consultation with the Central Design Group and governed by terms of reference

Following the December 2020 publication, BEIS and The Office of Gas and Electricity Markets (Ofgem) requested that we deliver an HND, in consultation with the Central Design Group (CDG). This group was set up in 2021, to establish and support our development of the HND and to ensure stakeholder views were considered in the design. The purpose of the CDG is to act as a vehicle for us to consult and collaborate with TOs on the HND, and to consult with stakeholder groups as the HND is developed.

The CDG is chaired by the ESO with the Transmission Owners (TOs) and the ESO as members. BEIS, Ofgem and the Scottish and Welsh Governments are observers.

The specific roles for developing the HND by the ESO, CDG and the CDG subgroups are explained in the *HND Methodology,*[22] which was published in February 2022, and the *HND Terms of Reference* (*ToR*).[23]

The ToR ask us to deliver an HND that considers the onshore and offshore network required to connect offshore wind. This is in order to connect offshore wind to facilitate the pace and certainty required to deliver the 2030 offshore wind ambitions, and the 2045 and 2050 net zero targets. The ToR require the HND to be economic and efficient, deliverable and operable, and minimise the impact on the environment and local communities.



22 nationalgrideso.com/document/239466/download
23 assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1059676/otnr-central-design-group-network-design-tor.pdf

Introduction

Stakeholder engagement and feedback has been key in developing the Holistic Network Design

We have worked in collaboration with a wide range of stakeholders who have challenged, shaped and informed the proposals to help deliver the HND. Our *Stakeholder Approach, Engagement and Feedback Report* contains the view of developers, environmental and community stakeholders, as far as appropriate and reasonably practicable, in developing the HND. This is in line with the requirements of the ToR.

We have taken a collaborative approach to our stakeholder engagement. Whilst we did not undertake a formal consultation, bespoke engagement, including a feedback window on draft recommended designs, has been carried out with a targeted group of stakeholders. There will be the opportunity for wider consultation as part of the consenting process when projects reach the Detailed Network Design (DND) phase and more specific locations are developed for the various elements of the network infrastructure.

When developing the offshore design and interface sites for the HND, we assessed community constraint information and previous feedback provided by community stakeholders on the principles that should be followed when assessing interface sites for connection. This information is summarised in the Holistic Network Design document for the recommended design. Input from community stakeholders will be essential at the DND stage. We expect this to include engagement while plans are developed, as well as statutory consultation periods during the planning process.

The OTNR partners consist of:

BEIS, The Crown Estate, Crown Estate Scotland,
The Department for Environment, Food and Rural Affairs (Defra),
The Scottish Government, The Marine Management Organisation, The Department for Levelling Up, Housing and Communities, Ofgem, The Welsh Government and the Electricity System Operator. The following summary shows the extent of collaboration during the development of the HND:

Engagement with TOs:

86 ESO/TO meetings (including CDG),
06 Commercial and
12 Stakeholder and Communication subgroup meetings.

Offshore wind farm developers:

114 bilateral meetings,
02 Offshore Developer forums and
01 Offshore Developer Celtic Sea forum.

CDG Environmental subgroup:

06 meetings,
05 workshops

Responses received on the draft design recommendations:

41 responses from offshore wind developers, environmental stakeholders, TOs and OTNR project partners.

A variety of additional bilateral meetings with OTNR partners and environmental subgroup members were also held.

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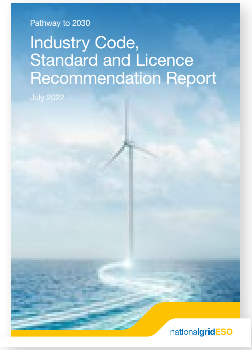
Navigating this suite of documents

The HND recommends the optimal transmission network based on the four design objectives to both connect the offshore wind farms to the transmission network and transport their power to where it is needed. This summary report sets out key messages from the following more detailed documents:

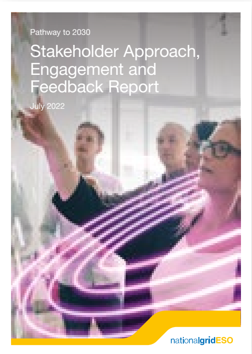
1. The ***Holistic Network Design*** sets out all of the network requirements to facilitate connection of the in scope offshore wind projects. This includes the offshore transmission network, the onshore works directly required to facilitate each connection and the network needed to transport the electricity around the country. It also includes two Appendices: 1) Comprehensive List of Onshore and Offshore Network Recommendations, including connections, enabling works and wider works and 2) Environment and Community Appraisal Summary.
2. The ***Industry Code, Standard and Licence Recommendation Report*** sets out our current view on the changes that need to be made to codes, standards and licences to enable delivery of the HND.
3. The ***Stakeholder Approach, Engagement and Feedback Report*** outlines the feedback we have received from our stakeholders and how that has shaped our recommendations.
4. The ***HND Methodology*** provides an overview of how we have delivered the HND and its building blocks, which was published in February 2022.[24]
5. The ***Network Options Assessment (NOA) 2021/2022 Refresh**** publication updates the *NOA 2021/22*, published in January 2022, by taking into account the offshore network design elements of the HND. It confirms the wider onshore network requirements that are set out in the HND against the established *NOA Methodology* and when they will be required. It also includes recommendations on onshore reinforcement projects that go beyond those required to meet the 2030 ambitions.
6. The ***Glossary*** explains the more technical terms used across the suite of documents.

Alongside this suite of documents, updates have been provided on coordination opportunities as part of the Early Opportunities workstream by the Department for Business, Energy and Industrial Strategy (BEIS) and organisations exploring the potential for offshore coordination as part of that workstream.

Holistic Network Design



Industry Code, Standard and Licence Recommendation Report



Stakeholder Approach, Engagement and Feedback Report

Methodology

*Network Options Assessment 2021/2022 Refresh**

Glossary

*The *NOA 2021/22 Refresh* publication is a standalone document that is represented here for completeness.

24 nationalgrideso.com/document/239466/download

Navigating the HND reports

The HND recommends the optimal transmission network based on the four design objectives to both connect the offshore wind farms to the transmission network and transport their power to where it is needed. This summary report sets out key messages from the following more detailed documents:

The Methodology provides an overview of how we have delivered the HND and its building blocks, which was published in February 2022.

The Glossary explains the more technical terms used across the suite of documents.

PATHWAY TO 2030: A HOLISTIC NETWORK DESIGN TO SUPPORT OFFSHORE WIND DEPLOYMENT FOR NET ZERO

1 HOLISTIC NETWORK DESIGN

- **KEY MESSAGES** 5 minute read
- **DESIGN OVERVIEW AND REGIONAL SUMMARY** 20 minute read
- **FULL DETAILED REPORT** 1hr + read, Appendix 1 Appendix 2

2 INDUSTRY CODE, STANDARD AND LICENCE RECOMMENDATION REPORT

- **KEY MESSAGES** 5 minute read
- **SUMMARY OF FINDINGS** 20 minute read
- **FULL DETAILED REPORT** 1hr + read

3 STAKEHOLDER APPROACH, ENGAGEMENT AND FEEDBACK REPORT

- **KEY MESSAGES** 5 minute read
- **SUMMARY OF FINDINGS** 20 minute read
- **FULL DETAILED REPORT** 1hr + read

4 NETWORK OPTIONS ASSESSMENT 2021/22 REFRESH

- **KEY MESSAGES** 5 minute read
- **SUMMARY OF FINDINGS** 20 minute read
- **FULL DETAILED REPORT** 1hr + read
- Includes recommendations on onshore reinforcement projects that go beyond those required to meet the 2030 ambitions

Navigating the HND reports

PATHWAY TO 2030: A HOLISTIC NETWORK DESIGN TO SUPPORT OFFSHORE WIND DEPLOYMENT FOR NET ZERO

1 HOLISTIC NETWORK DESIGN

The **Holistic Network Design** sets out all of the network requirements to facilitate connection of the in scope offshore wind projects. This includes the offshore transmission network, the onshore works directly required to facilitate each connection and the network needed to transport the electricity around the country. It also includes two Appendices: 1) Comprehensive Onshore and Offshore Network Recommendations, including connections, enabling works and wider works and 2) Environment and Community Appraisal Summary.

2 INDUSTRY CODE, STANDARD AND LICENCE RECOMMENDATION REPORT

The **Industry Code, Standard and Licence Recommendation Report** sets out our current view on the changes that need to be made to codes, standards and licences to enable delivery of the HND.

3 STAKEHOLDER APPROACH, ENGAGEMENT AND FEEDBACK REPORT

The **Stakeholder Approach, Engagement and Feedback Report** outlines the feedback we have received from our stakeholders and how that has shaped our recommendations.

4 NETWORK OPTIONS ASSESSMENT 2021/22 REFRESH

The **Network Options Assessment 2021/2022 Refresh** that updates the *NOA 2021/22*, published in January 2022, by taking into account the offshore network design elements of the HND. It confirms the wider onshore network requirements that are set out in the HND against the established *NOA* methodology and also when they will be required. It also includes recommendations on onshore reinforcement projects that go beyond those required to meet the 2030 ambitions.

A summary of the Holistic Network Design

A summary of the Holistic Network Design

The Holistic Network Design combines coordinated solutions and radial solutions to maximise benefits and support delivery of 2030 offshore wind ambitions.

What is the Holistic Network Design?

The purpose of the HND is to provide a recommended onshore and offshore design for a 2030 network that can facilitate the UK Government ambition for 50 GW of offshore wind in Great Britain by 2030. In line with the ToR, the HND connects 23 GW of offshore wind, which combined with the existing and planned offshore wind projects that are out-of-scope of the HND, facilitates up to 50 GW by 2030. The HND aims to provide an economic, efficient, operable, sustainable, and coordinated National Electricity Transmission System (NETS) including the onshore and offshore transmission network required to connect offshore wind and transfer power to where it is needed. The HND is informed by the Network Options Assessment (NOA), which identifies the wider network reinforcements needed to improve the capability of the network. The *NOA 2021/22* publication has been refreshed to integrate the offshore network design and provide an updated view on the required onshore network reinforcements necessary to produce the HND. It assesses options required not only to meet our 2030 targets, but also those beyond 2030 to enable the transition to net zero. The HND has been delivered by the ESO in consultation with the CDG. The onshore TOs have played a key role in the process, by identifying onshore interface options and providing options and cost estimates for wider network reinforcements.

The HND covers the following future offshore wind projects:

- A total of 8 GW of projects successful in The Crown Estate Offshore Wind Leasing Round 4[25] (referred to as R4_X within this report, with X representing numbers used to refer to individual projects).
- A total of 11 GW of projects successful in the ScotWind leasing round,[26] with capacity located in each of the leasing zones (referred to as SW_X, with the letters W (west), N (north), E (east) and NE (north east) denoting the respective leasing zones).
- Assumptions on 1 GW of floating wind from the upcoming Celtic Sea leasing round[27] (notional projects referred to as CS_FW_X).
- 3 GW of other sites that are located near to Round 4 and ScotWind sites, to test whether there are opportunities for coordination (referred to as PA_X).

The ScotWind leasing round awarded seabed leases that allow for almost 25 GW of offshore wind, significantly exceeding the capacity assessed in the Scottish Government's Sectoral Marine Plan[28] of up to 10 GW. This capacity in Scotland surpassed the assumptions in the *Future Energy Scenarios 2021* that were used to inform the outputs of the *NOA 2021/22*, and which served as an input to the HND.

Initial enquiries with developers successful in the ScotWind leasing round helped us confirm the information we required on each project and build on the publicly available information from Crown Estate Scotland. After careful consideration of multiple options, and in consultation with OTNR stakeholders, we determined that the appropriate approach was to ensure the *HND* is published in July 2022 as planned, while delivering connection plans for at least one project located in each of the Crown Estate Scotland seabed leasing zones. For those ScotWind projects that will be subject to a follow up network design process, we are committed to establishing a plan to provide certainty on their connection locations and dates as soon as practically possible, with the aim of completing this process by the end of March 2023.

25 thecrownestate.co.uk/en-gb/what-we-do/on-the-seabed/offshore-wind-leasing-round-4/
26 crownestatescotland.com/news/scotwind-offshore-wind-leasing-delivers-major-boost-to-scotlands-net-zero-aspirations
27 thecrownestate.co.uk/en-gb/what-we-do/on-the-seabed/energy/floating-offshore-wind/
28 gov.scot/publications/sectoral-marine-plan-offshore-wind-energy/documents/

A summary of the Holistic Network Design

The recommended Holistic Network Design

The result of the HND process is a design that:

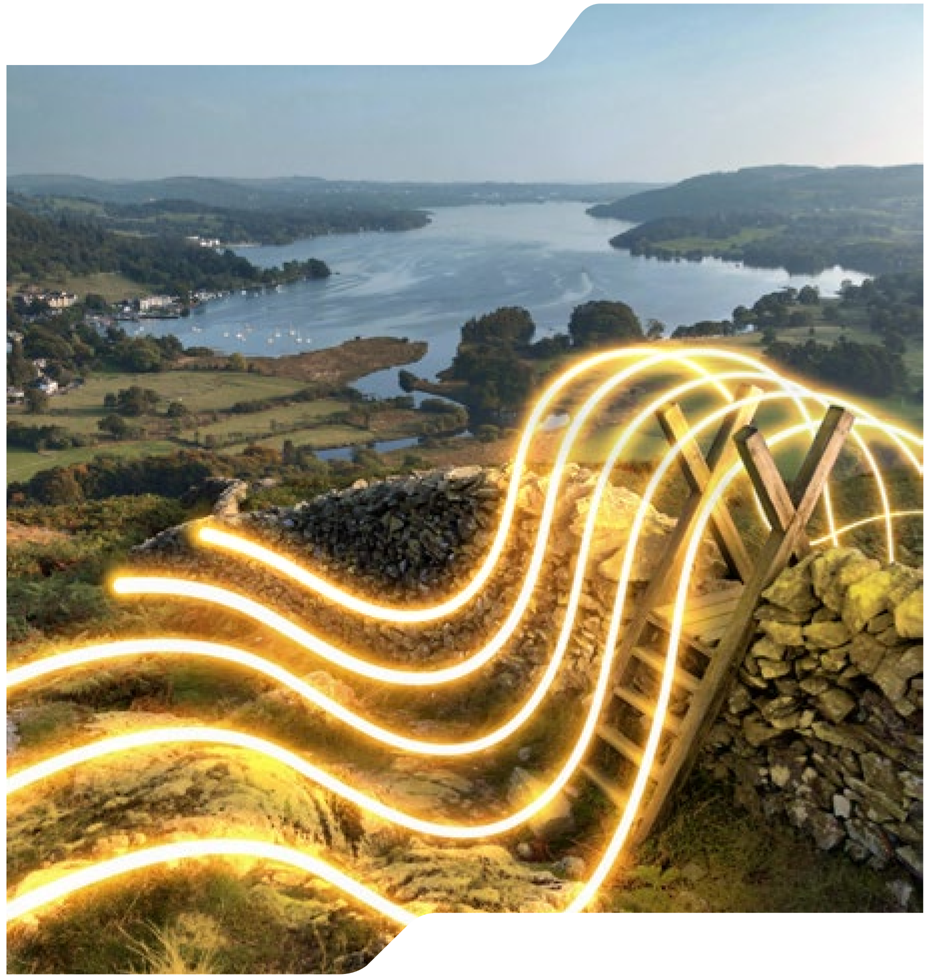
- Connects all 18 in scope offshore wind farms (with a total capacity of 23 GW) to the onshore network.
- Includes regions of strong coordination, and regions where radial connections are favourable.
- Has 15 landing points to shore.
- Establishes new offshore connections between different onshore regions to transfer power and avoid bottlenecks on the network, particularly between west Scotland and north Wales, as well as between east Scotland and the east of England.
- Identifies and clearly distinguishes onshore transmission projects that are required to facilitate the 2030 ambitions to allow the power to be transported to where it is needed.
- Identifies 11 onshore transmission projects that are required for 2030 but where a business-as-usual approach would result in delivery after 2030.

The technology recommended in the offshore design includes:

- 275 kV high voltage alternating current (HVAC) offshore substations and cables.
- 10 new, 525 kV high voltage direct current (HVDC) circuits with HVDC converter stations, offshore substations and cables.
- Two new multi-terminal HVDC systems.

The use of HVDC over HVAC connections is determined by the distance to the onshore interface points,[29] although some shorter HVDC corridors are included for operability and deliverability reasons.

The HND can deliver overall net consumer savings of approximately £5.5 billion compared to an optimised radial design. The recommended design requires an additional investment of £7.6 billion in additional offshore infrastructure, but this cost is outweighed by the £13.1 billion savings in constraint costs that are expected to result from the additional network capacity this infrastructure provides.



29 With increasing cable length, the effective capacity of HVAC cables to transmit real power reduces due to increased reactive power and losses increase. With HVDC cables, there is no transmission of reactive power, and losses increase more moderately with increasing distance.

A summary of the Holistic Network Design

Based on the assumptions used in our economic modelling, the costs of the offshore network infrastructure required in the recommended design would be around £32 billion. This compares to around £24.4 billion for the optimised radial design (giving the differential of £7.6 billion). These costs are based on high level assumptions, and we would expect them to change during the DND stage as routing and technology choices are decided. These costs relate to connecting the 23 GW of offshore wind which is in scope of the HND. The total cost of onshore infrastructure recommended between now and 2030 is £21.7 billion across 94 projects. These costs relate to the full set of onshore network reinforcements required to connect 50 GW of offshore wind by 2030.[30]

The HND builds upon previous recommendations

The HND is made up of a number of individual recommendations for the development of the onshore and offshore networks. These recommendations are expressed in terms of a need to be able to transmit power from one point to another, whether that is offshore, onshore or a combination of the two. Each of these recommendations needs to be considered carefully, designed in detail, and developed subject to the applicable planning and consenting processes.

Many of the HND's system-wide recommendations have been highlighted previously through our NOA process, where their description, driver and status is reassessed and published annually. New proposals for reinforcing the transmission system start with an initial assessment of early options submitted into the NOA. Following recommendations to 'proceed,' these projects are progressed and developed in more detail by the TOs. Some of these projects are now sufficiently advanced in development to have been shared with affected stakeholders and local communities.

30 The £54 billion referred to in related communications is made up of the £32 billion for the recommended offshore design and £21.7 billion for the onshore design, rounded to £22 billion.

A summary of the Holistic Network Design

When considering the development of the transmission system, smaller, incremental reinforcements utilising existing assets are considered first. This begins with reduced and no build options such as commercial arrangements to manage flows on the network, followed by increasing the capability of existing assets. Once these options are exhausted, new reinforcement options must be considered. These include the construction of new transmission assets, or longer subsea cables to provide power transfer capability over greater distances. Figure 1 illustrates the transmission network development journey highlighting upgrades to existing assets in dark grey with proposed new onshore transmission assets in purple and new subsea network reinforcements in light green.

Those recommendations that have been identified as necessary previously are shown in **Figure 1**.

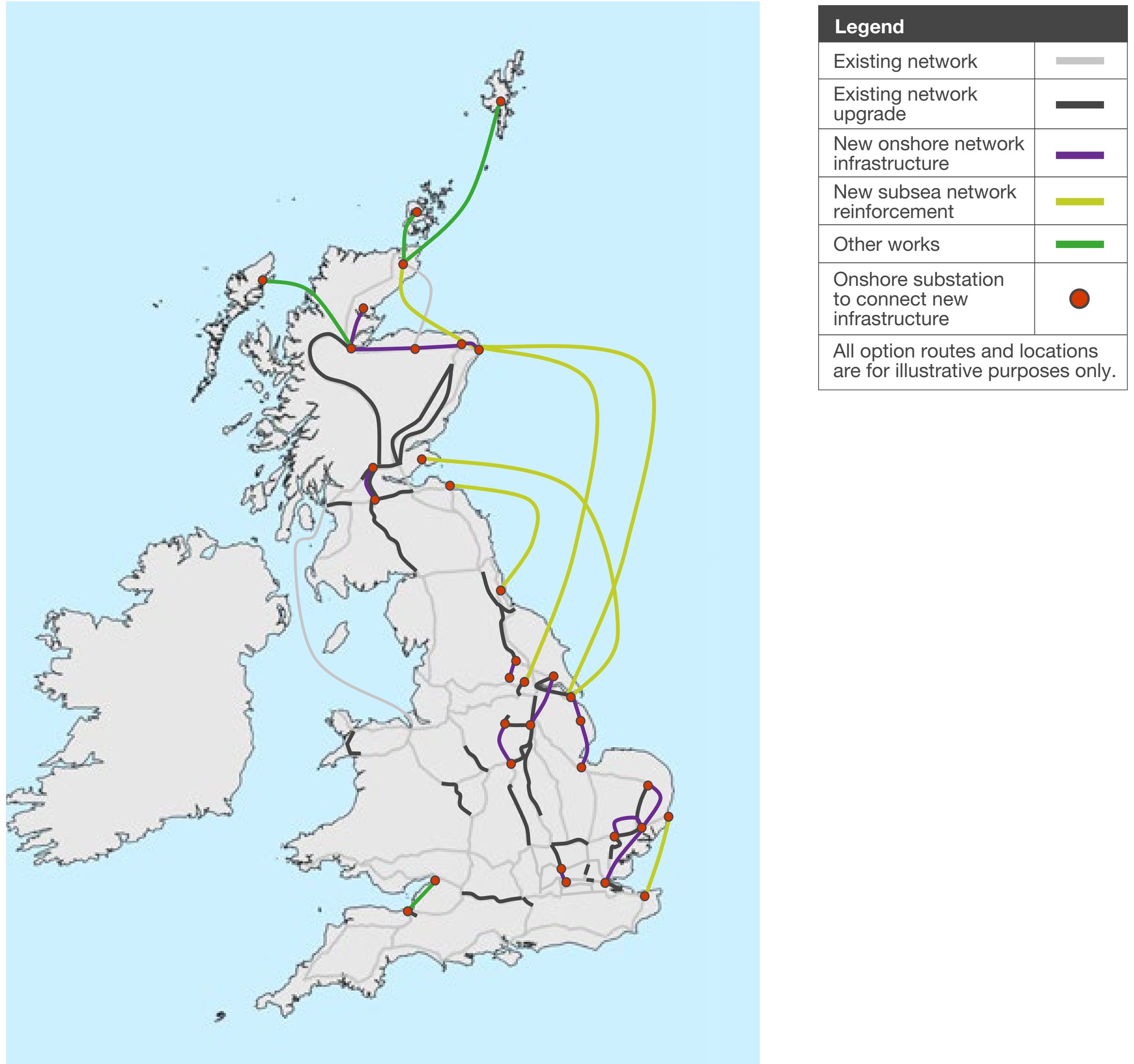


Figure 1: Those recommendations that have been identified as necessary previously.

Please note: The map is illustrative and highlights an identified need to transmit volumes of energy from point A to point B and does NOT represent specific routes. The next steps involve more detailed network design which will include specific locations and designs for projects. These will be designed and consulted on in future by the organisations appointed to fulfil the needs identified.

A summary of the Holistic Network Design

New network needs identified through the HND

Through the HND process we have developed a coordinated offshore network design. This design provides a greater level of coordination between offshore wind farms, optimising the number of landing points. In addition, we have recommended that some offshore wind farms connect further south than would have otherwise been considered through our usual connections approach. This coordination results in different power flows on the onshore network, driving some newly identified network needs.

These new network needs are illustrated in **Figure 2**. The HND has identified new needs for network located offshore, as well as three new requirements which build on the existing network and on previously planned development. These new network needs have not been previously published, unlike the other planned network reinforcements, which have been regularly assessed and documented in our NOA process.

These new network needs are still in the early stages of development and were assessed in the HND via the *NOA 2021/22 Refresh*, which has recommended the continued development of options with similar capabilities. As these options have been shown to provide significant benefit, further detailed design assessments will need to be undertaken by the relevant Transmission Owner to ensure a solution which balances the needs of the electricity system, environment and cost to energy consumers is taken forward. This will include exploring many different route options, including onshore, offshore or a combination of both. The selected option will then be taken forward to public consultation by the relevant TO as part of detailed design and consenting.

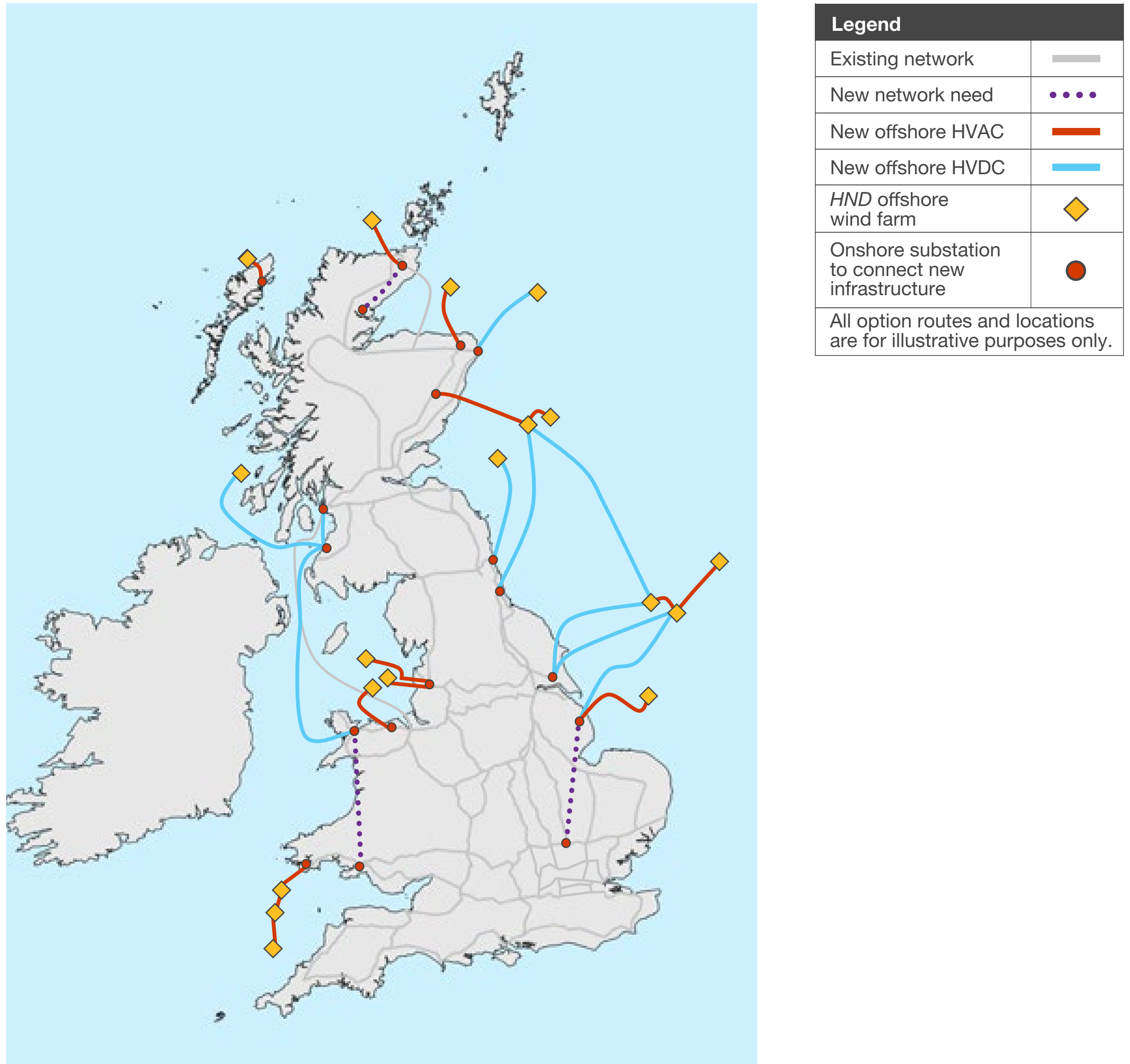


Figure 2: The new network needs identified through the HND.

Please note: The map is illustrative and highlights an identified need to transmit volumes of energy from point A to point B and does NOT represent specific routes. The next steps involve more detailed network design which will include specific locations and designs for projects. These will be designed and consulted on in future by the organisations appointed to fulfil the needs identified.

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A summary of the Holistic Network Design

Overall HND view of the system

Figure 3 shows the final HND, highlighting key onshore transmission system upgrades alongside the recommended offshore design required to facilitate the connection of 50 GW of offshore wind by 2030. This provides a combined view of previously identified transmission reinforcements paired with those newly recommended as a part of the HND, outlining what is required to meet the Government offshore wind targets.

The map illustrates upgrades to the existing transmission system in dark grey, new onshore transmission reinforcements and subsea cables previously recommended in NOA in purple and light green respectively. New network needs are shown as dotted purple lines and the coordinated offshore network in red and blue, representing the type of technology proposed.

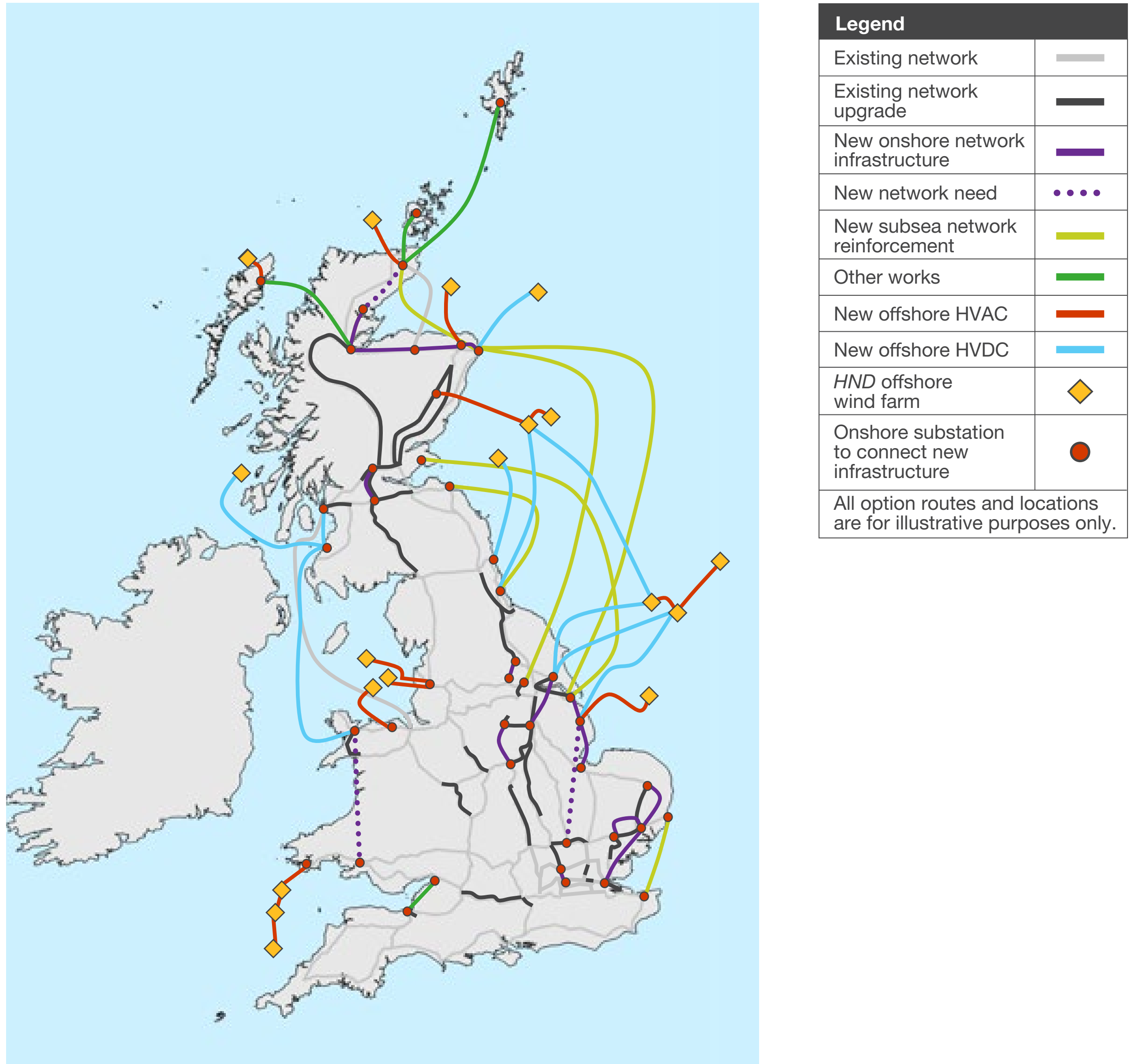

Figure 3: The full set of major network requirements recommended by the HND.

Please note: The map is illustrative and highlights an identified need to transmit volumes of energy from point A to point B and does NOT represent specific routes. The next steps involve more detailed network design which will include specific locations and designs for projects. These will be designed and consulted on in future by the organisations appointed to fulfil the needs identified.

A summary of the Holistic Network Design

Our recommended design offers significant benefits compared to an optimised radial design:

Economic and efficient[31]

The recommended design is forecast to provide a net saving of £5.5 billion to consumers through more efficient network development, leading to reduced operational costs when compared to the optimised radial design.

The recommended design has an additional investment cost of £7.6 billion in offshore network assets relative to the optimised radial design. However, this is offset by the improved network power flow capacity it provides which significantly lowers the costs associated with curtailing and re-dispatching generation by £13.1 billion.

The costs and scope of onshore boundary reinforcements are broadly comparable between the two designs. It is important to recognise that this is partly because there is a limit to the amount of boundary reinforcement that can be delivered in the lead up to 2030, which is due to the time taken to deliver large scale infrastructure projects, as well as other factors including supply chain capacity. This means that our assessment had a finite set of options to choose from. However, if these delivery constraints were removed and more network reinforcement options were available, the recommended design would reduce the requirement to invest in further onshore infrastructure. This is demonstrated through the significant reductions in constraint costs the recommended design provides compared to the radial alternative.

Deliverable and operable

The design is deliverable and operable, and provides the opportunity for wind farms to be able to connect by 2030. The longer, and more complex, links in the design are unlikely to be complete by 2030 in the absence of major acceleration in the supply chain. However, the design offers the potential to get generation connected by 2030, and increase capacity progressively, given timely allocation of responsibilities, delivery of the commitments in the *BESS* and a coordinated and concerted effort from all parties. Our analysis has not identified any significant operability challenges, although the DND will explore this further. The timings and required works for each connection will be determined as part of the connection contract update programme.[32]

31 We have used standard cost-benefit analysis (CBA) assumptions within our economic analysis: The onshore assets are amortised over an assumed asset life of 40 years. The offshore asset capital expenditure (CAPEX) is assumed to be gradually written off over 25 years, but many benefits exist for 40 years.
32 More information on the connection contract update programme can be found in the What happens next section on page 69.

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A summary of the Holistic Network Design

Cost categories

We have investigated three cost categories as part of the economic assessment and the total cost difference between the recommended design and optimised radial design is calculated by adding together the differentials across these categories:

- **New offshore/onshore capital and operational costs:** The cost of constructing and operating all offshore assets to connect the generators to the system, plus any onshore works required to connect in a manner compliant with relevant standards that are not NOA works. The costs of new offshore transmission network infrastructure are based on component unit costs derived from data provided by equipment suppliers. The input cost assumptions have been provided to in scope developers and OTNR stakeholders.
- **Boundary reinforcement costs identified through the NOA:** The cost of construction works that are required for the connection of the generators and/or boundary reinforcement, which have previously been included in a NOA assessment. These costs are broadly comparable between all options considered.
- **Constraint costs:** The cost of taking balancing actions to redispatch generation to prevent unacceptable network flows across parts of the network that have limited capacity. These consist of actions to decrease generation output in one part of the country, and actions to increase generation output in a different part of the country.

A summary of the Holistic Network Design

Technology required and its readiness

Our designs are made up of multiple pieces of equipment which link together to form a network. The equipment performs one of two broad functions, either to form a junction point for the network at a substation or to provide the long links between substations. Any offshore design will need platforms to carry substation equipment and will use cables to provide the links between them. Our design includes HVAC and HVDC assets that are proven technology:

HVAC assets:

- Subsea Alternating Current (AC) cables of voltage level up to 275 kV. These are commercially available from multiple suppliers and can achieve up to 500 MW of power transfer in a single 3-phase bundle. Higher power transfers can be achieved by using multiple cable bundles laid in parallel, for example a 1.5 GW AC connection could be designed using three parallel 500 MW AC cables. This takes up significant space as the cable bundles need to be spaced apart, potentially increasing environmental impacts.
- Offshore AC substations, of compact gas-insulated switchgear (GIS) design. Its functionality should allow circuit selection, maintenance access and fault disconnection. These are commonly used onshore and have also been constructed offshore. Considering the current level of experience of suppliers this is expected to be feasible.
- Onshore AC substations, which are part of the offshore transmission system needed to interface with the existing onshore network and provide the necessary switching and isolation facilities. These are commonly used and commercially available.
- HVAC circuit breakers. These are of a conventional design and are commercially available.
- Reactive power compensation. The power transmission capacity of AC submarine cables is limited by capacitive charging currents. To counteract this, reactive power compensation must be added. For short cables less than 100 km this can be kept to the ends of the cable, but longer cables require additional mid-point compensation. Reactive compensation installation onshore is common but less so offshore and extra platforms to host reactive power compensation may be needed on long offshore routes. Multiple suppliers of reactive compensation are available.

HVDC assets:

- Subsea Direct Current (DC) cables with a voltage level up to 525 kV. The HVDC circuits need a pair of HVDC cables, a positive and a negative cable. In most instances the pair of cables can be bundled and laid together, which minimises seabed disruption. For some HVDC circuits, larger than 1.8 GW, the cables need to be separated and an extra metallic return conductor added, so that a fault will not disconnect the whole HVDC circuit. Due to limitations on the availability of large capacity cables, the largest HVDC circuit used in the designs is 2 GW. 525 kV XLPE cables are now commercially available from several suppliers and are in the process of being delivered worldwide for multiple projects although none are yet operational.
- Offshore DC converters built onto an offshore platform with AC interface at 275 kV for meshed offshore network or AC interface at 66 kV for direct windfarm interface. Dependant on size and security needs, the converters may be of bipole or symmetric monopole design. Installations of offshore platforms using 320 kV HVDC are already in operation but none yet at 525 kV, although multiple countries have them planned for operation by 2030. A small number of suppliers are available.
- Onshore DC converters to interface with the onshore transmission network. The type needs to be consistent with that used at the other end. A small number of suppliers are available.
- HVDC isolators to allow offline disconnection of DC cable sections following fault or for maintenance. The design does not include HVDC circuit breakers, as we do not believe the technology will be mature enough to use until at least 2035. As a result of using isolators instead of circuit breakers, if there is a fault in a multi-terminal DC link, all ends will go offline.

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A summary of the Holistic Network Design

Environmental impact

The nature of the infrastructure required means the HND cannot be without impact. However, careful consideration has been given to the design to minimise cumulative environmental impacts.

The total length of cable corridors in the recommended design is slightly higher than in the radial design, as the radial design only considers infrastructure required to connect wind farm generation to the onshore network. The recommended design includes infrastructure to transfer power from north to south, not just from the point of generation to the onshore network. This infrastructure is required to transfer electricity from where it is generated to where it is needed. Without this infrastructure, zero carbon wind energy would be constrained off and typically higher carbon, fossil fuelled generation would be needed instead with additional energy security impacts. The coordinated design therefore saves 2 million tonnes of CO_2 between just 2030 and 2032.

In addition, the coordinated design reduces the total number of cables being laid to shore by up to a third due to the use of HVDC technology, reducing the impact on the seabed.

The design takes account of environmental constraints[33] and seeks to minimise the impact on sensitive habitats through the coordination of wind farm connections to shore. Cable route corridors can avoid many of the identified environmentally sensitive features, however this is not possible in all cases. Further consideration will need to be given to cable routing in the DND stage to minimise environmental and consenting risks. While the environmental mitigation hierarchy should be followed, it is likely that environmental compensation measures will be required, assuming no viable alternatives are identified in the DND stage. This might include measures at a regional or national level. However, in the first instance, measures to alleviate pressures on and protect sensitive habitats both within and outside Marine Protected Areas (MPAs) should be considered, and compensation seen as a last resort.

The environmental impacts of both onshore and offshore works are discussed further in the *HND* report.

Community impact of offshore cable routes

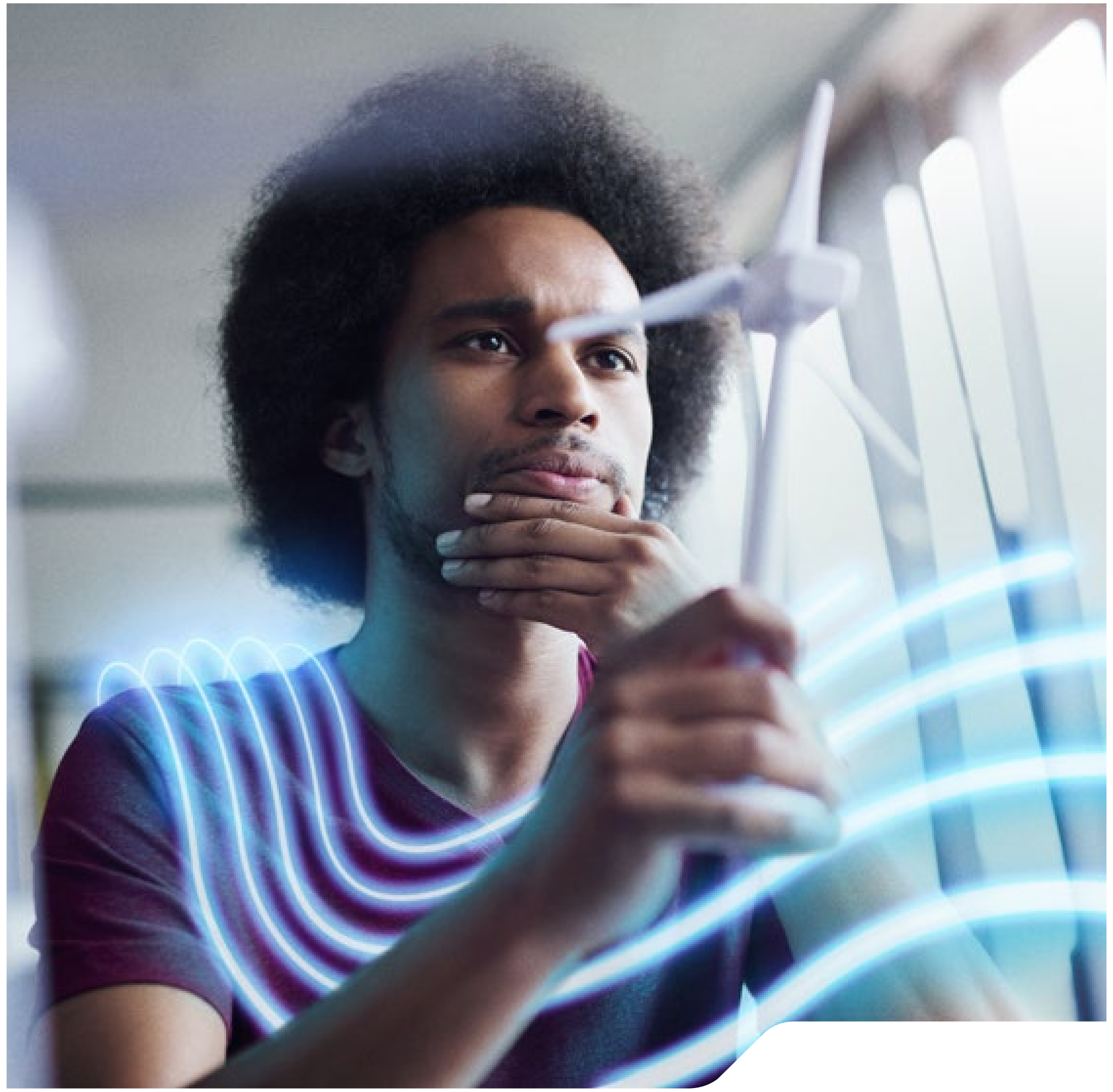
The design takes account of community constraints. It minimises the impact on local communities, for example, in relation to the volume of transmission network infrastructure in some areas, the cumulative impact associated with multiple connections, and onshore transmission reinforcements that are driven by the offshore network. There is also the potential for the route corridors to avoid many of the identified community constraints; specific route corridors will be defined as part of the DND.

A summary of the Holistic Network Design

Our approach to developing the design

We have developed a design approach for the HND that is tailored to achieve the following design objectives.

The objective	Our approach
Is economic and efficient	We used **economic assessment tools** to determine the optimal economic design from a range of proposed design options.
Is deliverable and operable	We applied a **deliverability assessment framework** that considered a range of factors including supply chain of technologies, construction timeframes, and consenting challenges.
Considers impact on environment	We conducted **assessments of environmental constraints** using a range of geospatial data sources to determine the location and the sensitivity of environmental constraints. We did this in consultation with Statutory Nature Conservation Bodies (SNCBs) through the CDG Environmental subgroup.
Considers impact on communities	We conducted **assessments of community constraints** using a range of geospatial data sources to determine the location and the sensitivity of community constraints.



A summary of the Holistic Network Design

The HND design approach is based on six building blocks:

1 Objectives and data

The **design objectives** (economic and efficient, deliverable and operable, minimising impact on environment and communities) were set by the OTNR project board.

The main scenario **data** used was an adaptation of the "Leading the Way" scenario from the 2021 Future Energy Scenarios.

2 Design options

Establishing the **design options** entailed mapping the study areas that jointly cover all in-scope wind farms, identifying technologies, and locating potential grid interface points.

Subsequently, we conducted a **high level appraisal** of options, against the objectives, to remove non-feasible options.

3 Initial strategic appraisal

We determined feasible cable route corridors between wind farms and interface sites. We carried out an **initial appraisal of these options against the HND objectives.**

This led us to develop a set of **radial and coordinated design options** which we took forward to more detailed assessment.

This was an **iterative process,** with the outputs of economic assessment leading to additional design options being developed.

4 Economic assessment

For each option, the economic assessment takes account of the costs of offshore transmission infrastructure, the costs of relevant onshore works, and the costs of redispatching generation due to network constraints. This allowed us to determine how each option performed from an economic perspective.

5 Final strategic appraisal

In the final appraisal we evaluated the performance of the designs against all four HND design objectives.

In this step the **final recommended design for the offshore network** was produced, based on a best fit against all design objectives.

6 Refresh network options assessment

The NOA process identifies onshore grid reinforcements to resolve network issues and recommends which should be taken forward.

This process was re-run with the recommended design for the offshore network used as an input. This is the NOA refresh process.

The output is a **fully optimised set of onshore reinforcement recommendations** that complement the recommended offshore design.

Final HND

The final Holistic Network Design consists of a recommended **offshore network design** and an updated **onshore network design.**

Stakeholder Engagement

Stakeholders were engaged throughout execution of the HND. We established a Central Design Group, consisting of representation from key stakeholders, including the onshore transmission owners (National Grid Electricity Transmission, SP Transmission, Scottish and Southern Electricity Networks - Transmission). This group was supplemented by four subgroups, where we received expert input and formal advice on specific elements of the design: (1) stakeholder and communications subgroup (2) commercial subgroup (3) environmental subgroup, (4) developer forum.

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A summary of the Holistic Network Design

The first step in our process was to establish an input dataset and use it to inform a series of steps developing potential designs. This dataset included the offshore wind generation in scope for the HND, the Leading the Way scenario from the 2021 Future Energy Scenarios, a model of the transmission network for 2030, and environmental and community constraint data. We considered options for potential interface sites - the locations where we expect offshore cables to link to the onshore network - and assessed them against our design objectives. This process allowed us to narrow down our options and take account of the design objectives early in the process by considering the relative costs and environmental and community impacts of work at a range of locations. We then developed an optimised radial design, which consists of point-to-point connections between offshore wind farms and onshore interface points. The approach used takes into consideration all in scope wind generation, rather than considering each application individually as has previously been done. This provides a credible counterfactual against which to compare our recommended design which was developed in the next step.

In developing radial and coordinated design process, we considered various types of environmental and community constraints:

- Environmental constraints, including: special areas of conservation (SAC), special protection areas (SPA) (related to wild birds), sites of special scientific interest (SSSI), marine conservation zones (MCZ), sensitive habitats, reefs and sandbanks.
- Community constraints, including:
    - Onshore: major settlements and urban areas, heritage coasts, bathing areas, registered parks and gardens, scheduled monuments and listed buildings.
    - Offshore: shipwrecks, sailing areas, existing and planned offshore wind farms, fisheries, military areas, and oil and gas wells.

Both offshore and onshore constraints were analysed and divided into categories that signify the degree of constraint: black, red, amber, and green (BRAG).

For onshore works, Transmission Owners assessed the environmental and community impacts in line with their respective project development process. Onshore projects are at various stages of development ranging from initial needs case agreed through to planning consents approved, so the level of detail within these assessments has varied depending on the stage of the project. They begin with an initial high-level assessment for early-stage options in the NOA process (such as avoiding new overhead lines in national parks) before completing full consideration for projects in the subsequent stages of development.

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	Environment/Community	Technical
Black	Features or designations which affect the likelihood of an option being achievable to such a degree that the option should not be considered as part of the HND.	Features or constraints that are likely to affect the feasibility of construction and/or buildability of the HND to such a degree that the option should not be considered as part of the design.
Red	Features or designations that are so significant or pose such a high degree of risk to the design that they should be avoided[34], except in exceptional cases which include where potential mitigation (or compensation) is known; where the potential benefits to the design would clearly outweigh the potential harm and/or impacts; or where there are no alternatives.	Features or constraints that are likely to affect the feasibility of construction and/or buildability of the design to such a degree that options affecting them should not be included in the HND without potential solutions to the issues raised.
Amber	The most protected features and/or areas that are likely to require detailed assessment and/or mitigation and should be avoided if possible.	Significant technical constraints that may cause cost increases and/or significant schedule delays; not ideal but likely to be achievable and/or capable of resolution.
Green	Features or designations to be taken into account in constraint assessment/study but which are likely to be capable of resolution.	Informative of approach but medium to low likely technical constraint causing significant cost increase and/or significant schedule delays.

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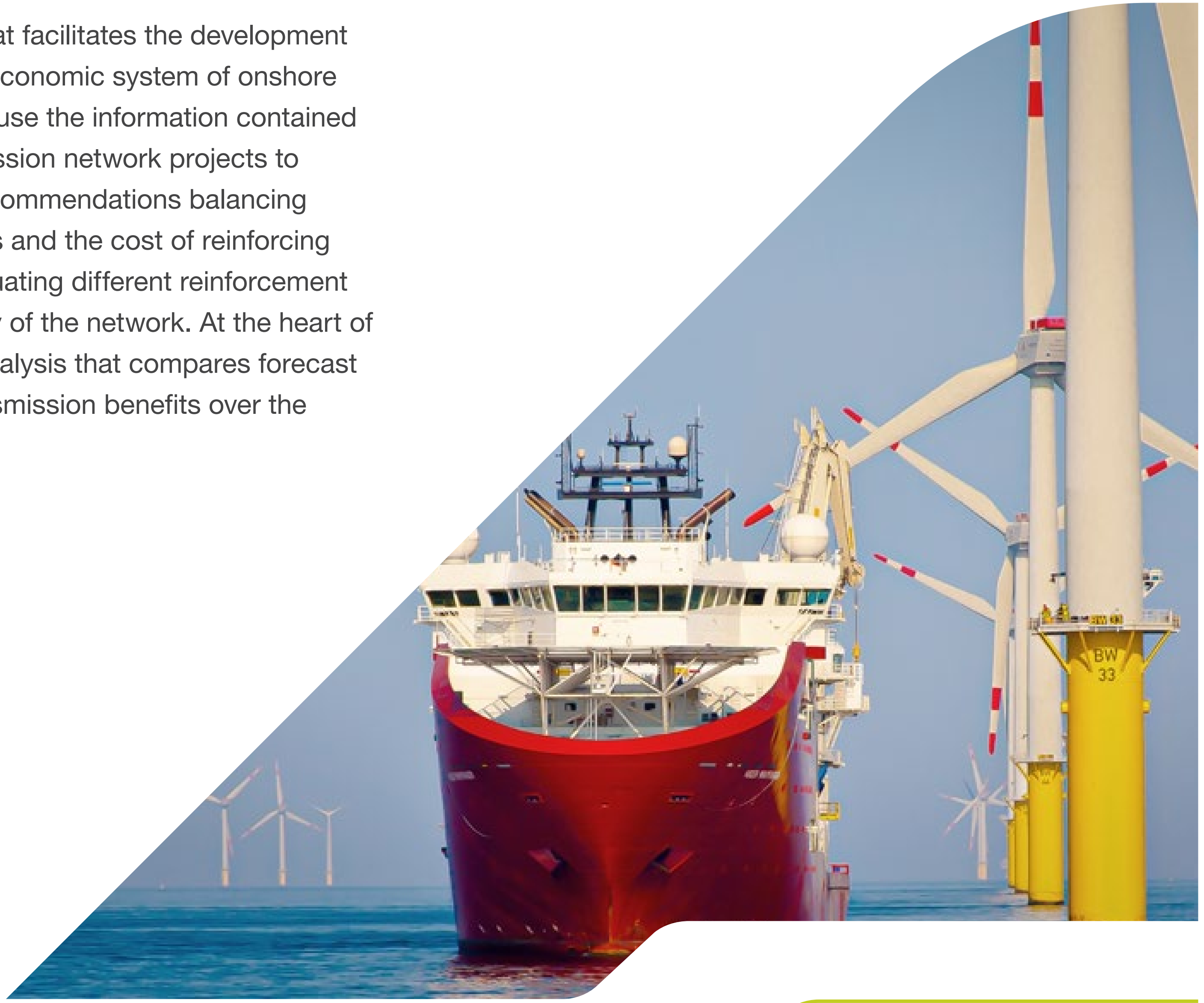
34 To be avoided except for linear constraints - being point to point features, where it may not be possible to avoid crossing these constraints.

A summary of the Holistic Network Design

Throughout the design process we also carried out power system studies, which ensured that designs complied with industry codes and regulations and were designed with power system operability and flexibility in mind.

Both the radial and co-ordinated offshore network designs were evaluated by integrating them with the existing onshore and offshore networks and planned reinforcement options. This allowed us to determine the corresponding onshore network that is needed both to connect the offshore wind and transport the power generated around the country. In addition to the use of an economic optimisation tool, we utilised and built on the established *NOA* cost-benefit analysis methodology.

The *NOA* is an annual process that facilitates the development of an efficient, coordinated, and economic system of onshore electricity transmission. The TOs use the information contained in it to help decide which transmission network projects to progress. We make economic recommendations balancing the costs of managing constraints and the cost of reinforcing the network. This is done by evaluating different reinforcement options that increase the capacity of the network. At the heart of the evaluation is a cost-benefit analysis that compares forecast capital costs and monetised transmission benefits over the project's life.



A summary of the Holistic Network Design

Following the completion of the HND's offshore design, the locations of where the in scope developers will connect to the main transmission network were updated and the onshore requirements were reassessed. We are publishing the results of this exercise as part of this suite of documents as the *NOA 2021/22 Refresh* publication. This builds on the *NOA 2021/22* published in January 2022, which was developed without knowledge of the connection arrangements recommended by the HND. The *NOA* considers a multiyear horizon looking beyond 2030 to provide the optimal delivery dates for projects that it recommends. Only onshore projects that are required to meet the 2030 offshore wind ambitions are outlined in the *HND* report. However, the full suite of recommendations, including those beyond 2030, can be found in the *NOA 2021/22 Refresh* publication. A comprehensive list of onshore and offshore network recommendations within the *HND* report, including connections, enabling works and wider works can also be found in Appendix 1.

Typically, the *NOA* process explicitly follows the previously published and approved *NOA Methodology*. This means that it applies different criteria than the offshore connection elements of the HND with the focus on technical and economic factors. However, to align with the offshore elements and ensure a consistent approach some adjustments to the *NOA* process have been made. Please see the *NOA 2021/22 Refresh* for more details.[35]

The HND detailed document and the *NOA 2021/22 Refresh* publication provide further details on the different developmental stages of the options, the level of environmental and community impacts undertaken at each stage and identify the projects on which the TOs have undertaken environmental and social impact appraisals at least equivalent to those undertaken for the offshore projects.

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35 https://www.nationalgrideso.com/document/262981/download

The recommended design

The recommended design

We have recommended connection and offshore network designs for four offshore regions of Great Britain that contain the in scope offshore wind projects and provided an update on the fifth region where projects sit outside the HND:

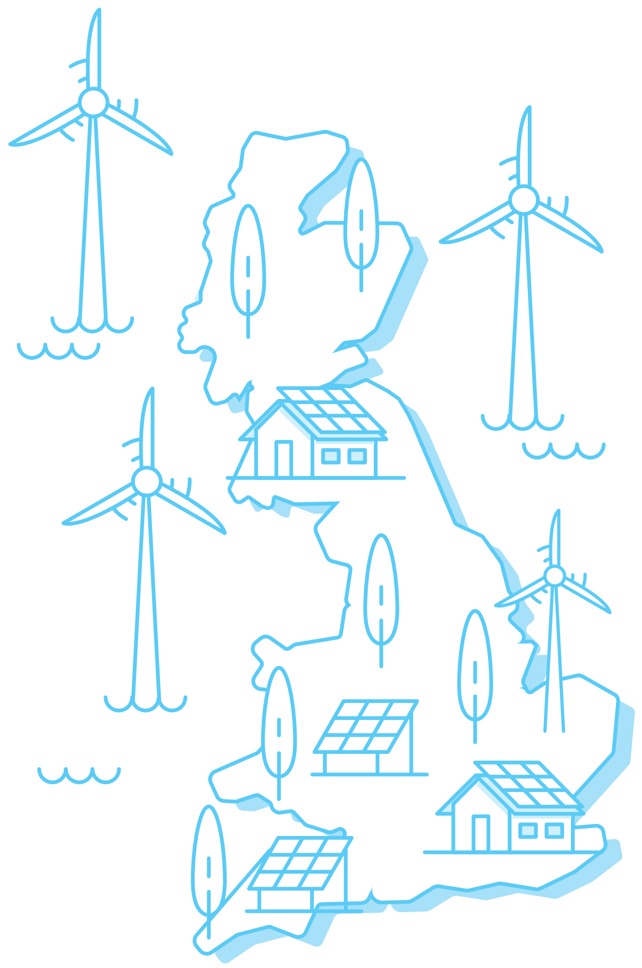
1. North West
2. North Scotland
3. East Coast
4. South West
5. The South East and South Coast of England

We have also recommended key wider system reinforcements based on a system-wide view which we describe later in this section. Whilst some of these system-wide reinforcements sit neatly within one region, the majority solve wider network issues outside of these regions. We have therefore included a system-wide view to reflect this.

Regional offshore view

Offshore network designs are presented by region based on the opportunity to coordinate between different offshore wind farms within the HND.

The East Coast of England and Scotland were treated as a single offshore region due to the opportunity for coordination across the wind farms. Similarly, for the west coast, we have grouped the west coast of Scotland, the north west of England and north Wales together in the North West Region. The South East and South Coast of England are also grouped together. The North Coast of Scotland and the South West are presented in their own groupings. Our system-wide view, which follows this section, provides a comprehensive overview across Great Britain.



The recommended design

The designs do not include specific route corridors, which will be developed by the delivery body carrying out the DND for each part of the network. The recommended designs for the North West, East Coast and South West regions are described below alongside our optimal radial design option for comparison. For North Scotland, where a radial approach is recommended, the best-performing coordinated design is included for comparison.

In all of the regions we have considered onshore and offshore environmental and community constraints and these are indicated on the regional maps. While offshore constraints are clearly visible in the diagrams, not all onshore constraints are. This is either due to the area of the constraints being too small to see at the scale of the diagrams, or in the case of constraints near to the interface points, the constraint areas are covered by the substation icons. The *HND* report contains diagrams of a larger scale showing onshore constraints.

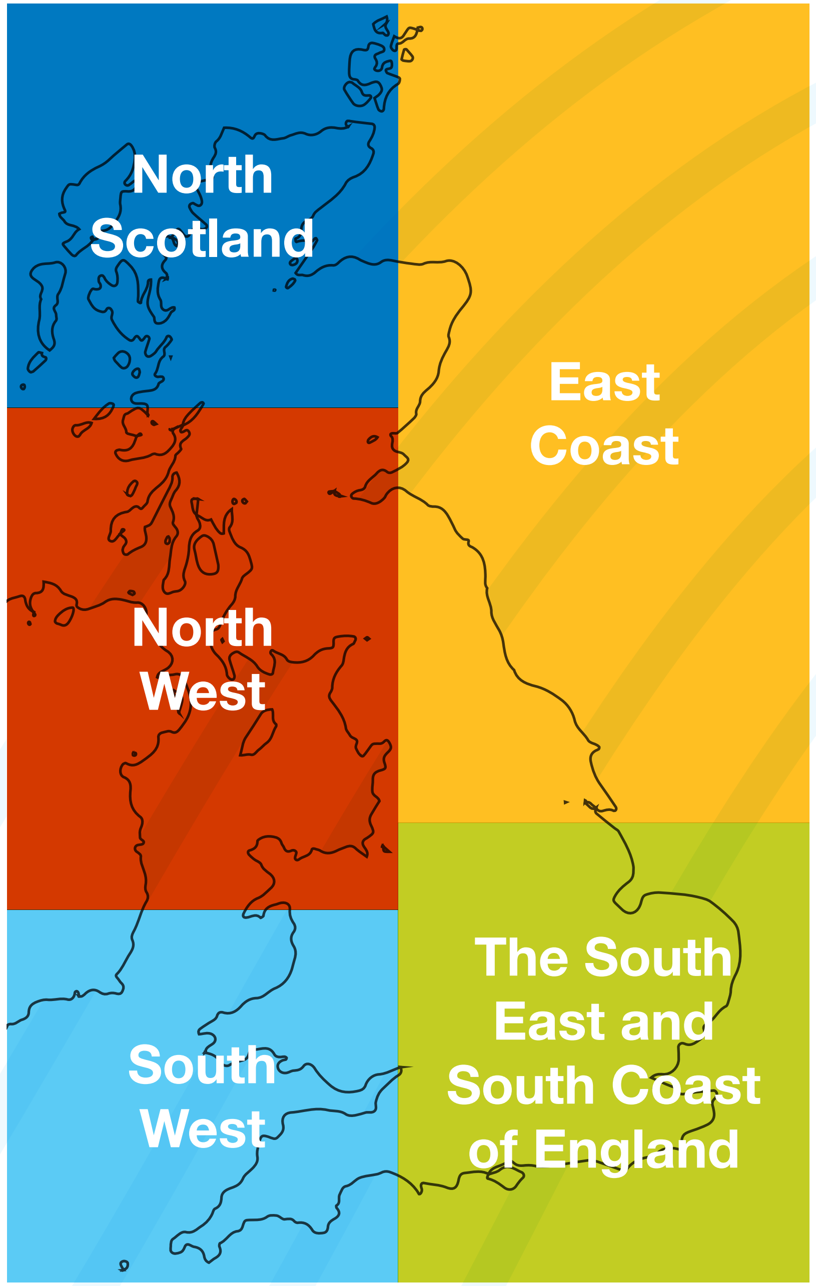
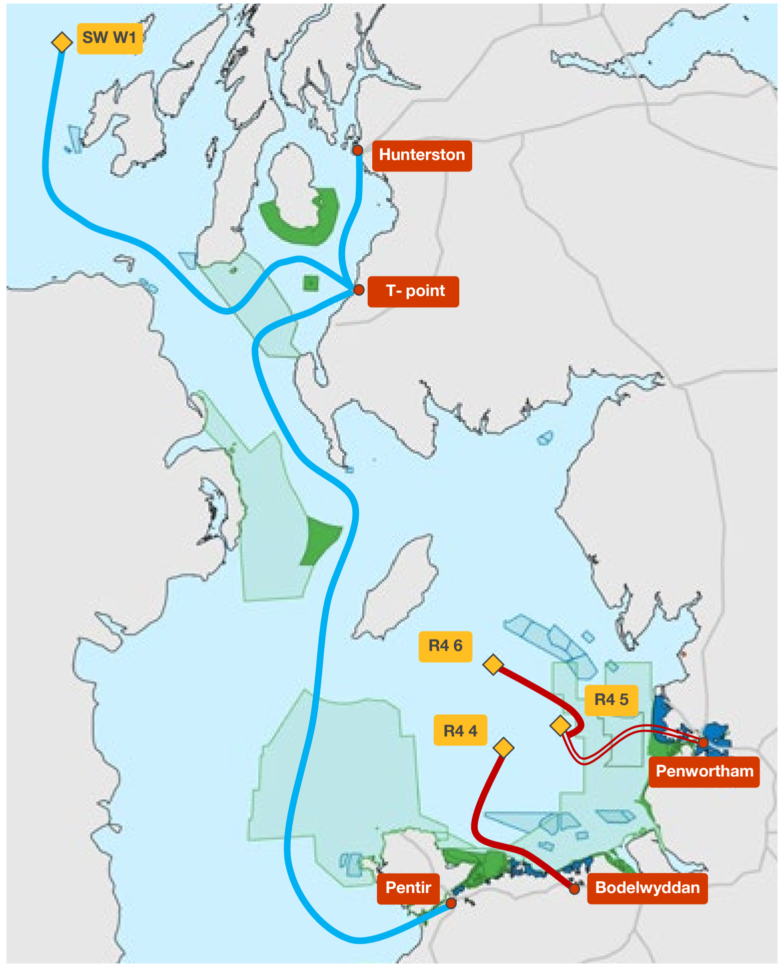


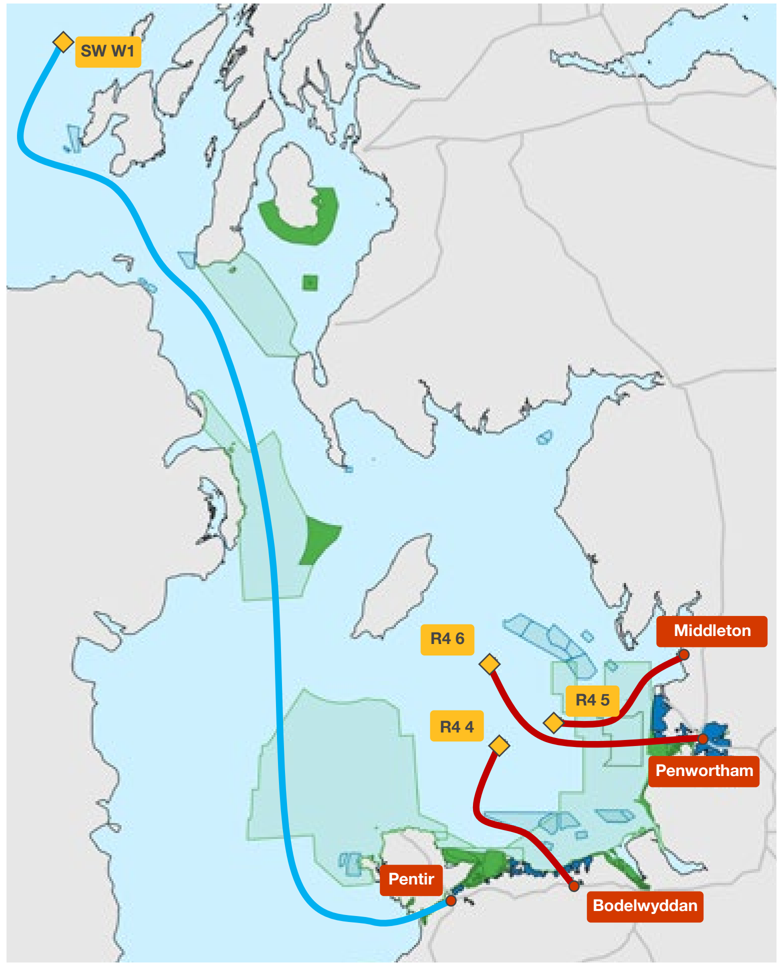
Figure 4: Overview of the regions

North West Region

Recommended design: Coordinated



Radial design



Legend	
HVDC	
HVAC	
Environmental constraint: avoidable	
Environmental constraint: unavoidable	
Community constraint	
Existing or planned wind farm	
In scope wind farm	
Onshore substation	
Existing network	
All option routes and locations are for illustrative purposes only.	

Figure 5: The recommended coordinated design and optimised radial design for the North West Region

Number of generators:
Four

Combined offshore wind capacity:
5.5 GW

Design:
Wind farm in West Scotland connects to a T-point with connections into both Scotland and Wales. Irish Sea wind farms connected radially with two sharing a route corridor.

North West Region

Environmental constraints:

We anticipate it will be possible to define route corridors which avoid important environmental constraints, including:

- The Shell Flats and Lune Deep area.
- The Ribble and Alt Estuary SPA.
- The Menai and Conwy Bay SAC, which can be avoided by a route corridor which approaches Pentir via a slightly longer route from the south than if approached from the north.
- Queenies Corner MPA/MCZ.
- Sefton Coast SAC.
- Morecambe Bay SAC.

However, there are some environmental constraints which cover extensive areas situated onshore or are close to or directly at the point of the subsea cables, making crossing these areas unavoidable due to the locations of wind farms and onshore substations. These include:

- The Liverpool Bay area SPA, which cannot be avoided for approaches to Bodelwyddan and Penwortham.
- The Clyde Sea Sill MPA, which cannot be avoided for approaches to Hunterston.
- The Fylde MCZ, which cannot be avoided for approaches to Penwortham.
- North Anglesey Marine SAC, which can be avoided in a northern approach to Pentir but cannot be avoided in a southern approach.

Community constraints:

It is expected to be possible to define a route corridor to Penwortham which avoids the major urban areas of Blackpool and Lytham St Annes, and a route corridor to Bodelwyddan that avoids major urban areas and the proposed Awel Y Mor wind farm, which is at a more advanced stage of development than those included in the HND. The substation in Pentir is located in the Arfon area landscape and the substation in Hunterston is located in the raised beach coast and cliffs landscape, which are moderate constraints.

The degree of constraint of the T-point depends on its exact location, which will be defined as part of the DND. The final route corridors and new substation or converter station locations are not defined by the HND and will be developed by the party carrying out the DND for each part of the network. These will assess the environmental effects and mitigation measures required and will take into account local community constraints at all of the locations.

The substations in Pentir and Hunterston are situated at the Arfon area landscape and Raised Beach Coast and Cliffs landscape respectively, which are moderate constraints.

North West Region

The recommended design

The recommended design in the North West Region is formed of a connection through offshore waters between Scotland and Wales and connections from the Irish Sea to the north west of England and north Wales. It includes an HVDC connection from wind farm SW_W1 to a T-point located in the vicinity of South Ayrshire, which further connects to Hunterston and Pentir. This delivers an offshore connection between Scotland and Wales, which bypasses onshore grid constraints and enables transmission of electricity from Scotland to the south, towards areas of higher electricity consumption. HVDC technology needs to be used for this due to the long cable length and large capacity.[36] Due to environmental and deliverability constraints, we have assumed that this cable route approaches Pentir from the south, although route corridors will be determined at the DND stage.

The links to Hunterston and Pentir provide a wider transmission system benefit by providing transmission circuit capacity between those points, avoiding the need for an additional north to south link. There is also potential for other projects to connect into the T-point. We would therefore envisage the possibility that the T-point to Hunterston and/or Hunterston-Pentir circuits could form part of the onshore transmission system and would be delivered and operated through the appropriate mechanisms for onshore transmission assets. The SW_W1 developer could therefore only be responsible for the link from SW_W1 to the T-point, with the other circuits being described as TO works within its connection agreement. However, as this situation is not specifically clarified within Ofgem's May 2022 *Minded-to Decision and further consultation on Pathway to 2030*, further analysis on the primary function of the assets will be needed to confirm this, as envisaged by Ofgem.

36 With increasing cable length, the effective capacity of HVAC cables to transmit real power reduces due to increased reactive power. There is no such technical limitation for the use of longer HVDC cables.

North West Region

There is also a potential opportunity to integrate the planned LirIC interconnector from Scotland to Northern Ireland into the proposed design. The LirIC interconnector is currently planned to connect from Kilroot in Northern Ireland to Kilmarnock South in Scotland.[37] An improved economic, environmental and community outcome could potentially be achieved by connecting it into the T-point. However, further analysis will be required to determine whether this is deliverable.

The design further recommends collaboration between generation developers in the Irish Sea. For the R4_5 and R4_6 wind farms, we are recommending radial connections with a shared cable corridor, consistent with the developers' proposal for coordination. This reduces environmental and community impacts by sharing a cable corridor and landfall, without the need for an offshore switching station. Although the electrical design is radial, it brings many of the benefits of coordination such as reduced environmental impact but is expected to limit deliverability risks.

The R4_4 wind farm will be connected radially into Bodelwyddan in North Wales.

The works on the onshore transmission system include substation extensions at Hunterston, Pentir, Bodelwyddan and Penwortham. Works would also be required at other sites, including substation works, uprating of other circuits and new transmission circuits. It also requires the delivery of an HVDC T-point. More comprehensive onshore network recommendations within the *HND* can be found in Appendix 1.

The DND stage will confirm whether Hunterston is the most appropriate connection site for the northern circuit connecting to the T-point.

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37 tinv.com/intercon-projects/liric/

North West Region

Benefits of the recommended design

The recommended design for the North West Region has significant benefits compared to the radial design. On all four of the design objectives this design performs as well, if not better than, the alternative designs considered. It balances the design objectives successfully to provide an efficient holistic design.

Economic and efficient	The design is economic and efficient, with lower overall costs than the radial design. The coordinated design has higher costs for connecting and operating the transmission network infrastructure needed to connect the wind farms. However, the design of the SW_W1 connection and T-point will provide a wider network benefit, delivering significant savings in constraint costs by transferring additional power from north to south and bypassing onshore boundary constraints.
Deliverable and operable	The design is partly deliverable by 2030 under current regulatory and consenting frameworks. Although firm connections will not be available until later years in some cases without delivery of the commitments in the *BESS*, the design could be built using a phased approach. The design includes a significant volume of HVDC cables, and it will be challenging to deliver the full three-ended HVDC link by 2030. Additionally, some of the required reinforcement works currently have dates which extend beyond 2030. We are working with the relevant TOs to review the programme for these works in light of the commitments in the *BESS*. The timings and required works for each connection will be determined as part of the connection contract update programme. Our analysis has not identified any significant operability challenges, although the DND will explore this further.
Environmental impact	The design seeks to minimise the impact on the environment. It is expected to be possible to define route corridors which avoid many important environmental constraints. Whilst it is not expected to be possible to avoid all environmental constraints, this design performs better than the alternative radial design by introducing a shared cable corridor to Penwortham and avoiding the Morecambe Bay SAC.
Community impact	The design seeks to minimise local community impact. It is expected to be possible to define a route corridor that avoids key community sensitivities in the region. The recommended design for the Irish Sea provides community benefits over the radial design by reducing the number of cable corridors, which will reduce community impact from construction activities.

Alternative designs

In addition to the recommended design, we investigated several alternatives as part of our appraisal, including a design that includes an additional HVDC connection to form a ring in the Irish Sea and a direct connection between wind farm SW_W1 and Wales. From an economic perspective, this alternative design does not perform as well as our recommended design. For the Irish Sea, an additional HVDC link would lead to additional asset costs (due to converter stations), which would not be outweighed by savings in constraint costs. A direct link from SW_W1 to Wales would not provide a wider transmission system benefit in the situation where the SW_W1 wind farm is not generating at full output. We also considered a coordinated solution where R4_5 and R4_6 shared an offshore platform and connection into Penwortham, however this performed less well than our recommended option from an economic perspective.

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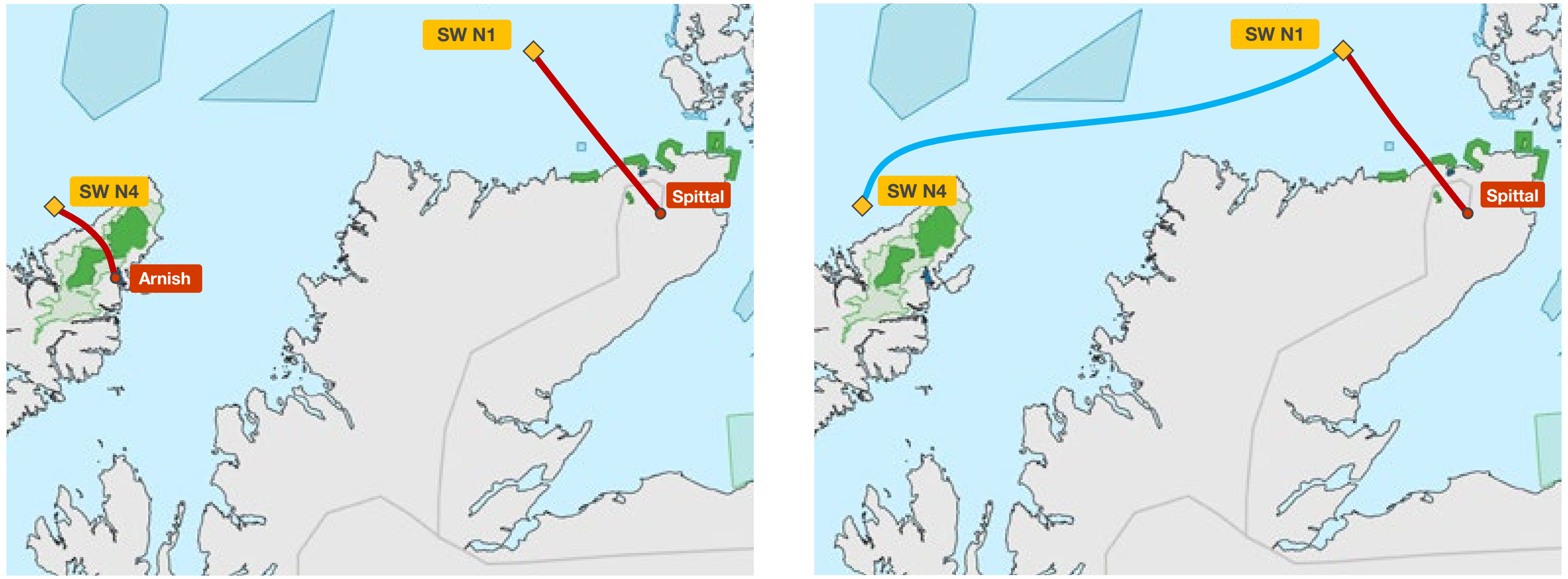
North Scotland Region

Recommended design: Radial

Coordinated design



Legend	
HVDC	
HVAC	
Environmental constraint: avoidable	
Environmental constraint: unavoidable	
Community constraint	
Existing or planned wind farm	
In scope wind farm	
Onshore substation	
Existing network	
All option routes and locations are for illustrative purposes only.	

Figure 6: The recommended radial design and the coordinated design considered for the North Scotland Region

Number of generators:
Two

Combined offshore wind capacity:
3 GW

Design:
Radial connections

North Scotland Region

Environmental constraints:

It is expected to be possible to define route corridors which avoid important environmental constraints such as:

- The North Caithness Cliffs SPA and MPA (situated at and near the coast of the Great Britain mainland).
- The Caithness Lochs SPA (situated on the Great Britain mainland).
- The Lewis Peatlands SAC (situated on the Isle of Lewis).

However, due to the location of the respective wind farms it is not expected to be possible to define onshore cable route corridors which avoid the Lewis Peatlands SPA on the Isle of Lewis (for the SW_N4 connection to Arnish), or the River Thurso SAC (for the SW_N1 connection to Spittal).

Community constraints:

Within the potential route corridors there are shipwrecks, scheduled monuments and urban areas, although it is expected to be possible to avoid these sites.

The final route corridors and new substation or converter station locations are not defined by the HND and will be developed by the party carrying out the DND for each part of the network. These will assess the environmental effects and mitigation measures required and take into account local community constraints at all of the locations.

North Scotland Region

Recommended design

The recommended design in the North Scotland Region uses only radial HVAC connections, with no coordination between wind farms. In this region, a coordinated design performs less well against the HND objectives. This is due to the distance between the wind farms in scope, which means that a coordinated design would require an HVDC link between wind farms, with significantly higher transmission network infrastructure costs than a simpler radial design.

Because SW_N4 is connecting to Arnish on the Western Isles, an HVDC link will need to be established from the Western Isles to the Great Britain mainland, forming part of SSEN Transmission's network. The nature of this link depends on whether SSEN Transmission's proposed 600 MW link from Arnish to Beauly, which is planned to be completed in 2027, goes ahead. This is subject to regulatory approval and a sufficient volume of onshore generation on the Western Isles. If the 600 MW link does not go ahead, a 1.8 GW HVDC link from Arnish to Beauly could be constructed. If the 600 MW link goes ahead, SSEN Transmission would construct a separate 1.8 GW link from the Western Isles to the mainland, which would connect to a different mainland substation as it is not feasible to construct two separate links from Arnish to Beauly. Our analysis within the HND assumes that connecting SW_N4 to Arnish would require a new 1.8 GW link from Arnish to Beauly. This link would also provide some headroom for additional generation to connect in the future.

The onshore works required for SW_N1 to connect at the new Spittal site include establishing a new 400 kV double busbar arrangement and a connection to the existing Spittal 275 kV substation. For a connection at Arnish in addition to the new HVDC link from Arnish to Beauly, a new substation site will be required at Arnish. More comprehensive onshore network recommendations within the *HND* can be found in Appendix 1.

North Scotland Region

Benefits of the recommended design

The radial design for the North Scotland Region has benefits compared to the coordinated design. On all four of the design objectives this design performs as well, if not better than, the alternative designs considered. It balances the design objectives successfully to provide an efficient holistic design.

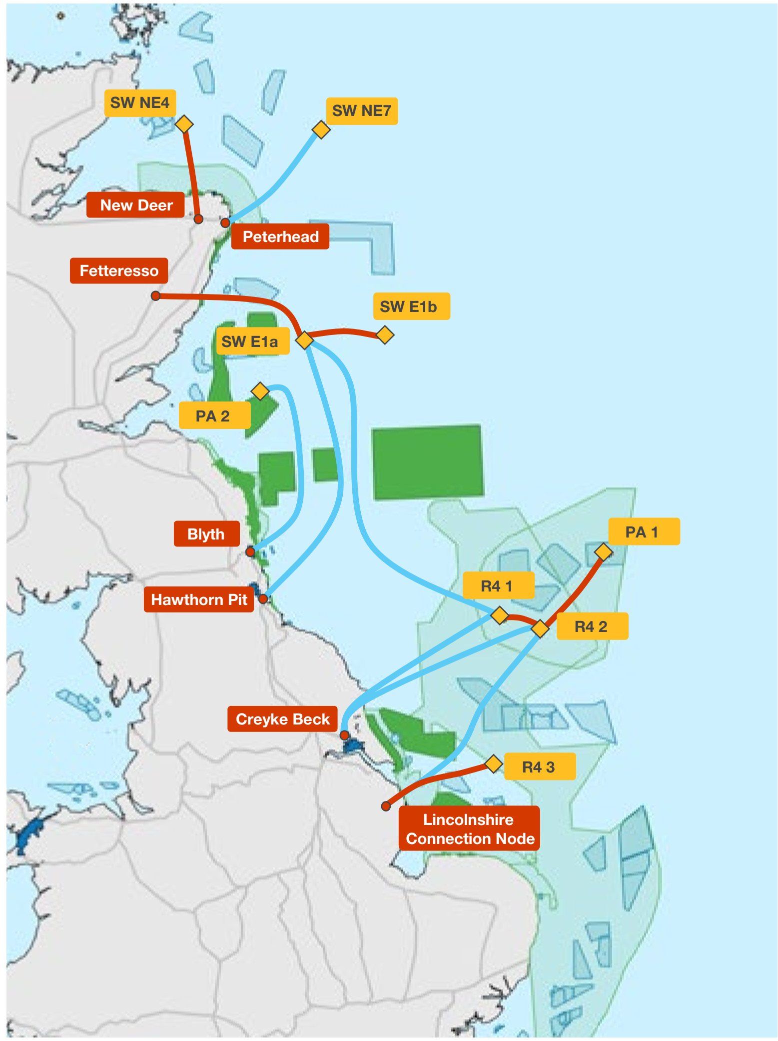
Economic and efficient	The radial design is economic and efficient compared to the coordinated design. The coordinated design would have significantly higher infrastructure costs, as it would include an HVDC link with associated offshore converter stations between SW_N4 and SW_N1, and slightly higher constraint costs due to effectively connecting the SW_N4 generation further north.
Deliverable and operable	The design is deliverable and operable. The HVAC offshore connections and works at the interface point substations are deliverable by 2030. We intend to work with the TOs to accelerate works which are required elsewhere on the network to enable the connections by 2030 in light of the commitments in the *BESS*. The timings and required works for each connection will be determined as part of the connection contract update process. Our analysis has not identified any significant operability challenges, although the DND will explore this further.
Environmental impact	The design seeks to minimise the impact on the environment, as it is expected to be possible to define route corridors that avoid several onshore and offshore areas of environmental significance on the Isle of Lewis and the Great Britain mainland, such as the North Caithness Cliffs SPA and MPA, the Caithness Lochs SPA, and the Lewis Peatlands SAC.
Community impact	The design seeks to minimise local community impact, as it is expected to be possible to define route corridors that avoid heritage assets and urban areas within the route corridors.

Alternative designs

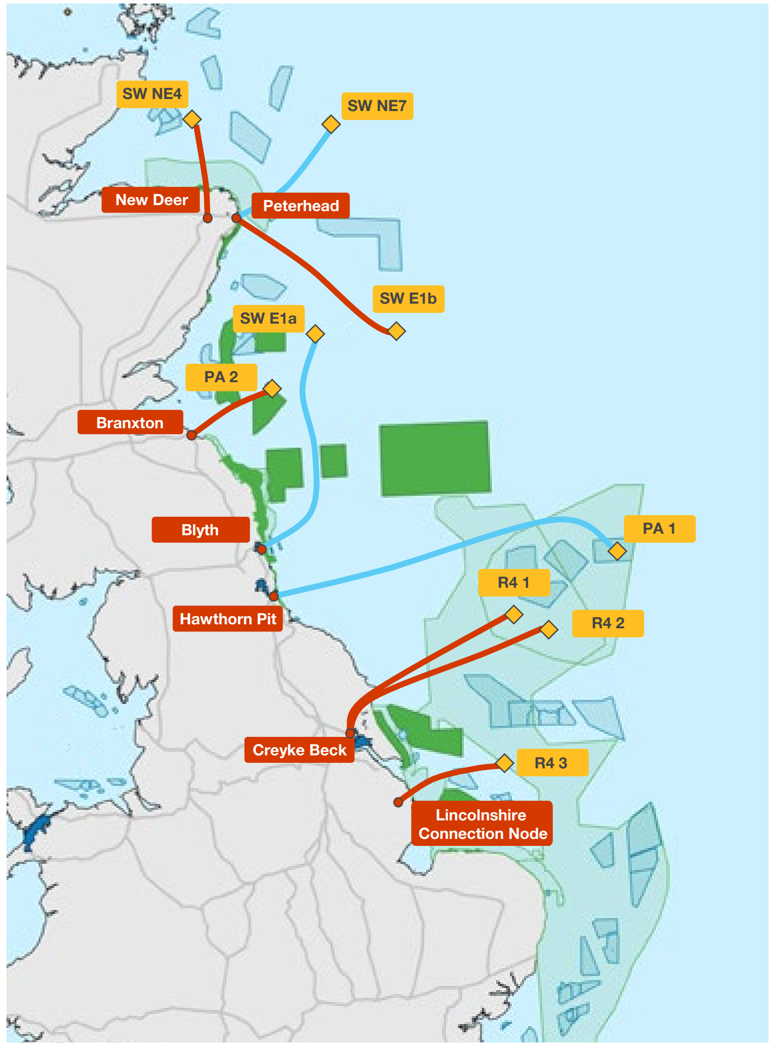
Due to the large distance between the two in scope wind farms in this region, coordinated design options such as an offshore HVDC link between the two in scope wind farms performed worse against the HND Objectives. Other coordinated connections with wind farms in other regions were also ruled out due to technical feasibility or because they performed worse than the radial design against the four HND objectives. In addition to the recommended radial design and the coordinated design, we investigated an alternative radial design where both wind farms connect to the Dounreay interface point just south of the SW_N1 wind farm using HVAC cables. This design is not recommended as it is not future proof to additional Western Isles onshore and offshore generation.

East Coast Region - east of England and east of Scotland

Recommended design: Coordinated



Radial design



Legend
HVDC
HVAC
Environmental constraint: avoidable
Environmental constraint: unavoidable
Community constraint
Existing or planned wind farm
In scope wind farm
Onshore substation
Existing network
All option routes and locations are for illustrative purposes only.

Number of generators:

Nine

Combined offshore wind capacity:

13.3 GW

Design:

Combination of radial (4) and coordinated (5) connections. Offshore network connects wind farms and provides additional capacity between Scotland and England.

Figure 7: The recommended coordinated design and optimised radial design for the East Coast Region

East Coast Region - east of England and east of Scotland

Environmental constraints:

When compared to the optimised radial design, the recommended design provides environmental benefits by introducing additional HVDC links. This reduces overall cable corridor widths and leads to further potential environmental benefits if HVDC cables are laid together. However, there are significant environmental constraints at interface points on the east coast; notably, the cumulative impact of cable routes into the Creyke Beck site and the impact of cable routes and transmission network infrastructure development at the Lincolnshire Connection Node. Whilst the selection of cable routes and installation methods will be able to avoid a number of these constraints through detailed design, not all of the environmental constraints can be avoided. Mitigation and, potentially, compensation measures for residual effects will need to be developed during the DND and environmental assessment stages at these sites. This might need to include the strategic compensation in the marine environment referred to in the British Energy Security Strategy.[38]

The recommended design for the East Coast Region does not propose any additional connections into East Anglia beyond those already planned, as it is not expected to be feasible in the timescales the HND is considering to define an offshore route corridor for the in scope offshore wind projects which avoids the environmental constraints in this region.

We have recommended an HVDC connection from SW_NE7 into Peterhead. For the proposed 1.5 GW connection, this is expected to result in fewer cables and a narrower route corridor, leading to more feasible landfall options at what is already a congested site.

All the design options considered increase the cable route length in the Dogger Bank SAC, which is unavoidable due to the location of three of the windfarms within the SAC. The current layout of the coordinated design reduces the number of cables to shore by connecting PA_1 into an offshore hub at R4_2, however, it increases the cable route length in the Dogger Bank SAC. The impact on the SAC could be reduced by siting the offshore hubs outside the SAC and careful consideration of cable routing to minimise the impact.

Within the recommended design, it is expected to be possible to define route corridors that avoid important offshore environmental constraints such as:

- Firth of Forth Banks MPA.
- The Holderness Inshore and Offshore MCZs.
- The Outer Firth of Forth and St Andrews Bay Complex SPA.

It is also expected to be possible to define route corridors that avoid important onshore environmental constraints such as:

- Hesledon Moor West Site of Special Scientific Interest (SSSI).
- Saltfleetby-Theddlethorpe Dunes and Gibraltar Point SAC
- Greater Wash SPA.
- Humber Estuary Ramsar site and important bird area.

However, it is not expected to be possible to define route corridors that avoid the following offshore constraints:

- Dogger Bank SAC.
- Southern North Sea SAC.
- Rosehearty to Fraserburgh Coast SSSI.
- Southern Trench MPA.
- Coquet to St Marys MCZ.

38 gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy

East Coast Region - east of England and east of Scotland

Community constraints:

The recommended design brings community benefit by avoiding further connections into East Anglia beyond those already planned, where there is already, existing and planned offshore transmission network infrastructure. However, there are community impacts at other interface points on the east coast, notably Creyke Beck, where a significant amount of transmission network infrastructure is planned to be located and at the Lincolnshire Connection Node where a new site is planned to be established and would be extended to accommodate the connection from the offshore hub and R4_3. Careful planning will be required in the DND stage, working with communities, to reduce impacts and maximise community benefits.

Within the recommended design, there is the potential to define a route corridor which avoids moderate community constraints at Peterhead, such as residential properties and landscape and cultural heritage features. However, it is not expected to be possible to avoid community constraints in all areas, for example at New Deer where it may not be possible to avoid visual impacts on nearby residential areas when connecting into the interface points at this location.

The final route corridors and new substation or converter station locations are not defined by the HND and will be developed by the party carrying out the DND for each part of the network. These will assess the environmental effects and mitigation measures required and take into account local community constraints at all of the locations.

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East Coast Region - east of England and east of Scotland

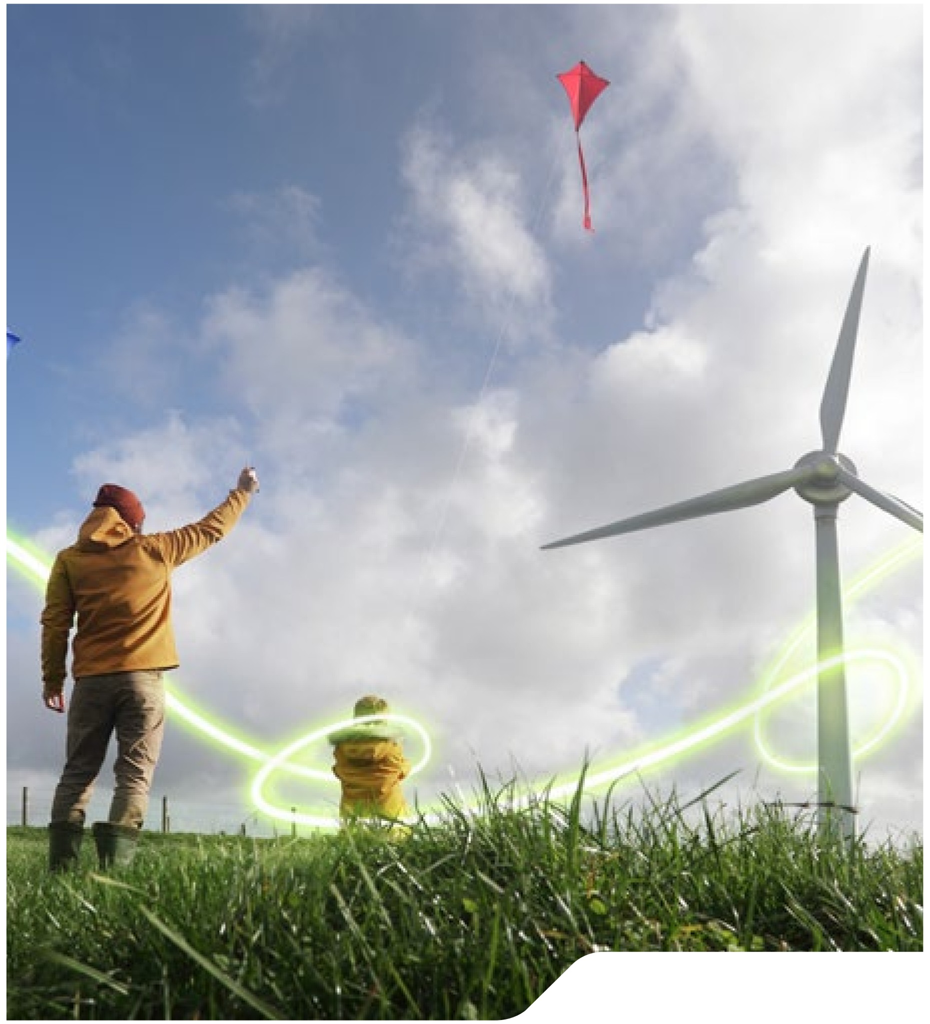
Recommended design

In the East Coast Region there is clear value in transferring power through the offshore network from the Eastern ScotWind zone to the south via the offshore wind developments off the east coast of England, resulting in a design with substantial coordination. The value is provided by avoiding costs that would be incurred due to curtailing and then re-dispatching generation because of insufficient network capacity to transport power to where it will be consumed. The four Eastern HVDC links being developed by the TOs and already recommended in the *Network Options Assessment 2021/22* are required in addition to the coordinated offshore network, but the north to south links proposed in this design offset requirements for further additional links.

The offshore network design on the east coast therefore provides significant economic benefit with no greater community impact than the optimised radial design, as the number of landfall locations remains the same as the optimised radial design. It does, however, introduce additional environmental impacts due to the number of cables in the Dogger Bank SAC, which is difficult to avoid due to the location of the wind farms. At the DND stage, further consideration can be given to cable routing and equipment siting to avoid or minimise impact.

Compared to the optimised radial design, the recommended design also introduces additional complexity due to the four additional HVDC links, which are in addition to those already being developed by the TOs, increasing supply chain and delivery risk. Due to the complexity of the coordinated design and requirements for onshore works, the full east coast design is unlikely to be deliverable by 2030. A staged build approach could be adopted to allow the generation to connect by 2030. There are also significant onshore works required, some of which cannot be delivered by 2030 under current planning and regulatory frameworks and are reliant on delivery of the *BESS* commitments to facilitate connections by 2030. Despite these considerations we still believe that our recommended design is the best overall solution.

We note that additional ScotWind generation is due to connect into the northern part of this region. This will be fully considered shortly and it is envisaged that this will lead to further opportunities for coordination. We envisage that a modular approach to offshore platform design will aid deliverability and make the design more expandable. This should be considered further by those undertaking the DND stage.



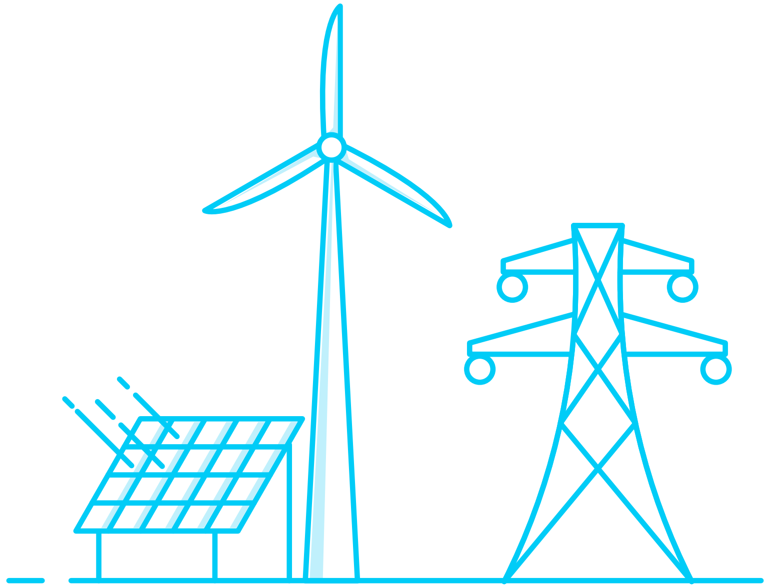
East Coast Region - east of England and east of Scotland

Ofgem's May 2022 *Minded-to Decision and further consultation on Pathway to 2030* confirms that the existing generator build and Offshore Transmission Owner (OFTO) build models will be available to developers where the HND indicates a radial solution. For the coordinated parts of the east coast design, it will be necessary to classify each element as onshore or offshore transmission, depending on its primary function within the network. Ofgem envisages that generators would design and build the offshore transmission network infrastructure, although this is subject to consultation. The assets categorised as onshore transmission will be delivered and operated through the appropriate mechanisms for onshore transmission assets.

Although the recommended design has a greater total cable corridor route length, it benefits from fewer cables coming to shore than the radial design due to the increased use of HVDC technology.

This benefit is enhanced if the HVDC cables coming to shore in the recommended design can be laid as bundled pairs, significantly reducing the size of the cable corridor and therefore footprint on the seabed compared to an HVAC design.

The recommended design does not include any new connections from offshore wind farms into East Anglia beyond those currently planned. Although the location performed well from an economic point of view, environmental constraints mean that it is unlikely to be feasible in the timescales the HND is considering to find a route that is acceptable from an environmental or technical perspective beyond those already in place and in development.



East Coast Region - east of England and east of Scotland

For the four wind farms that are recommended to connect radially, a coordinated solution did not deliver sufficient benefit against the optimised radial design when all four HND objectives were considered on an equal basis. Four wind farms are connected radially - SW_NE4 to New Deer, SW_NE7 to Peterhead, PA_2 to Blyth, R4_3 to Lincolnshire Connection Node. An alternative connection location further inland is still under consideration for R4_3, as a new circuit is planned to be built for the Lincolnshire Connection Node but this would not be available until 2031. The radial part of the design comprises two HVDC links (SW_NE7 and PA_2) and two HVAC links (SW_NE4 and R4_3).

The Lincolnshire Connection Node is a new site that is planned to be developed on the Lincolnshire coast. The NOA has previously identified a requirement for a new circuit to reinforce this part of the network. Developing a substation on this new circuit provides the opportunity to connect multiple offshore customers at this location, coordinating connections in this region and mitigating the development of a high number of cable routes to connection points further inland. The design proposed in the HND would expand this already planned new site to accommodate the connection of R4_3.

A key driver that makes the recommended design more economic and efficient is the coordinated offshore network, which connects Fetteresso in Scotland to Hawthorn Pit, Creyke Beck and the Lincolnshire Connection Node in England, whilst also connecting wind farms SW_E1a, SW_E1b, R4_1, R4_2 and PA_1. This part of the design includes four HVAC links, three point-to-point HVDC links, and a three-ended HVDC circuit.

Onshore works are required at interface sites and at other sites. At the onshore substations, the required works include extending substations to accommodate new connections and establishing a new double busbar substation at Peterhead. The new sites already planned at Creyke Beck and Lincolnshire Connection Node need to be expanded. Various other works are also required including works at other substation sites, reconductoring and uprating various circuits, the use of various power control technology and new transmission circuits. More comprehensive onshore network recommendations within the *HND* can be found in Appendix 1.

East Coast Region - east of England and east of Scotland

Benefits of the recommended design

The recommended design for the East Coast Region has significant benefits compared to the radial design. On all four of the design objectives this design performs as well, if not better than, the alternative designs considered. It balances the design objectives successfully to provide an efficient holistic design.

Economic and efficient	The design is economic and efficient, as it provides significant savings in constraint costs compared to the radial design, due to the delivery of additional links offshore between Scotland and England. It also provides operational redundancy[39] compared with the radial design. These impacts outweigh the additional investments for the offshore transmission network infrastructure compared to the radial design.
Deliverable and operable	The design is deliverable and operable and provides the opportunity for in scope wind farms to be able to connect by 2030 under the current regulatory and planning frameworks. The longer, and more complex, HVDC links in the design are unlikely to be complete by 2030 in the absence of major acceleration in the supply chain. However, the design offers the potential to get generation connected by 2030, and increase capacity progressively, given timely allocation of responsibilities, delivery of the commitments in the *BESS* and a coordinated and concerted effort from all parties. The Lincolnshire Connection Node requires a new onshore circuit which is currently not anticipated to be delivered until 2031; an alternative site further inland remains under consideration as a connection point for R4_3. The timings and required works for each connection will be determined as part of the connection contract update process. Our analysis has not identified any significant new operability challenges, although the DND will explore this further.
Environmental impact	The design seeks to minimise the impact on the environment by avoiding areas of significant constraint where possible, although not all environmentally sensitive areas can be avoided. The north-south links in the design provide additional power flow capabilities without increasing the number of onshore connection points, and offset future requirements for reinforcement.
Community impact	The design seeks to minimise local community impact where possible, by avoiding further connections into East Anglia in the HND beyond those already planned. Careful planning at the DND stage should enable community impacts elsewhere to be minimised.

Alternative designs

In addition to the recommended and radial designs, we investigated an alternative coordinated design, which uses fewer onshore interface points than the recommended design. However, due to the need for a longer HVDC connection and increased complexity, it is less economic and less deliverable than the recommended design.

Both Branxton and Blyth were considered as options for the connection of PA_2. We have recommended a connection to Blyth within the recommended design. Although connecting PA_2 into Branxton would lead to lower capital costs, when considered as part of the recommended design it would lead to a significant increase in constraint costs and therefore an increase in total costs. A connection into Blyth also avoids environmental constraints and other planned offshore connections at Branxton and is consistent with development work carried out to date. More detail on alternative options considered is provided within the *HND* report.

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39 Redundancy in this context means in case a connection fails, another connection is able to fully or partially transmit power. Without redundancy, a connection failure would result in losing the ability to transmit power.

Case study

Connection of wind farm R4_3 to Lincolnshire Connection Node:

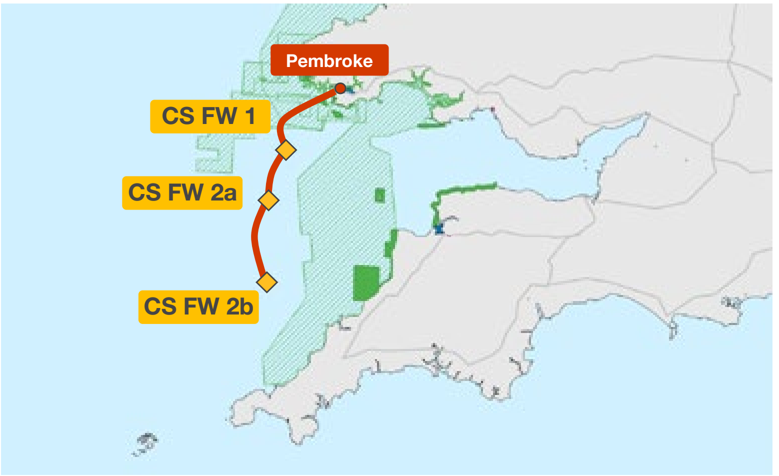
We take a balanced approach in designing for multiple, and at times conflicting objectives. This is illustrated in a case study on our approach to connecting the in scope wind farms situated off the east coast of England.

Recommended design	In the recommended design, wind farm R4_3 connects to the Lincolnshire Connection Node.
Variation	One of the options considered for connecting wind farm R4_3 was a connection to Norwich Main substation. This option performed well from an economic perspective, as it would enable other wind farms in the region to connect further south, reducing constraint costs.
Comparison with recommended design	Due to the technical, environmental and community impacts of adding this connection on top of those already in place and planned, the variation with a connection to Norwich Main substation or other sites on the north coast of East Anglia were not selected for the HND as a part of the recommended design. Particular challenges relevant to the HND include the likelihood that the environmental constraints at Cromer Shoals MCZ and Haisborough, Hammond and Winterton SAC could not be avoided without taking an alternative route, which has previously been dismissed due to technical and cable safety concerns. There are a number of offshore wind farms already connected or planned to connect into East Anglia and the cumulative impact of an additional connection at this time was considered.
Reason for disregarding	For the reasons set out above, an additional connection into Norwich Main is considered high risk of being undeliverable in the timescales required in the HND. As a result, Norwich Main is not considered to be a suitable connection site in the HND, even though it performs better from an economic perspective. Further connections to Norwich Main are therefore not recommended at this time.

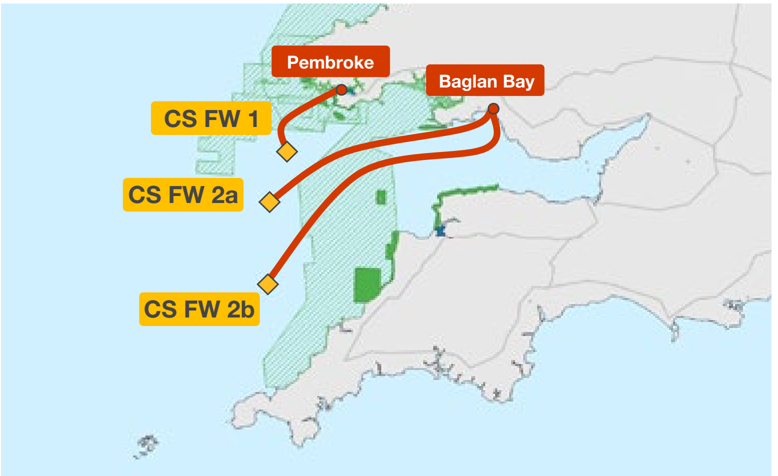
South West Region

Recommended design: Coordinated subject to Celtic Sea leasing round outcomes

Coordinated



Radial design



Legend	
HVDC	
HVAC	
Environmental constraint: avoidable	
Environmental constraint: unavoidable	
Community constraint	
In scope wind farm	
Onshore substation	
Existing network	
All option routes and locations are for illustrative purposes only.	

Figure 8: The recommended coordinated design and optimised radial design for the South West Region

Number of generators:
Three
(assumed projects and locations)

Combined offshore wind capacity:
1 GW

Design:
Coordinated connection to Pembroke.

South West Region

Environmental constraints:

The coordinated design reduces the number of landfall points compared to the radial design.

We anticipate it will be possible to define a route corridor which avoids important environmental constraints, including:

- Castlemartin coast SPA.
- The Limestone coast of South West Wales.
- Bristol Channel Approaches SAC.

However, there are some environmental constraints situated onshore or offshore directly at the point of the subsea cables making landfall that are unavoidable due to the locations of wind farms and onshore substations. These include:

- Pembrokeshire Marine SAC.
- Skomer, Skokholm and the seas off Pembrokeshire.
- West Wales Marine SAC.

Community constraints:

The indicative route to Pembroke has the potential to avoid the urban area within the route corridor. However, it is not expected to be possible to avoid the national park and national trails.

The final route corridors and new substation or converter station locations are not defined by the HND and will be developed by the party carrying out the DND for each part of the network. These will assess the environmental effects and mitigation measures required and take into account local community constraints at all of the locations.

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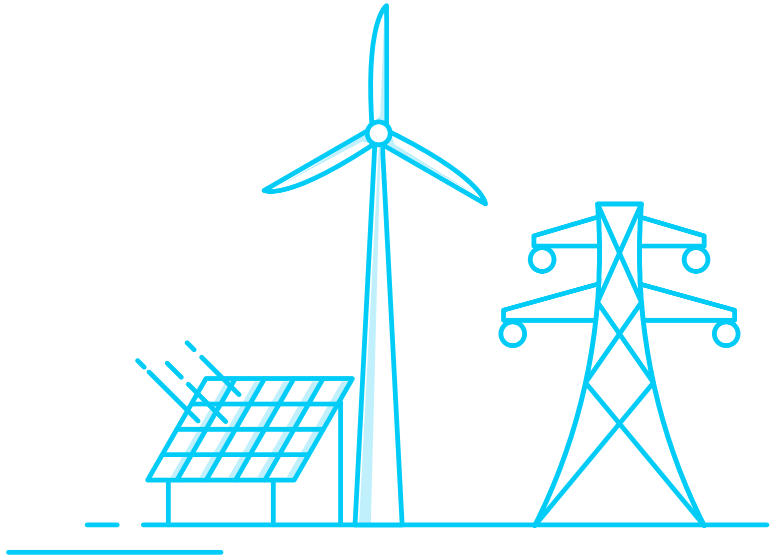
South West Region

The recommended design (subject to Celtic Sea leasing round outcomes)

In the South West Region, the locations and capacities of the in scope wind farms are not yet known and will depend on the outcome of The Crown Estate's upcoming seabed leasing round in the Celtic Sea, which currently expects to see rights awarded by the end of 2023.[40] To allow us to develop an indicative design in advance of the leasing round we have made assumptions on the capacity and locations of the wind farms. The design provides a proposal for how 1 GW of offshore wind could be connected in the Celtic Sea, but no fixed design recommendations are made at this stage.[41]

Our indicative recommendation is to connect all three assumed wind farms through a coordinated HVAC link to Pembroke. Our analysis has identified significant onshore and offshore constraints around the Pembroke site; careful consideration will need to be given to future developments in this location. When more detail is known on the capacity and location of seabed leases in the Celtic Sea, we will further consider how to develop the network in the South West Region.

The works on the onshore transmission system associated with the design include the substation to accommodate new connections at Pembroke. Further onshore works include uprating circuits and installing flow control devices to manage power flow. More comprehensive onshore network recommendations within the *HND* report can be found in Appendix 1.



40 thecrownestate.co.uk/en-gb/what-we-do/on-the-seabed/energy/floating-offshore-wind/
41 Note the results of the South West Region are largely given for information and interest, and it is our intention to not give a firm recommendation on the best overall solution until a more accurate view of the wind farms in the area can be agreed upon and studied in a future process.

South West Region

Benefits of the recommended design

The recommended design for the South West Region has significant benefits compared to the radial design. On all four of the design objectives this design performs as well, if not better than, the alternative designs considered. It balances the design objectives successfully to provide an efficient holistic design.

Economic and efficient	The design is economic and efficient, and offers savings compared to other coordinated designs considered.
Deliverable and operable	The design is deliverable by 2030. The design does not trigger requirements for any new transmission circuits that are not already being considered by the TOs; all the works required for this option are deliverable by 2030. Our analysis has not identified any significant operability challenges, although the DND will explore this further.
Environmental impact	The design seeks to minimise the impact on the environment as it results in fewer landing points and is expected to result in fewer crossings of environmentally constrained areas compared to the optimised radial design. Our analysis has identified significant onshore and offshore constraints around the Pembroke site; careful consideration will need to be given to future developments in this location.
Community impact	The design seeks to minimise local community impact as there is potential to define a route which avoids urban areas and other community and heritage features. There are some national parks and trails that cannot be fully avoided: mitigation measures will be considered as part of the DND stage. The coordinated design would lead to fewer interface points than the radial design.

Alternative designs

In addition to the recommended design, we investigated several alternatives, including a design with the coordinated HVAC link to Pembroke but with a HVDC link from the middle wind farm (CS_FW_2a) to Alverdiscott. This alternative design does not perform as well as our recommended design, primarily as it would result in additional capital costs which would be greater than the associated savings in constraint costs resulting from additional capacity between South Wales and the South West Peninsula.

South East and South Coast of England Region

The South East and South Coast Region does not contain any offshore wind directly covered by the HND due to the well-developed nature of the majority of the projects in this area.

The Department for Business, Energy and Industrial Strategy (BEIS) has now announced four initial pathfinder projects. These are well-advanced projects that are leading the way in utilising the regulatory and policy changes being developed through the OTNR to increase transmission network coordination and deliver the OTNR's objectives.[42] Two of these projects are in this region:

- Equinor's proposal for an integrated transmission system for the Sheringham Shoal and Dudgeon Extensions in Norfolk.
- Orsted's proposal for Boudica, to co-locate a 200MW battery as part of the grid connection in Norwich, of Hornsea 3 offshore wind farm.

National Grid Electricity Transmission (Sea Link), National Grid Ventures (Nautilus and EuroLink interconnectors) and the two offshore wind farms North Falls and Five Estuaries have published an update on their work together to explore the potential for offshore coordination as part of the OTNR Early Opportunities workstream too.

Also, as set out in relation to the East Coast Region, the recommended design does not include any new connections from offshore wind farms into East Anglia beyond those currently planned. Although the connecting of offshore wind off the east coast into Norwich performs well from an economic point of view, environmental constraints mean that it is unlikely to be feasible in the timescales the HND is considering to find a route that is acceptable from an environmental or technical perspective beyond those already in place and in development. The case study in the East Coast Region on the connection of wind farm R4_3 to the Lincolnshire Connection Node describes this in more detail.

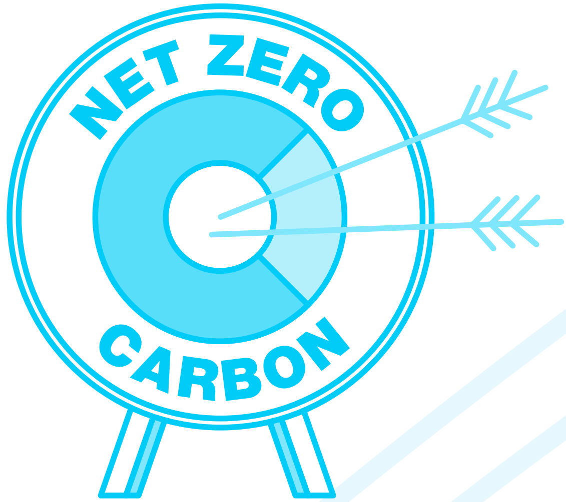
42 https://www.gov.uk/government/groups/offshore-transmission-network-review

System-wide view

The current onshore transmission system has around 25,000 km of high voltage overhead lines to transmit power across the country and into our homes. Whilst this network meets our needs for today, as we look to the future, and the ambitious targets set by the UK Government, we need to make upgrades to ensure we have a power system capable of delivering on the UK's 2030 offshore wind ambition and our net zero targets.

Alongside the development of regional offshore connections options, our assessment examined a full set of offshore and onshore network options to produce one HND, ensuring that power produced by offshore wind farms can be transported from where it is generated to where it is needed to power cities, towns and homes. By analysing projected year-round electricity demand and generation conditions to 2030 and beyond, we have identified economic, efficient, deliverable network upgrades, which consider both environmental and community impacts, facilitate the UK Government's ambition for 50 GW of offshore wind by 2030 and set the network up well to meet net zero by 2045 in Scotland and 2050 across the whole of Great Britain.

To create an onshore electricity transmission network fit for the future we use the NOA process. This recommends where, when, and whether to invest in network upgrades across the Great Britain transmission system. It weighs up the benefit of investing in upgrading or building new transmission infrastructure against the costs of curtailing generation that would otherwise be incurred due to power transfer capability limitations in the existing network. The NOA ensures that assets are built at the right time, maximising their lifetime benefit, and ensures that the recommendations we make result in a network for the future that provides the most value to consumers. Whilst the NOA recommends the most economic and efficient network upgrades for the whole of Great Britain it is not intended to address network compliance. Additional onshore reinforcements may be identified for network compliance, which is an integral part of designing a secure, operable transmission system capable of facilitating net zero.



System-wide view

The 2030 onshore transmission network will look very different to the one we see today. To meet the 2030 ambitions and facilitate the delivery of the offshore wind in scope of the HND, 94 reinforcement projects totalling £21.7 billion are required to be delivered by the end of the decade. These range from very small upgrades to large new transmission infrastructure such as new onshore routes or subsea cables with the sole purpose of transporting electricity from where it is produced to where there is demand for it. This investment is driven by the increasing level of renewable generation connecting to the system, often in places that have historically seen no requirement for onshore transmission network.

Of the 94 reinforcements required by 2030, many must be delivered earlier to maximise consumer benefit. The NOA process provides this additional insight via an optimal date; ensuring that reinforcements are recommended to be delivered when they are needed and that the costs of building them outweigh the costs of managing power flows around the network without them in place. A full list of the 94 options required to meet 2030 targets and their optimal delivery dates can be found in Appendix 1.

Almost 90 per cent of the reinforcements are expected to be delivered and in place by 2030. However, we have identified 11 reinforcements that are required for 2030 but will not be delivered in time under the current regulatory and consenting processes. Accelerating these projects will require the UK Government intervention suggested in the April 2022 *BESS* and equivalent activities in Scotland.

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System-wide view

Slightly different approaches have been taken to the assessment of the onshore reinforcements and the regional offshore network designs against the four design objectives due to the different levels of maturity of the processes. The majority of the onshore reinforcements have consistently been identified through the NOA process as delivering the most value to consumers through their ability to help reduce the cost of network constraints and the HND reaffirms this. Those in this category have been assessed against the four design objectives in their development as the TOs consider the environmental, social, cost and deliverability impacts of the options during their option development processes. A higher level of assessment has been carried out on new network needs that are required for 2030, which are in the very early stage of their development. The TOs will further develop these reinforcements (including consideration of offshore and onshore options) plus others in the very early development stage. As part of that they will carry out more detailed analysis in these four design objective areas.

Planning the development of the transmission network does not stop in 2030 and the *NOA 2021/22 Refresh* publication has stated the need for the continual development and coordination of network reinforcements as we transition to net zero. Looking beyond 2030, the *NOA 2021/22 Refresh* has signalled a requirement for a further 17 onshore reinforcement options at a cost exceeding £6 billion. These reinforcements, alongside new proposals, will be evaluated to provide a coordinated view beyond 2030 in our HND follow up process.

Figure 9 illustrates the upgrades to the existing transmission system in dark grey, new onshore transmission reinforcements and subsea cables previously recommended in NOA in purple and light green respectively. New network needs are shown as dotted purple lines and the coordinated offshore network in red and blue, representing the type of technology proposed.

Please note the map is illustrative and highlights an identified need to transmit volumes of energy from point A to point B and does NOT represent specific routes. The next steps involve more detailed network design which will include specific locations and designs for projects. These will be designed and consulted on in future by the organisations appointed to fulfil the needs identified.

More detail on the onshore transmission system upgrades required to meet our 2030 ambitions can be found in the *HND*, its comprehensive annex on onshore and offshore network recommendations and the *NOA 2021/22 Refresh* publication. For more detail on the onshore requirements up to and beyond 2030, please see our *NOA 2021/22 Refresh* publication.[43]

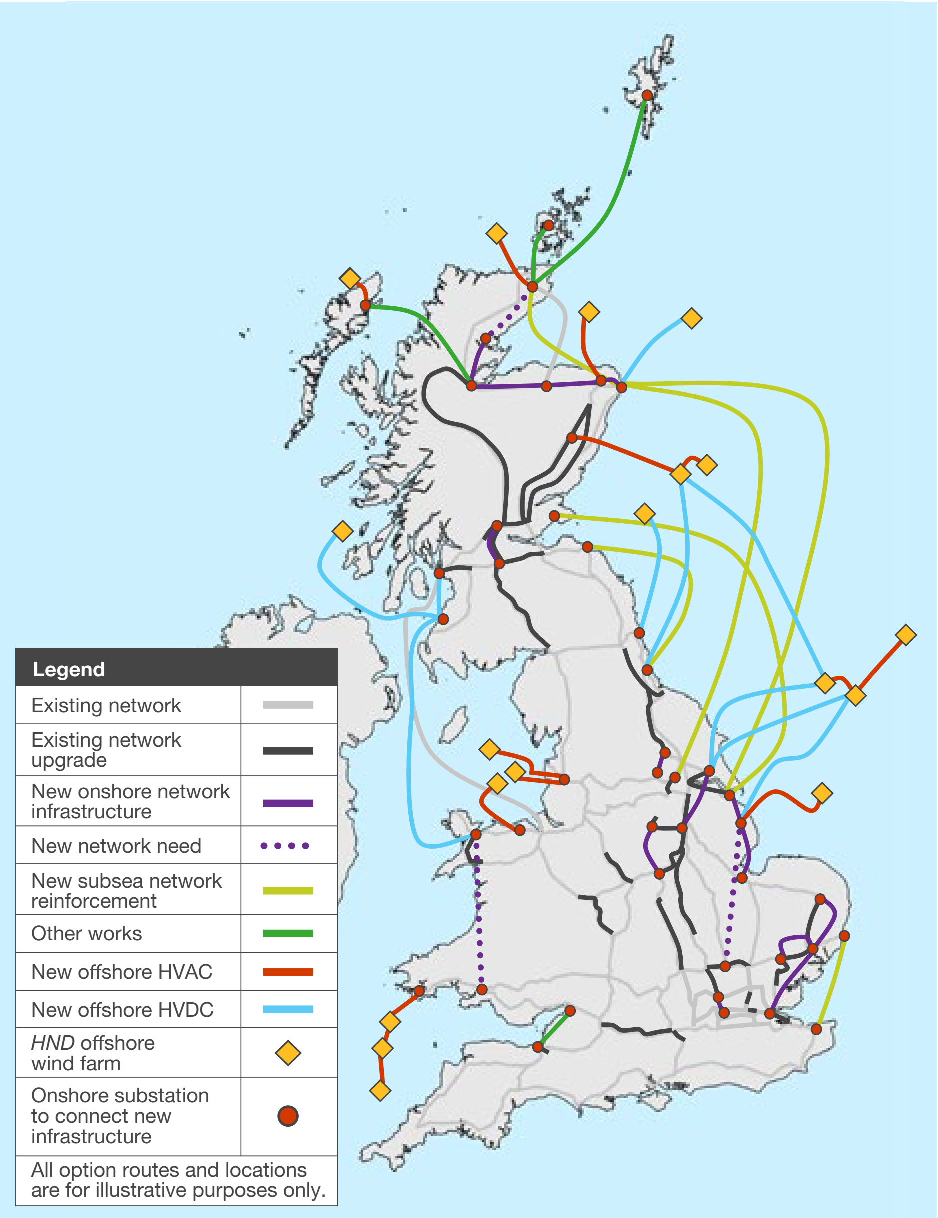
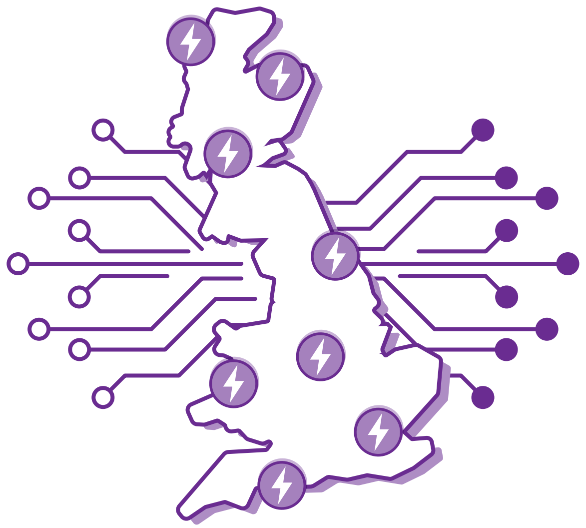


Figure 9: Illustration of key wider network reinforcements

43 nationalgrideso.com/research-publications/network-options-assessment-noa

Changes to industry codes, standards and licences

We have developed initial views on the key barriers and enablers for successful implementation of the HND plus the potential changes required to the relevant industry codes, standards, and licences. These views are informed by Ofgem's *Consultation on our Minded-to Decision on Anticipatory Investment and Implementation of Policy Changes* related to the Early Opportunities workstream[44] and Ofgem's *Minded-to Decision and further consultation on Pathway to 2030* related to offshore delivery models.[45] They are also subject to further refinement as we continue to develop our own thinking, including via engagement with relevant and interested stakeholders.



Connection contract update programme

Ofgem's minded-to decision on offshore delivery models and our HND recommendations now need to be brought together and translated into connection contract updates for in scope developers. This is to identify:

- The works to be delivered by each party.
- The works each party is dependent upon prior to their connection.
- The delivery date of those works.
- Any other required information, such as any access restrictions related to those works.

In addition, there are risks and uncertainties that need to be managed via the connection contracts. We are currently working on a connection contract update programme with the aim to provide updated connection contracts to in scope developers in the autumn, and to commence tripartite discussions with those developers and the relevant TO(s) in the summer. These timescales are subject to further clarity being provided, such as which party is delivering which component of the offshore transmission system and may result in connection contract updates extending beyond the autumn. We will work with Ofgem and developers to agree how coordinated elements of the HND will be delivered so that connection contracts can be updated as soon as practicable.

The exception to the above timescales relates to developers within the Celtic Sea. For those developers we will update connection contracts after the conclusion of the follow up HND process[46] and/or once leases for the region have been awarded. As we have previously communicated, at an appropriate time we also plan to terminate connection contracts with ScotWind developers that did not receive a seabed lease.

44 www.ofgem.gov.uk/publications/offshore-coordination-early-opportunities-consultation-our-minded-decision-anticipatory-investment-and-implementation-policy-changes
45 ofgem.gov.uk/publications/minded-decision-and-further-consultation-pathway-2030
46 The follow up HND process is further discussed on page 70.

Changes to industry codes, standards and licences

Code, standard and licence change recommendations

Our initial view and recommendations are that changes will be required across a number of codes, standards and licence obligations to enable the HND and Ofgem's minded-to offshore delivery model. These include:

- **System Operator-Transmission Owner Code** changes to introduce new concepts such as offshore TOs for non-radial connections and offshore transmission interface sites.
- **Security and Quality of Supply Standard (SQSS)** changes to increase the limit on the infeed risk of HVDC circuits to allow higher capacities to be transported on each circuit and also how some of the HVDC network configurations in the HND are treated, such as bipoles. This will build on the changes consulted on and set out in our SQSS review.[47]
- **Grid Code** changes require further consideration and will be needed to help ensure that where the offshore network is built in a modular way the different parts of the network can operate effectively together and in line with the SQSS.
- **Access Rights** will need further engagement and assessment to understand whether established queue-based principles, where an earlier contract start date can mean fewer or less onerous access rights restrictions, are relevant for the non-radial components of the offshore transmission system. We do not anticipate any changes being required in respect of access rights on the onshore transmission system, or on the radial components of the offshore transmission system.
- **Network Charging** changes will be needed to reflect the network configurations in the HND.
- **User Commitment** changes are likely to be required to define anticipatory investment as a concept and to extend user commitment arrangements.[48]
- **Queue Management** changes related to the offshore delivery model are expected to be incorporated into the code modification that is already planned on the broader queue management principles.

It is important that the network components within the HND are classified as offshore transmission or onshore transmission as soon as possible and also whether offshore transmission is radial or non-radial. This will be an important distinction as there may be different impacts on codes, standards and/or connection contracts depending on whether a particular network component is classified as radial or non-radial offshore transmission or onshore transmission. We look forward to supporting Ofgem with technical information to help inform their decision-making process on asset classification.

Further information on each of these topics and others can be found in the *Industry Code, Standard and Licence Recommendation report*. We would welcome your feedback on its content. The report sets out information on how you will be able to engage with potential changes to codes and standards.

47 nationalgrideso.com/calendar/nets-sqss-review
48 Customers are required under User Commitment arrangements to financially secure spend in relation to their connection contract.

Working with stakeholders to develop the Holistic Network Design

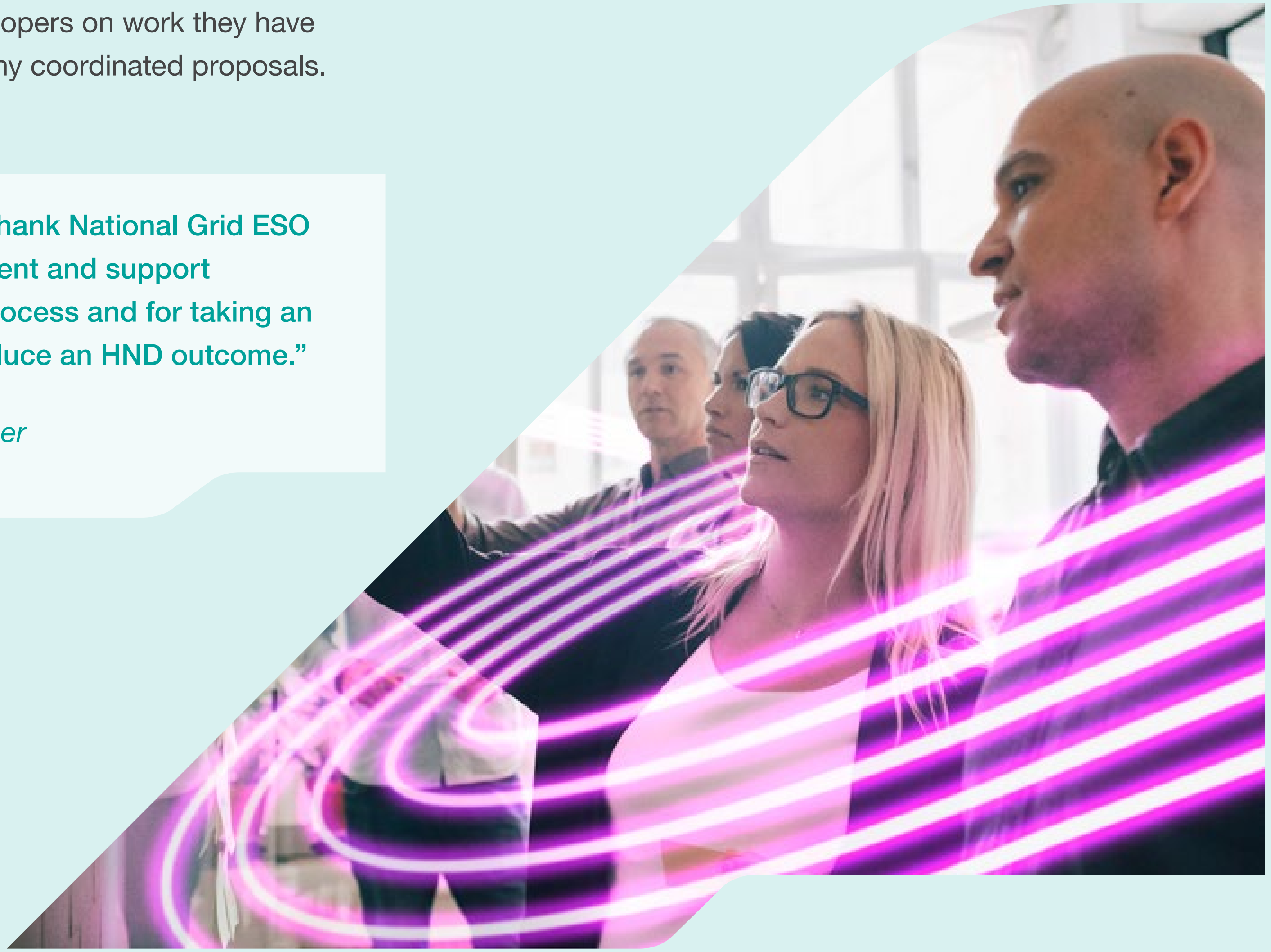
Stakeholder input, review, and feedback: what have we worked with stakeholders on?

We could not have delivered the HND publication package without the input, feedback, challenge and review from stakeholders throughout its development.

We engaged and worked in collaboration with stakeholders on the following areas when developing the HND:

- Projects in scope: selection and decision.
- Offshore unit costs.
- HND Methodology.
- Environmental and community constraints.
- Interface site shortlisting and constraints at sites.
- Draft recommended design.
- Potential changes required to industry frameworks to enable the recommended design to be delivered.
- Input from offshore developers on work they have completed to date and any coordinated proposals.
- TO project options.

> We would like to thank National Grid ESO for their engagement and support throughout this process and for taking an active role to produce an HND outcome."
>
> *- Offshore developer*



Working with stakeholders to develop the Holistic Network Design

Feedback window themes - May 2022

On 29 April 2022 we opened a two week feedback window on the draft recommended design and received **41 responses**. The themes can be summarised as follows:

- Detailed environmental constraints, which can be taken forward into the DND, were provided and will be packaged up to be used in the DNDs.
- Supply chain and how this is set up to deliver the recommended design.
- Framing of recommendations and the importance of setting the next stage of the process up for success.
- The need for clarification on the next steps for implementation including the delivery model.
- Variation of and further considerations on recommended designs were requested.
- The importance of not closing off options for future coordination, with the remaining ScotWind developers to be factored into the follow up process.
- The need for a smooth handover into the DND following the publication of the *HND* report.
- The need for the commitments outlined within the *BESS* to be delivered to ensure the design is deliverable by 2030.

Feedback received at each stage of the formation of the HND has been summarised within the *Stakeholder Approach, Engagement and Feedback report* and where information has been non-confidential, we have also added feedback and responses in more detail.

> “Industry needs to accelerate delivery of projects, collaborate and coordinate across the industry and provide certainty to developers and the supply chain to enable reaching this target. The HND is an opportunity to deliver on these principles and is fundamental to achieving the UK and Scottish governments’ 2030 target, and ultimately net zero”
>
> *- Transmission Owner*

> “The BRAG scoring of each of the options do not differ in respect of Scottish interests and therefore we are supportive of the overall consideration of a design, which enables the GB energy system to operate most reliably”
>
> *- Environmental stakeholder*

What happens next

The publication of this report marks a first, significant step towards a more centralised and strategic approach to transmission network planning. It lays the foundations for a plan to facilitate delivery of the UK Government 's ambition for 50 GW of offshore wind by 2030, with substantial benefit to consumers and a reduction in the impact on the environment and communities, compared to the status quo.

Both we and our stakeholders understand substantial work needs to continue at pace to deliver this plan. We will drive progress where this is within our remit, under the overarching direction from the OTNR:

- We are currently working on a connection contract update programme with the aim to provide updated connection contracts to in scope developers in the autumn, and to commence tripartite discussions with those developers and the relevant TO(s) in the summer. These timescales are subject to further clarity being provided, such as which party is delivering which component of the offshore transmission system and may result in connection contract updates extending beyond the autumn.
- The information provided in the HND will inform the DND, which will set out the next level of detail for the required network assets. It is at this stage of the process that route corridors and technology choices are chosen, and statutory consultation is carried out. The DND will be progressed by the party responsible for delivering each asset. Onshore transmission will be delivered via the usual onshore arrangements (via the incumbent TO under their price control arrangements, or subject to onshore competition). For offshore this was indicated in the recent minded-to decision from Ofgem on offshore delivery models. Ofgem has stated they will work with the ESO and developers to agree how any non-radial offshore transmission system will be delivered once the HND is finalised.
- There are many remaining uncertainties related to the design and delivery model in the context of codes and standards. We are therefore proposing a period of further analysis and stakeholder engagement prior to formal code and standard modifications. As such, we welcome feedback and are planning to further engage with industry stakeholders throughout summer 2022 with the aim of formally raising any necessary code and standard modifications in autumn 2022, subject to an assessment of urgency and priority. We will work with industry stakeholders, including via the OTNR Expert Advisory Group code and standard subgroup on when code and standard changes are necessary and the content of the code and standard changes.

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What happens next

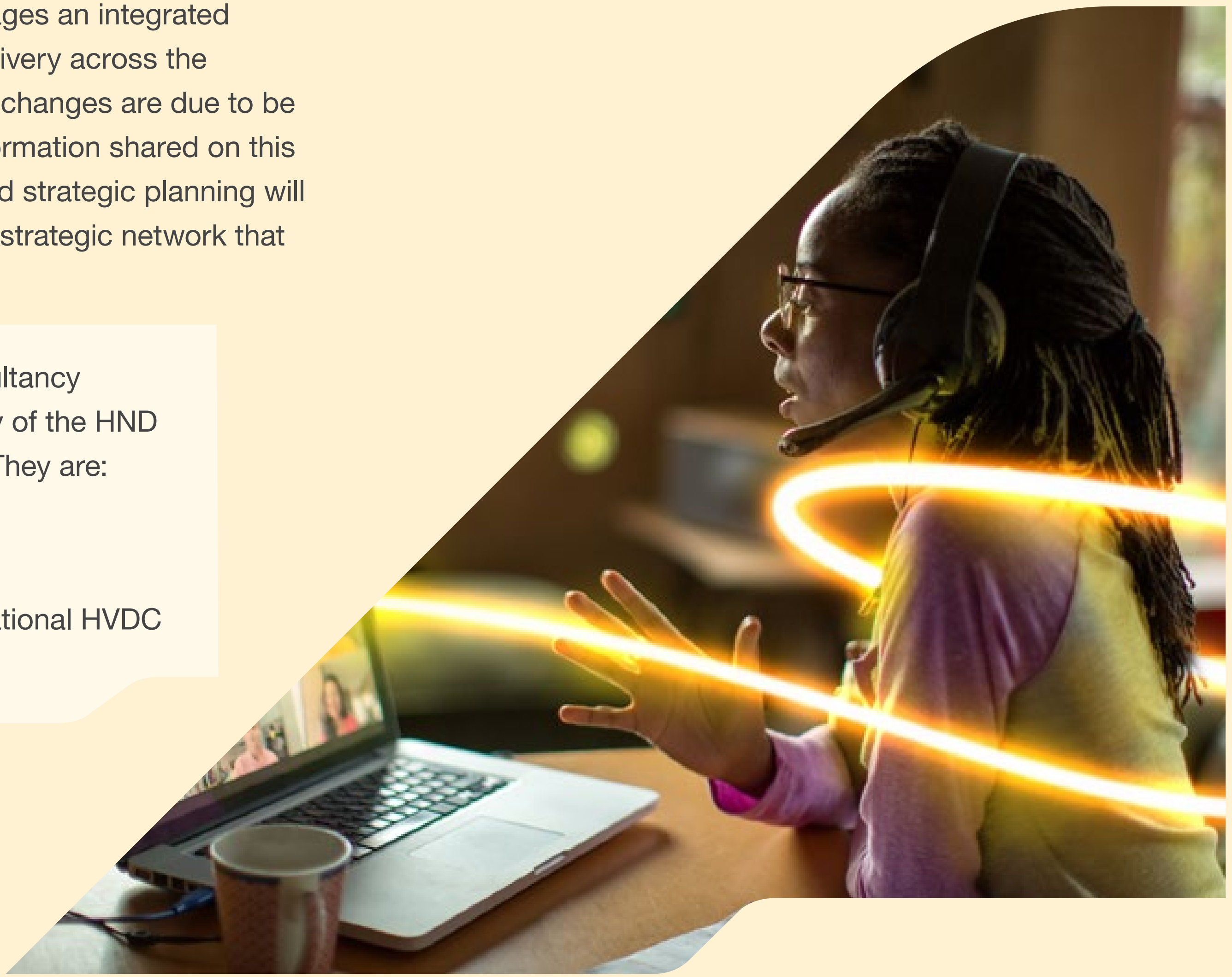
- Further information on our plans for our code and standard modification programme engagement throughout summer 2022 will be made available in due course.

- We are also currently developing the HND follow up process, which aims to provide in scope developers with recommendations in Q1 2023. We will start this process following this publication in July 2022. This will include the remaining ScotWind leaseholders and any capacity made available through the ScotWind clearing process. It is also expected to include approximately 4 GW of Celtic Sea capacity. The details of the follow up process, including confirmation of scope, a more detailed timeline and other key aspects, such as the methodology to be used for the process, will be communicated in the summer. We will work closely with the TOs and developers involved to support further progress towards net zero targets.

- This HND and the follow up design process are initial and significant steps towards centralised strategic network planning. The HND follow up design is planned for delivery in the first quarter of 2023, which will include iterations towards the Centralised Strategic Network Plan (CSNP) proposed by Ofgem in their Electricity Transmission Network Planning Review (ETNPR).[49] The CSNP envisages an integrated approach to network design and delivery across the onshore and offshore networks and changes are due to be implemented by 2024 with more information shared on this process in summer 2022. Centralised strategic planning will be an important change to deliver a strategic network that enables net zero by 2050.

We would like to thank our consultancy partners who have made delivery of the HND and these documents possible. They are:

- Imperial College London
- RPS
- Guidehouse
- Atkins
- WSP
- The National HVDC Centre



49 https://www.ofgem.gov.uk/publications/consultation-initial-findings-our-electricity-transmission-network-planning-review

Continuing the conversation

Email us with your views on offshore coordination or any of our future of energy documents at box.OffshoreCoord@nationalgridESO.com and one of our team member will get in touch.

For further information on the project and current and past events please visit: www.nationalgrideso.com/future-energy/projects/offshore-coordination-project

Write to us at:

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CV34 6DA

@ng_eso

National Grid ESO

National Grid ESO

50 These reports are: Holistic Network Design Report, Industry Code, Standard and Licence Recommendation Report and Stakeholder Approach, Engagement and Feedback Report.

51 assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1059676/otnr-central-design-group-network-design-tor.pdf - dd. 01 March 2022.