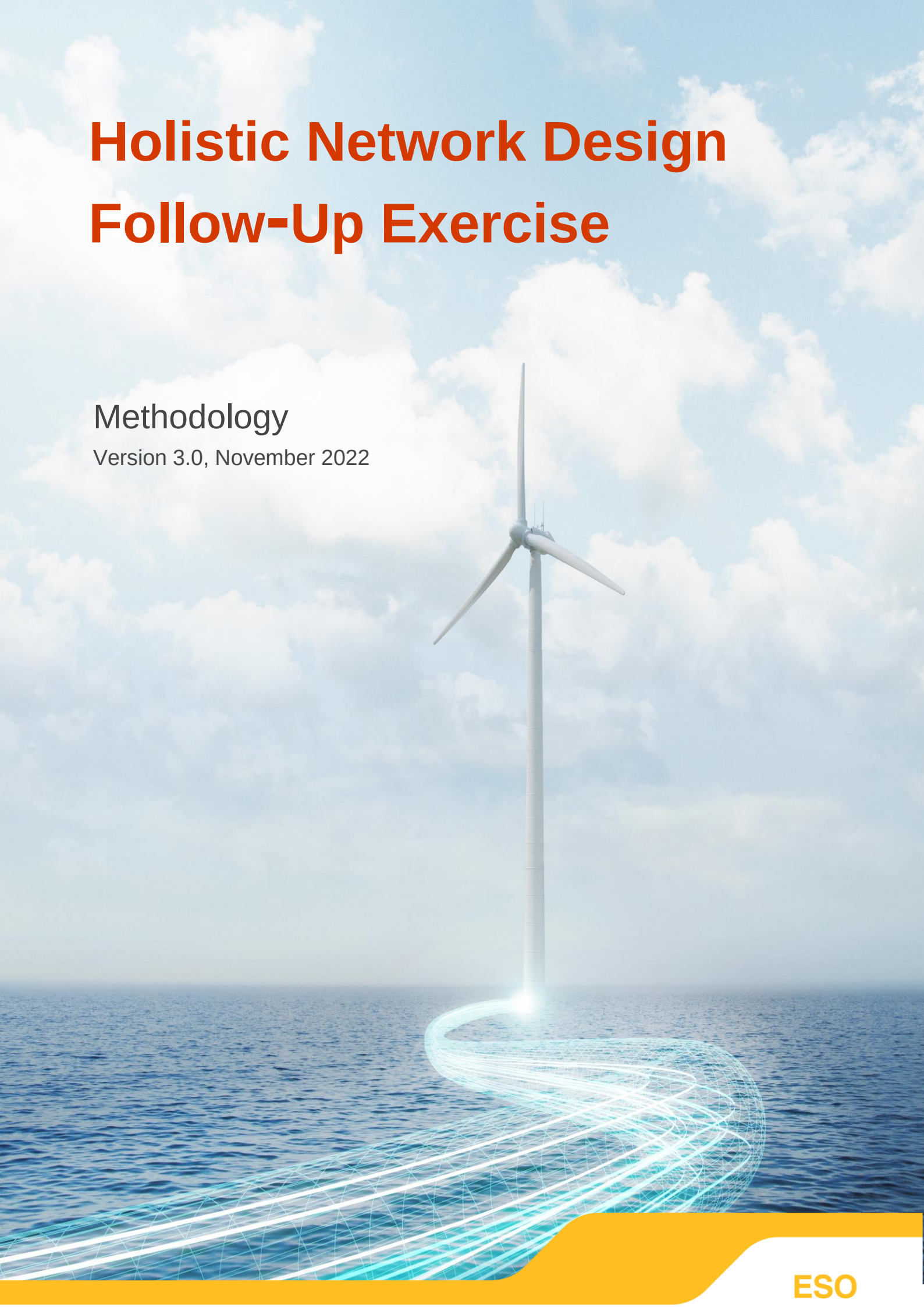
Holistic Network Design Follow-Up Exercise

Methodology

Version 3.0, November 2022



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Welcome to our Holistic Network Design Follow-Up Exercise (HNDFUE) Methodology document.

This document provides an overview of our approach to developing HNDFUE design, which is the follow-up to the initial Holistic Network Design (HND) that was delivered in July 2022. The HNDFUE design process considers the outcomes of the HND carefully when determining the follow-up design.

The HND and HNDFUE form part of the Department for Business, Energy and Industrial Strategy's (BEIS) Offshore Transmission Network Review (OTNR).

The Executive Summary provides an overview of the design process for the HNDFUE and highlights any changes in the methodology compared to the methodology used to develop the Initial HND. The Executive Summary has been written for any stakeholder who may have an interest in the design process. The full document provides further detail on the design process and explains the steps taken to ensure design objectives are met. This further detail is aimed at stakeholders that are part of the energy industry and therefore provides more detailed technical explanations.

This document is the third version of the HND Methodology, that has a revised name of HNDFUE Methodology. The first HND Methodology for the initial HND was published in January 2022 and a revised second version of the HND Methodology was published in June 2022. This document has now been updated to reflect changes which have been made for the HNDFUE and as a result of feedback from the HND developers, Transmission Owners and Central Design Group (CDG) Environmental Subgroup.

Executive Summary

Offshore wind has been identified as a critical technology in achieving net zero greenhouse gas emissions by 2050. To help realise this target, a step-change in both the speed and scale of deployment of offshore wind is required. One of the challenges to delivering the ambition for offshore wind deployment in the timescales required will be making sure that the offshore and onshore transmission network enables this growth in a way that is efficient for consumers and takes account of the impacts on communities and the environment.

The Electricity System Operator (ESO) Offshore Coordination Project, which contributes to the Department for Business, Energy and Industrial Strategy (BEIS) led Offshore Transmission Network Review (OTNR)[1], was set up in March 2020. Phase 1 of the project progressed at pace to assess the costs and benefits of a coordinated offshore transmission network. The purpose of the coordination was to connect windfarms to the onshore network in a more efficient manner than the current radial (point-to-point) approach. Phase 1 also assessed the technical and procedural considerations to achieve coordination. In December 2020 we published our Phase 1 Final Report[2].

As part of Phase 2 of the project, BEIS and the Office of Gas and Electricity Markets (Ofgem) requested that we deliver a Holistic Network Design (HND) for a coordinated onshore and offshore network. The HND supports the government ambition for 50 GW of offshore wind by 2030 for Great Britain, including 11 GW by 2030 for Scotland (Scottish Government target), as well as contributing to the Sixth Carbon Budget targets for 2035 and net-zero by 2050 for Great Britain and by 2045 for Scotland (Scottish Government target). In July 2022 we published our HND recommendations which, when compared to connecting wind farms radially, should:

- Save consumers £5.5 billion (£2.18 per year for every British energy consumer) in costs from 2030 by increasing network capacity and reducing the need to pay to reduce the output of windfarms when wind generation exceeds network transmission capacity (we call this paying "constraint costs").
- Reduce the impact on the seabed with up to a 30% smaller footprint from cables to shore.
- Reduce CO_2 emissions by 2 million tonnes between 2030 and 2032 - equivalent to grounding all UK domestic flights for a year.

As part of Phase 3 of the project, the ESO is now considering additional offshore wind farms in Scotland and in the Celtic Sea. This HND follow-up exercise (HNDFUE) will further support the Government's previously stated government targets for offshore wind and net zero. The HNDFUE will facilitate an economic, efficient, operable, and coordinated National Electricity Transmission System (NETS) (including offshore and associated onshore assets required to connect in scope projects). This will be achieved in a way that minimises the impact on the environment and communities by assessing options against the Network Design Objectives depicted in Figure 1. This includes connections, their associated system needs and the boundary capability requirements necessary to connect in scope offshore generation.

[1] https://www.gov.uk/government/groups/offshore-transmission-network-review
[2] https://www.nationalgrideso.com/document/183031/download

The detailed scope of the HNDFUE is defined in the Terms of Reference (ToR) set out by the OTNR project board. The terms of reference also set out **four network design objectives**, that are to be considered during the design process. These objectives, shown in Figure 1, are to be considered on an equal footing:

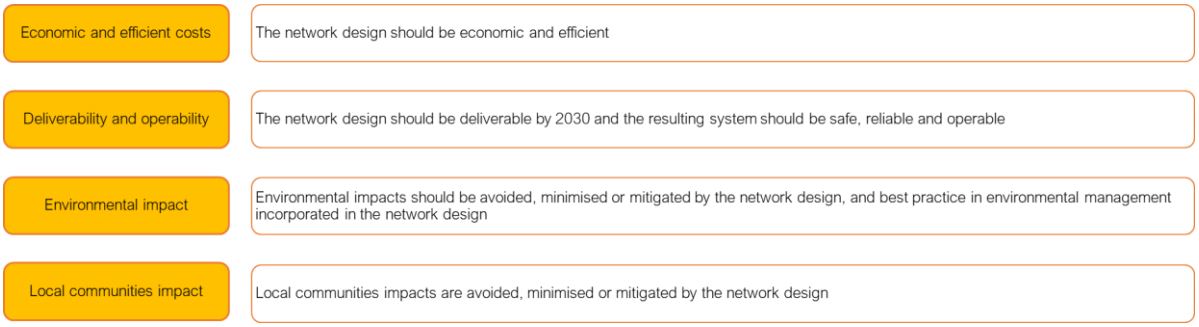


Figure 1 Network Design Objectives of the HNDFUE

The HNDFUE is being developed using a structured design approach created by the ESO and discussed with Transmission Owners (TOs), BEIS, Ofgem, in scope developers, and environmental and community representatives. The design process consists of five key building blocks, shown in Figure 2:

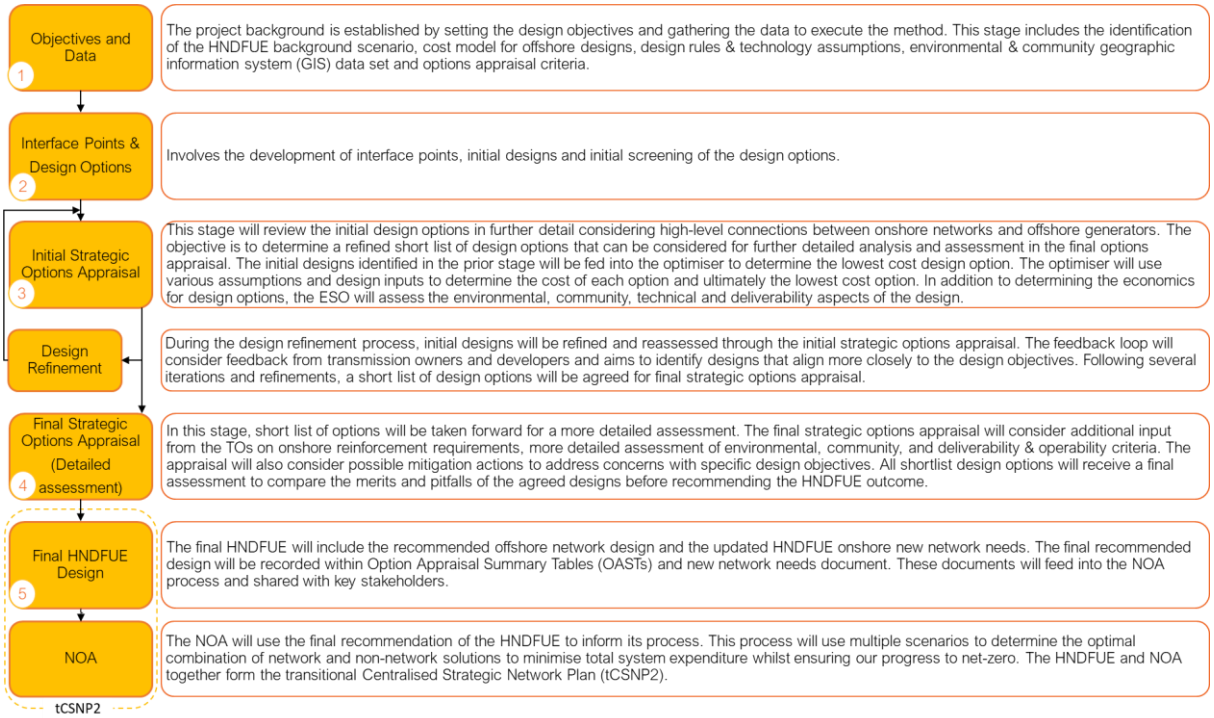


Figure 2 Overview of HNDFUE process

The resulting coordinated offshore network design and newly identified onshore network requirements will form the HNDFUE design. The New Network Needs identified through the HNDFUE will be further developed later through the Network Options Assessment (NOA) as part of the second Transitional Centralised Strategic Network Plan (tCSNP2).

Considering the wide range of stakeholders impacted by the HNDFUE, BEIS requested that we use a Central Design Group (CDG) as a forum to consult the onshore TOs, in scope developers, environmental and community representatives.

Holistic Network Design Follow-Up Exercise Methodology Changes

The Holistic Network Design Follow-Up Exercise (HNDFUE) follows a methodology similar to the original HND methodology[3]. In response to feedback from stakeholders, the methodology has been updated to enable a more collaborative and efficient design process. There are five primary changes to the methodology from the HND:

1. The economic assessment (step four in the HND) will not be a standalone step in the HNDFUE process but will be included in both the initial and final strategic options appraisal. The analysis for the initial strategic options appraisal will cover all four network design objectives and will seek to consider the high-level impacts of each design option. The final strategic options appraisal will then comprise a more detailed economic analysis and assessment against the other network design objectives.
2. The purpose of the initial strategic options appraisal process will be to reduce the number of options taken forward to detailed study, resulting in fewer options being taken forward to the final strategic options appraisal stage. This will create additional time to undertake more detailed assessment on the short-listed design options which are selected from the Initial Strategic Options Appraisal Process. Detailed studies, including the Transmission Owner (TO) Customer Connection Studies, will take place later in the process than for the HND (in the final strategic options appraisal) and only be conducted on the shortlist of options from the initial strategic options appraisal.
3. In order to better facilitate discussions with the supply chain and to understand deliverability considerations in more detail, a deliverability forum has been created. The purpose of this group is to support the development of the HNDFUE Design Rules and Technology Assumptions and HNDFUE Deliverability Options Appraisal Criteria. The Deliverability Forum should also be able to provide expert advice on deliverability criteria at option appraisal workshops.
4. The first HND included an assessment of onshore reinforcements in a refresh of the Network Options Assessment (NOA process). The HNDFUE cannot include a refresh of the NOA process as there has not been a subsequent NOA process since the delivery of the initial HND. The HNDFUE will still assess wider network needs through the evaluation of options at the initial and final options appraisal process steps. This assessment will include the development of a set of new network needs if there are no known reinforcement options available. The new network needs from the HNDFUE will be further assessed against a range of alternative options in the next iteration of the NOA later in 2023. In concert, the output of the HNDFUE and the next iteration of the NOA will form the second iteration of the 'Transitional Centralised Strategic Network Plan' (tCSNP2).
5. Finally, the publication documents for the HNDFUE will differ from the HND. The Terms of Reference (ToR) for the HNDFUE does not currently include requirements for publication of the results. While an optimal radial design was developed for the HND and communicated to stakeholders, the HNDFUE will not produce a radial counterfactual design for HNDFUE in the same way. Radial design options will be considered alongside coordinated design options as part of a single process.

[3] https://www.nationalgrideso.com/document/239466/download

Introduction

Purpose of the Holistic Network Design Follow-Up Exercise

The purpose of the Holistic Network Design Follow-Up Exercise (HNDFUE) is to provide network design recommendations for in scope projects that were not fully considered in the Holistic Network Design (HND). The HNDFUE will be delivered by the Electricity System Operator (ESO) in consultation with the Central Design Group (CDG). This will be done in a holistic way, taking account of the four network design objectives (economic and efficient, deliverable and operable, minimising environmental impact, minimising community impact). This design supports the Government ambition for 50 GW of offshore wind by 2030 for Great Britain including 5 GW of Great Britain's floating wind, as well as contributing to the Sixth Carbon Budget targets for 2035 and net-zero by 2050 for Great Britain and by 2045 for Scotland (Scottish Government target).

1. The purpose of the CDG is to act as a vehicle for the ESO to consult and collaborate with Transmission Owners (TOs), in scope developers, environmental and community representatives.
2. The purpose of this HNDFUE methodology document is to provide an overview of the methodology that we are following and to show how the network design objectives are considered.

Background

3. Offshore wind has been identified as a critical technology in achieving net zero greenhouse gas emissions by 2050. In order to realise this target, a step-change in both the speed and scale of deployment of offshore wind is required. Delivering the ambition for offshore wind deployment in the timescales required will be a challenge and will rely on an offshore and onshore transmission network that enables this growth. The transmission network needs to be expanded in a way that is efficient for consumers and considers the impacts on communities and the environment.
4. The ESO Offshore Coordination Project, which contributes to the Offshore Transmission Network Review (OTNR), was set up in March 2020. Phase 1 of the project assessed the costs and benefits of a coordinated offshore network compared to the current non-coordinated radial approach, the technical considerations to achieve such a network, and how the offshore connections regime could change to drive greater coordination.
5. The Department for Business, Energy and Industrial Strategy (BEIS) and the Office of Gas and Electricity Markets (Ofgem) asked the ESO to carry out further work as part of the OTNR. We are working closely with the OTNR project partners (The Crown Estate, Crown Estate Scotland, The Department for Environment, Food and Rural Affairs (Defra), Marine Scotland, The Marine Management Organisation, The Department for Levelling Up, Housing and Communities, Ofgem, The Welsh Government) and wider stakeholders to realise the economic, local, and environmental benefits of a coordinated approach. Our current work involves delivering the ESO led activities of the OTNR across three workstreams and time horizons:

    - **Early Opportunities** – working with developers of projects that are fairly well advanced in their development, the Transmission Owners (TOs) and other stakeholders to assess the costs, benefits and various implications of projects that have put themselves forward to explore early coordination. Also identifying and progressing required changes to industry codes, standards, and processes.
    - **Pathway to 2030** – delivering a holistic network design for a coordinated onshore and offshore network to 2030 and assessing and progressing the required changes to relevant industry codes and standards.
    - **Enduring Regime** – engaging with the Enduring Regime workstream of the OTNR, contributing to the discussion and development of relevant areas. This will be further shaped by the conclusions of the recent BEIS consultation[4] on the Enduring Regime and Multi-Purpose Interconnectors (MPIs).

[4] https://www.gov.uk/government/consultations/offshore-transmission-network-review-proposals-for-an-enduring-regime

6. In July 2022, the Pathway to 2030 Holistic Network Design Report was published. The HND demonstrated that:

   - 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 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 and a reduction in the impact on the environment.
   - 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.
   - 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 British Energy Security Strategy (BESS).

   The HND provides the foundation for the future, which this HNDFUE process will develop to plan for the connection of further offshore wind projects that were not in scope of the HND.

7. This methodology has been developed based on the OTNR HNDFUE Terms of Reference (ToR) developed for the Pathway to 2030 workstream. The ToR is included in Appendix III of this document. The HNDFUE ToR, that has been agreed with the OTNR partners, sets out that the HNDFUE should provide the following:

8. The ESO, in consultation with the CDG, will deliver the HNDFUE that facilitates an economic, efficient, operable, and coordinated National Electricity Transmission System (NETS) (including offshore and associated onshore assets required to connect in scope projects). The HNDFUE, should minimise the impact on environment and communities (where possible) by considering different design options against the Network Design Objectives. This includes connections and associated system needs and boundary capability requirements necessary to connect in scope offshore generation to facilitate the pace and certainty required to deliver the government's offshore wind ambitions.

9. The HNDFUE ToR sets out four network design objectives, which are to be considered on an equal footing:

   - **Economic and efficient costs** – the network solution should be economic and efficient.
   - **Deliverability and operability** – the network solution should contribute to delivery of Sixth Carbon Budget and net zero ambition, and the resulting system should be safe, reliable and operable.
   - **Environmental impact** – environmental impacts should be avoided, minimised or mitigated by the network design, and best practice in environmental management should be incorporated into the network design.
   - **Local communities' impact** – impacts on local communities should be avoided, minimised or mitigated by the network design.

Engaging stakeholders in developing the design

10. The development of a coordinated onshore and offshore NETS impacts a wide range of stakeholders; therefore, stakeholder engagement is critical to the successful delivery of the HNDFUE. The stakeholder engagement approach aligns with the HNDFUE ToR, that specifies which stakeholders should be engaged throughout the design process.

11. Although the HNDFUE is led by the ESO, several partners and stakeholders are engaged at regular touchpoints. A CDG consisting of representation from key stakeholders, including the transmission owners (National Grid Electricity Transmission, SP Transmission, Scottish and Southern Electricity Networks - Transmission), community representatives, environmental representatives, and in scope developer representatives has been established to support the development of HNDFUE and act as a channel for the ESO to consult and collaborate with these stakeholders. BEIS, Ofgem and the Scottish and Welsh Governments sit on the group as observers. The specific roles of the ESO, CDG and CDG subgroups are described below.

The ESO – responsible and accountable

12. The ESO, in consultation with the CDG, will deliver a design recommendation that ensures an economic, efficient, operable, and coordinated offshore and onshore NETS that minimises impacts on the environment and local communities. The design will include connections and associated strategic onshore infrastructure necessary to connect offshore generation in order to facilitate the pace and certainty required to deliver the 2030 offshore wind targets and the 2045 and 2050 net zero targets.

The CDG – consulted and informed

13. The CDG will act as a vehicle for the ESO to consult with transmission owners on the HNDFUE, and to consult with stakeholder groups as the HNDFUE is developed. The CDG members will meet on a periodic basis to discuss key design options and considerations. Five CDG subgroups, that align with the stakeholder engagement requirements set out in the HNDFUE ToR, have been established to focus on various objectives of the design. The CDG subgroups provide a focused forum to receive expert input and formal advice on specific elements of the design. In addition to the subgroups, we have established a developer forum for in scope developers to provide feedback. The CDG subgroups and forums are described below:

    - **Stakeholder and communications subgroup** – the purpose of this subgroup is to enable the ESO to consult with the transmission owners and other stakeholders on communication and engagement plans for the delivery of the HNDFUE. This engagement helps to ensure clarity and continuity for wider stakeholders.
    - **Commercial subgroup (as required)** – the purpose of this subgroup is to ensure the industry Codes, Standards and Licence Recommendations are comprehensively considered and provide advice on the commercial impacts of and interactions with the HNDFUE output, for example in respect of codes and connections.
    - **Environmental subgroup** – the purpose of this subgroup is to bring together key environmental stakeholders that provide advice to the CDG on environmental impacts of the technically viable options being considered in developing the HNDFUE.
    - **HND working level subgroup –** the purpose of this subgroup is to meet weekly with representatives from the TOs who are involved in the work being undertaken and to ensure any issues are addressed ahead of the CDG meetings.
    - **Deliverability subgroup -** the purpose of this group is to support the development of the HNDFUE Design Rules and Technology Assumptions and HNDFUE Deliverability Options Appraisal Criteria. The Deliverability Forum should also be able to provide expert advice on deliverability criteria at option appraisal workshops.
    - **Developer forum** – the purpose of this group is to bring together in scope developers to have collective discussions on the development of the HNDFUE.

Holistic Network Design process steps

Overview of process

14. The design process considers each of the design objectives (economic and efficient, deliverable and operable, minimising environmental impact, minimising community impact) on equal footing and builds on learning from developing the first Holistic Network Design (HND). Similarly, to the HND, the Holistic Network Design Follow-Up Exercise (HNDFUE) design process involves the designing assessing a wide variety of network designs before recommending a preferred final design. The final design consists of a coordinated set of onshore network requirements and a complementary offshore network design, which may include various degrees of interconnection across offshore windfarms/generators and in some cases may include radial connections between windfarms and the onshore transmission network.
15. Overall, the design process consists of five key phases shown in Figure 3. The design process has been developed in collaboration with the transmission operators, in scope developers, environmental and community representatives, and considered feedback from stakeholders involved in developing the first HND.
16. Stakeholder feedback forms a key part of the design process. Transmission Owners (TOs), in scope developers, environmental and community representatives will be engaged at various stages in the design process.

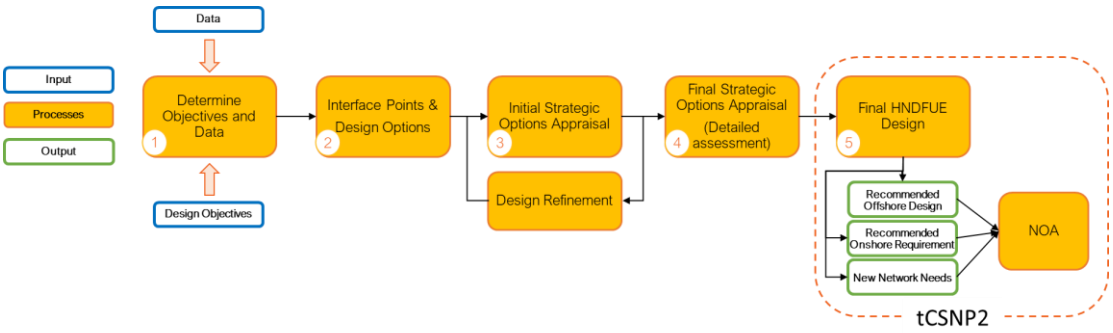
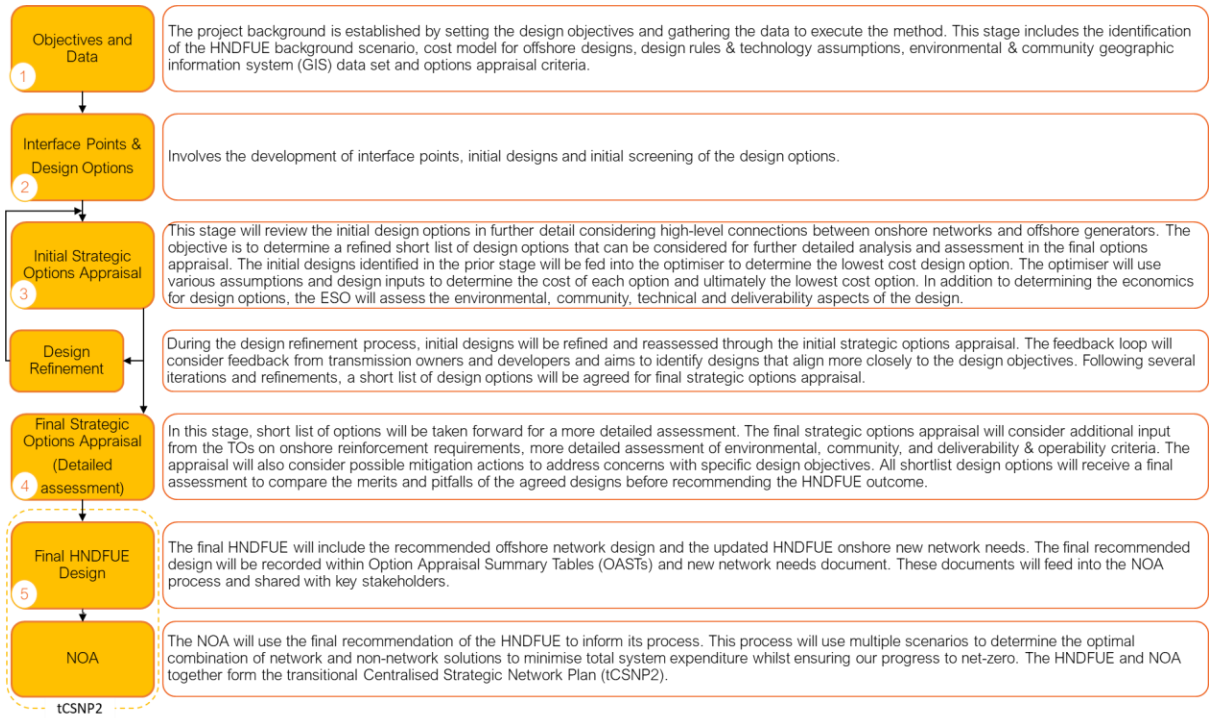


Figure 3 Overview of HNDFUE process

A brief explanation of each phase is provided in Figure 4.



A more detailed schematic of the HNDFUE process is presented in Appendix II

Figure 4 HNDFUE approach

Defining objectives and data inputs

Figure 5 shows the initial step in the context of the overall HND process.

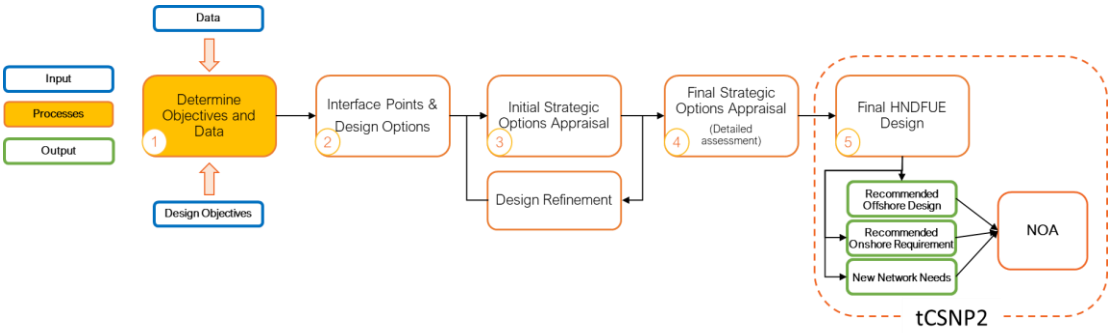


Figure 5 Step 1 - Defining objectives, approach, and inputs

Approach to HNDFUE network design objectives

17. The design objectives were set by the Offshore Transmission Network Review (OTNR) project board and documented in the HNDFUE Terms of Reference (ToR), which is included in Appendix III.
18. In developing the HNDFUE, we are seeking to minimise the whole system cost to consumers while also meeting network planning and operational standards and appropriately balancing local community, environmental and economic impacts to ensure clean, affordable, and reliable energy to the consumer.
19. The approach taken for developing the HNDFUE and balancing the four objectives is an iterative options appraisal process, where a robust methodology is used to compare different design options. The appraisal assesses associated advantages and disadvantages of the design options across a range of criteria.
20. We will initially identify and review technically feasible design options that meet the requirement to connect all in scope offshore wind. The options will be narrowed down through technical, strategic, environmental, community, and economic assessment to determine the recommended network design.
21. Each network design objective will be considered on balanced judgement through the initial strategic options appraisal and final strategic options appraisal.

Establishment of HNDFUE data set

22. The first step in developing the HNDFUE is to establish the scope of the study, the geographic area, and the background data inputs required.
23. It is necessary to establish the offshore generation in scope and develop a suitable generation background on which the NETS can be studied. The HNDFUE is using the 2022 Future Energy Scenario (FES) Leading the Way scenario[5] to form the basis of the background for which studies and analysis are completed. The 2022 Leading the Way scenario has been modified for the purposes of the HNDFUE to align this scenario with the wind generation in scope for the HNDFUE and to be studied as part of the HNDFUE.
24. In addition to using the FES, the output of the initial HND will also be used as an input to the HNDFUE.
25. The design process will consider what onshore reinforcements may be required to enable the connection of the offshore generation that is being considered in the study. Specifically, we will use the reinforcement recommendations of the *Network Options Assessment (NOA) Refresh 2021/22*[6] to form the network background assumptions for technical studies. Network boundaries will be restudied and used as an input to the economic assessment, noting that additional reinforcement will be proposed through the assessment process if required to meet network boundary capabilities. A boundary is a point that splits

[5] https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2021
[6] https://www.nationalgrideso.com/research-publications/network-options-assessment-noa

the transmission system into two parts, crossing critical circuit paths that carry power between the areas where power flow limitations may be encountered[7]. In addition to the onshore reinforcement considerations, the economic assessment will use data on the costs of offshore network assets, and electricity market data to assess the cost of developing and operating the system in the future.

26. To address the environmental and community design objectives, the design will use Geographic Information System (GIS) data from a range of sources to assess the impact of various options on the environment and communities.

27. To develop the HNDFUE, the following non-exhaustive list of data will be considered:

- GIS maps including:
- Environmental constraint data
- Community constraint data
- Technical constraint data
- Generation maps and associated data[8]
- Future energy scenarios[9]
- The latest boundary capabilities and reinforcements based on the agreed generation background
- Electricity market data
- Forecast network demand
- Interconnector flows
- Initial HND
- Onshore and offshore asset cost data
- NETS interface points.

[7] For more information, visit https://www.nationalgrideso.com/research-publications/etys
[8] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1035655/otnr-generation-map.pdf
[9] https://www.nationalgrideso.com/future-energy/future-energy-scenarios

Identification of offshore design options and interface points

Figure 6 shows the second step, identification of interface points and offshore design options in the context of the overall Holistic Network Design (HND) process.

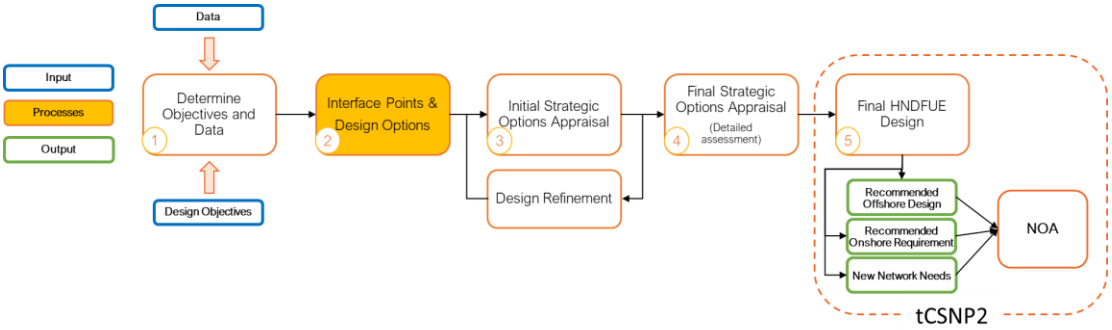


Figure 6 Step 2 - Identification of offshore design options and interface points

Approach to developing the initial long list of design options

28. Once the in scope generators and input data have been finalised, potential onshore interface points and offshore designs will be developed. An onshore interface point is a connection between the onshore transmission network and the offshore transmission network. A connection to the onshore transmission network could include a connection to an existing substation or a new substation that is being planned by the Transmission Owners (TOs) for existing customers or for the Holistic Network Design Follow-Up Exercise (HNDFUE). An offshore design option is a design of the offshore transmission network that connects all in scope generators within a region to a variety of onshore interface points. Figure 7 and Figure 8 provide an illustrative sketch of interface points that can be considered and an offshore design option.

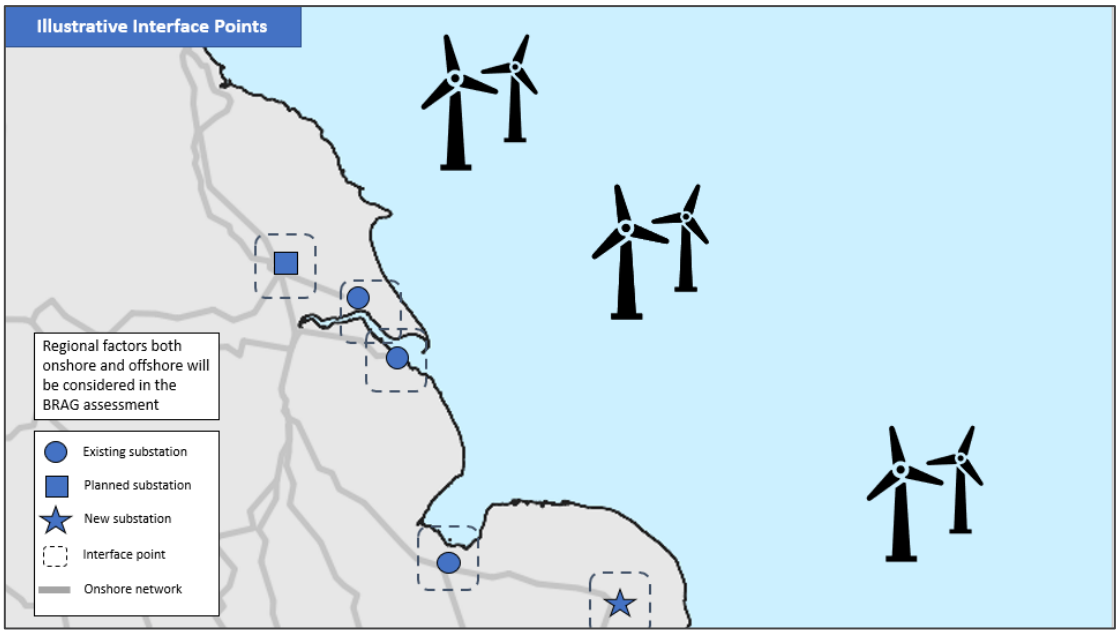


Figure 7 Illustrative interface points

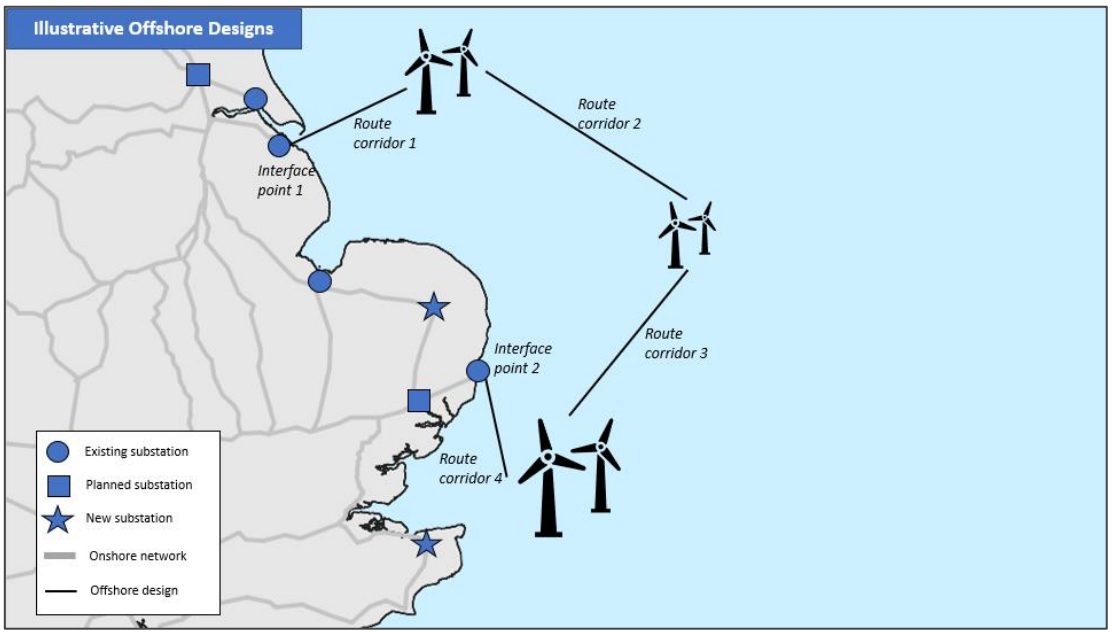


Figure 8 Illustrative Offshore Design

29. The aim of this process is to identify a list of options for interface points and offshore designs, that include multiple route corridors connecting offshore wind farms to shore or interconnecting offshore wind farms. The high-level screening process aims to remove any interface points and offshore designs that are clearly not feasible based on the design objectives. The overall approach to options identification is summarised in the step-by-step process set out in Figure 9. This high-level screening will be carried out on a regional basis and in scope developers will be consulted on interface site options during bilateral meetings and/or via regional developer forums. The initial long list of possible designs will be progressed for further appraisals, including economic appraisals, during later stages in the design process.

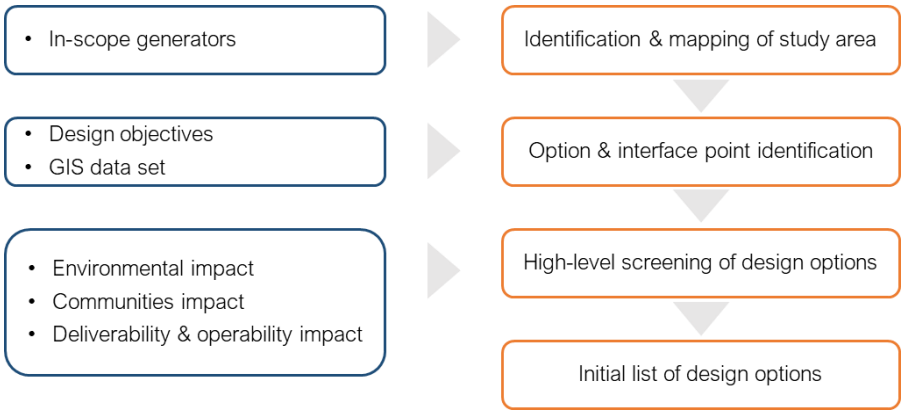


Figure 9 Options identification approach

Identification and mapping of study area

30. In the first step, discrete study areas or regions will be established to cover in scope generators around the Great British coast that are considered in the HNDFUE. The regions will be broad geographic areas around Great Britain where generators are clustered. For the HNDFUE, network design options will be considered across two regions, specifically split by ScotWind and Celtic Sea areas. For each study area, relevant data sets gathered previously will be packaged accordingly to support detailed appraisal.

Identification of interface points and offshore design options

31. The interface points being considered within this study will be existing transmission substations, planned substations, and newly proposed substations as a result of the HNDFUE. A list of potential interface points will initially be identified by reviewing geographical proximity of the onshore network to offshore wind farms.

32. A number of offshore design options that show the connection between the offshore wind farm and onshore network will be developed. These designs include transmission technology and offshore interconnection (for coordinated designs). These design options will consider technology readiness by 2030 and technical and commercial code requirements. From a technology selection perspective, cable routes that clearly exceed 150km, Direct Current (DC) technology must be used instead of Alternating Current (AC).

33. The objective of the initial screening of options is to remove obvious non-feasible options and refine the list of interface points and offshore design options to an initial long list that can be taken forward for initial strategic options appraisal. The initial screening process will involve a very high-level BRAG (Black, Red, Amber, Green) assessment of interface points and design options considering environmental, community, and deliverability and operability constraints.

34. Through this initial screening process, some design options that are considered clearly infeasible will be removed. At this early point in the HNDFUE design process, it is important to keep as many design options in consideration as possible. We will only remove design options that are considered clearly unviable from a community, environment, or deliverability and operability perspective.

Initial long list of design options

35. The options identification process and high-level screening provides an initial list of design options to be taken forward to the next phase of the methodology which is the initial strategic options appraisal. The purpose of the initial long list of options is to provide a diverse range of design options that capture a large solution space to be modelled in the economic optimiser. The long list will not be exhaustive and could lead to further options being developed and included later in the process. In scope developers and TOs will be consulted on the Electricity System Operator (ESO) developed offshore design options and the opportunity provided to propose further designs for consideration.

Initial strategic options appraisal

Figure 10 shows step 3, the initial strategic options appraisal process, in relation to the other steps in the Holistic Design Network (HND).

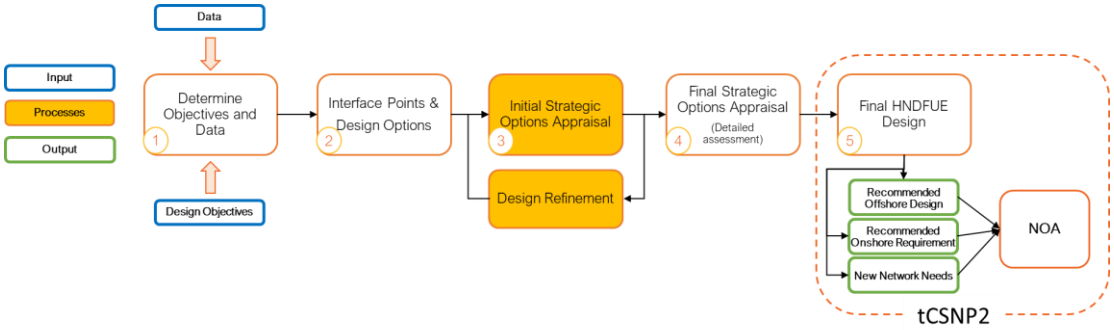


Figure 10 Step 3 - Initial Options Appraisal

Objective and summary of the appraisal process

36. The objective of the initial strategic options appraisal process is to consider the initial long list of potential design options against the four network design objectives. The appraisal will build on the high-level screening performed during the interface point and design option phase. It will consider the high-level infrastructure siting, cable routing, and technology choices in greater detail when appraising the options against design objectives. During this appraisal, we will also consider and compare the economic impact of the design options as well as the community, environmental, deliverability and operability impacts. The community, environmental, deliverability and operability impacts will be assessed using a BRAG (Black, Red, Amber, Green) assessment process that is described in further detail in the following sections. The economic assessment uses an economic optimisation tool to determine the costs associated with a specific design.

37. When appraising the design options and comparing them to determine preferred options, we will consider the design objectives on equal footing as per the requirement set out in the Holistic Network Design Follow-Up Exercise (HNDFUE) Terms of Reference (ToR). The approach to assessing objectives on equal footing will be based on expert judgement and feedback from stakeholder groups including environmental and community representatives. This expert judgement and stakeholder feedback assists in decision-making and helps achieve an appropriate balance between the competing interests that must be considered when recommending the HNDFUE design.

38. The design refinement process is informed by outcomes of the environmental, community, deliverability and operability BRAG assessments and the economic assessment. The purpose of the refinement process is to determine if and how designs can be improved to better meet the design objectives. This iterative approach and refinement of design options leads to an improved set of high performing designs that are progressed for further detailed assessment in the final strategic options appraisal.

39. An integral part of the design refinement process is to seek feedback from Transmission Owners (TOs) on how offshore designs may affect the onshore network. They help to guide the overall design process by highlighting specific constraints on their networks, whether technical or environmental, and offer solutions or alternative connection locations that facilitate the HNDFUE design. As well as highlighting constraints, these feedback sessions are used to highlight potential design opportunities such as integrating offshore designs into planned TO projects and highlighting areas of the network with greater connection capacity.

Environmental and Community Appraisals

40. During the initial strategic options appraisal, environmental and community impacts are assessed for offshore cable route corridors. Based on relevant features and constraints a cable route corridor will receive one BRAG assessment for environmental impacts and separate BRAG assessment for community impacts. The appraisal will focus on the location and construction of required infrastructure. The BRAG ratings applied during this stage of the appraisal will assume that no further mitigation is applied.

41. The objective of this appraisal is twofold: determine feasible cable route corridors to an interface point; and assess the feasibility of a particular offshore design, considering the locations of onshore and offshore infrastructure required. This is a high-level, desktop based, strategic options appraisal is not intended to identify a route corridor for detailed network design, consenting and construction, or the final siting of any infrastructure.

42. *Table 1* and *Table 2* provide descriptions of the BRAG definitions being used for community and environmental impact for cable routes.

Table 1 Community BRAG Appraisal Table

Ranking		Community
●	Black	Significantly constrained Option. Unlikely to be viable due social/community issues.
●	Red	Heavily constrained Option. Potentially viable however, will have to overcome many social/community issues.
●	Amber	Moderately constrained Option. Likely viable however, may have to overcome some social/community issues.
●	Green	Lightly constrained Option. Likely viable without any major social/community issues.

Table 2 Environmental BRAG Appraisal Table

Ranking		Environment
●	Black	Significantly constrained Option. Unlikely to be viable due to significant environmental issues.
●	Red	Heavily constrained Option. Potentially viable however, will have to overcome many environmental issues.
●	Amber	Moderately constrained Option. Likely viable however, may have to overcome some environmental issues.
●	Green	Lightly constrained Option. Likely viable without any major environmental issues.

43. The output of this stage is an environmental and community BRAG assessment for potential route corridors. These individual assessments form the basis for assessing the environmental impacts and environmental impacts for a design option that consists of multiple offshore cable routes. The consolidated allocation of a community BRAG and environmental BRAG rating for a design option is assigned based on expert judgement considering the BRAG ratings of the cable routes. The allocation of individual BRAG ratings for environmental impacts and community impacts ensures that these design objectives can be considered on equal footing when recommending designs.

44. The design options will be made up of different combinations or radial or coordinated connections between offshore wind farms and interface points with the onshore National Electricity Transmission System (NETS).

Deliverability and Operability Appraisals

45. A key part of the appraisal will be to review the technical design options and consider their deliverability and operability. This assessment will focus on identifying a reasonable earliest in-service date (EISD) for each option, considering:

    - Design complexity: technical difficulty in realising a design i.e. interface/landing points, interconnectivity of sites, cabling, and/or offshore substation.
    - Construction complexity: To realise the design including potential risks of a particular design option for both onshore and offshore activities.
    - Technology Readiness Level: High voltage alternating current (HVAC) is proven design whereas high voltage direct current (HVDC) connections are less mature.
    - Planning and consenting complexity both onshore and offshore.
    - Supply chain availability, although not a direct limitation to ensure a level of ambition and signal to industry the need to scale up, in consultation with the deliverability forum some design options may alter if considered practically infeasible. (Replaced by the bullet above)
    - Planning and Consenting: Issues arising from a design i.e. overhead lines (OHL), new landing sites that require specific consents that are separate from environmental considerations.

46. Each design option will receive a Deliverability and Operability combined BRAG status based on the considerations above. Table 3 defines each of the BRAG ratings across the Deliverability and Operability criteria. This appraisal allows for the determination of possible difficulties, risks and timelines for different aspects of the design. Any design option with a 'Black' rating will be excluded and will not be taken forward to the economic assessment process.

Table 3 Deliverability and Operability BRAG Appraisal Table

Ranking		Deliverability and Operability
●	Black	Highly complex design(s) with new or emergent technology unlikely to be deliverable for 2030. The design is subject to high likelihood of constraints and risks affecting the construction, consenting and/or operability of the HNDFUE to such a degree that the option should not be considered further.
●	Red	Design that features some complex elements or technology that may be challenging to deliver for 2030. The design is subject to constraints that are likely to affect construction, consenting or operability of the HNDFUE to such a degree that the option should not be included without potential solutions identified.
●	Amber	Design of moderate to significant complexity, with constraints or risks which may impact some construction, operability or consents. Design is likely to be achievable and issues capable of resolution for the HNDFUE.
●	Green	Design of low to moderate complexity using proven technology. The design is subject to low likelihood of constraints affecting construction and/or consenting. Option very likely to be achievable by 2030.

Figure 11 shows an illustrative BRAG assessment table for assessing community, environmental, deliverability and operability design objectives for cable route corridors and consolidated design options (multiple route corridors).

Holistic Network Design BRAG assessment - Initial Options Appraisal

Holistic Design Option	Design Feature	Community BRAG rating	Notes	Environment BRAG rating	Notes2	Deliverability & Operability BRAG rating	Notes3
Option A	Wind Farm 1 to Interface Point 1		*<rationale for BRAG selection>*		*<rationale for BRAG selection>*	*N/A*	
	Wind Farm 2 to Interface Point 2					*N/A*	
	Wind Farm 3 to Wind Farm 2					*N/A*	
	Offshore Network Design		*<rationale for BRAG selection>*		*<rationale for BRAG selection>*		*<rationale for BRAG selection>*

Figure 11 Illustrative options appraisal considering community and environment

Economic Assessment and Optimisation

47. The economic assessment of design options is performed during the initial strategic options appraisal process. The assessment and optimisation provide the total capital and ongoing operational cost of a recommended option. This data is considered along with the environmental, community and deliverability BRAG ratings to determine if it should be considered for further investigation within the design refinement process.

48. The data inputs considered in the economic assessment are presented at a high-level in Figure 12 and described in further detail below.

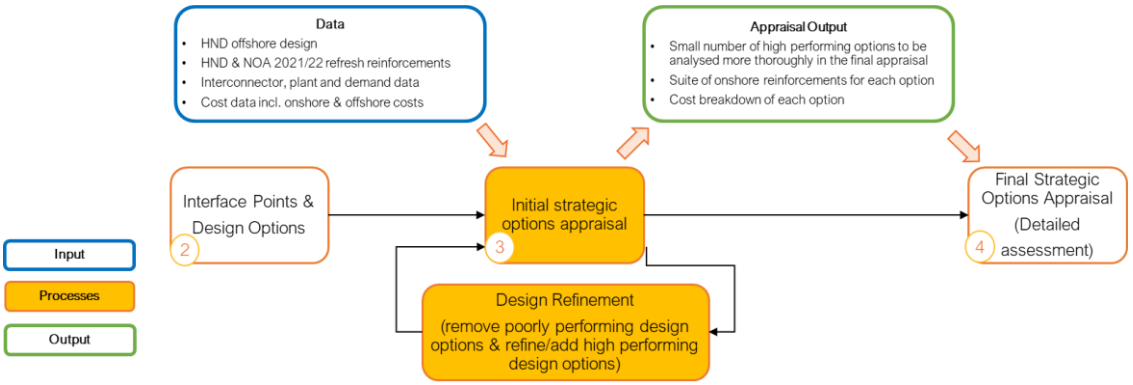


Figure 12 Initial Strategic Options Appraisal Economic Assessment

49. The following data sets are key inputs to the economic optimisation model as outlined in the input and data collection:

    1. Design recommendations from HND:
        a. Offshore network
        b. Optimal onshore network in Network Options Assessment (NOA) Refresh up to and including work with an Earliest In Service Date (EISD) of 2034.

    2. Generation Background (based on the 2022 Future Energy Scenario (FES) Leading the Way scenario, with modifications to list of offshore wind generation):
        a. Electricity market data
        b. Demand
        c. Initial GB market dispatch
        d. Interconnector flows

    3. Offshore design options:
        a. Network capability and associated costs
        b. Technology types
        c. In scope wind farms
        d. Interface points and associated costs
        e. Required onshore works
        f. Potential offshore cable routes

    4. Onshore network:
        a. Network boundary capabilities
        b. Remaining onshore network reinforcements from *NOA 2021/22 Refresh* and associated costs
        c. Further onshore reinforcement options, including notional reinforcement[10]
        d. Onshore network studies

[10] A notional reinforcement is defined as a capital cost and boundary increment only, no other parameters, such as technology or routing, is defined at this stage. Guidance will be sought from the TOs on the viability of notional reinforcements as well as a high-level assessment of the capital cost assumptions.

50. The existing transmission system will be studied to understand the base capabilities for boundaries and reinforcements up to a certain point. This is to provide updated boundary capabilities for the generation scenario that is being used in the optimiser.

51. The TOs will perform desktop analysis to determine what reinforcements may be required to connect the new generation to the network. The work will also determine the infrastructure required at the interface points to enable the connection of the new generator. The output of this analysis will provide the initial input data to the economic assessment model. It will identify a connection point for the new generator, an approximate EISD and the cost for the interface point connection. This information will be used to inform the economic assessment and form part of the initial strategic options appraisal.

52. The economic optimser model acts as an optimisation tool by assessing the cost of the design options and choosing the optimal interface site, connection designs and network topology for both the offshore and onshore transmission networks.

53. Connecting large capacities of offshore wind into the NETS presents challenges around the network boundaries. Network boundary transfer capability may not be sufficient in certain areas and therefore network reinforcement will be required. The economic optimisation process calculates the onshore reinforcement that is economically optimal for each option. It assesses the offshore network provided by the various offshore design options and associated onshore network requirements, considering generation and demand profiles. This is calculated by constantly assessing NETS boundary constraints, wind curtailment and total asset and operational costs.

54. *Figure 13* shows a high-level description of the inputs and outputs of the economic model. Note that in this case 'optimal' means the least cost design.

Figure 13 Optimiser Model

55. The optimiser minimises the overall annuitised cost of the network, including operational costs, associated carbon costs for thermal plants, constraint costs, curtailment costs, storage costs and costs associated with interconnector flows. The model satisfies power balance for each considered period i.e., generation, including interconnection and storage, must be equal to demand, and selects connection options such that all in scope offshore wind farms must be connected.

Strategic modelling approach

56. The objective of the initial strategic options appraisal is to filter out the majority of the design options (for both the offshore and onshore networks). This allows a large solution space to be evaluated using high-level assumptions without having to wait for all the required data to be provided in more detail for all options. The resulting smaller number of options can be taken forward to the final strategic options appraisal where they can be assessed in more detail.

57. Unlike the first HND, there is no separate radial only (counterfactual) step, this does not mean that no radial designs will be considered. Radial, coordinated and, part-radial and part-coordinated designs will be evaluated against each other simultaneously. A purely radial design, which has not been optimised, may still be considered.

58. The majority of known onshore reinforcements from NOA 2021/22 were recommended by the first HND and the NOA 2021/22 Refresh. It is likely that further onshore reinforcement will be economically viable, therefore notional reinforcements will be used to model this additional onshore reinforcement. A notional reinforcement is defined as a capital cost and boundary increment only, no other parameters, such as

technology, routing, environmental impact, community impact, are defined at this stage. Guidance will be sought from the TOs through their feedback in the process, on the viability of notional reinforcements as well as a high-level assessment of the capital cost assumptions.

59. As the initial strategic options appraisal process proceeds, more promising designs (both onshore and offshore) will be identified. These designs will be prioritised for further refinement and checking. Where the optimiser recommends notional reinforcements, this will be communicated to the relevant TO(s) who will have a chance to review whether the capital cost and boundary capability assumptions are reasonable and whether the project (possibly in combination with other notional reinforcement(s)) is viable. If new information is obtained from the TO(s) then this will be put back into the optimiser to see whether the previous proposal is still optimal. This will be an iterative process with poorly performing options eliminated throughout the process. This appraisal will be the first step in informing the development of new reinforcements to meet future network needs. These will be appraised in the final options assessment and subsequently refined in the next iteration of the NOA. The outputs of both processes will form the Transitional Centralised Strategic Network Plan (tCSNP2).

Shortlisting design options

60. The output of the initial strategic options appraisal process is an analysis of the implications of each option in the form of an initial options appraisal table. An appraisal will be prepared for each option, summarising that option with regard to the technical design, deliverability and operability aspects, economic, efficient, environmental, and community considerations (offshore, landfall, onshore, transmission owner). The summary table will provide a summary of the main factors that have been considered in reaching a conclusion for each option.

61. Once all the information has been brought together in the tables, a Design Review workshop will be held and options appraisal workshops with representatives from the Central Design Group (CDG). The purpose of the Design Review and Options Appraisal workshops is to review all of the appraisal work undertaken, to challenge judgements made regarding the effects of particular options and to compile an overall view of the relative performance of each option. Specific outcomes of the workshop will be shared with relevant stakeholders to obtain their feedback.

62. Once the feedback has been reviewed, this will then be considered in combination with expert judgement to determine the shortlist of design options for the final strategic options appraisal.

63. Figure 14 shows an overview of how design options will be appraised using the BRAG (Black, Red, Amber, and Green) ratings and economic values across the design objectives. The economic assessment is not assigned a BRAG status since the costs are quantified. The comparison table allows for easy comparison of design objectives across options and comparison of design objectives between varying design options.

Holistic Network Design BRAG assessment - Initial Options Appraisal

Holistic Design Option	Design Feature	Community BRAG rating	Notes	Environment BRAG rating	Notes2	Deliverability & Operability BRAG rating	Notes3	Economic Assessment
Option A	Wind Farm 1 to Interface Point 1		<rationale for BRAG selection>		<rationale for BRAG selection>	N/A		
	Wind Farm 2 to Interface Point 2					N/A		
	Wind Farm 3 to Wind Farm 2					N/A		
	Offshore Network Design		<rationale for BRAG selection>		<rationale for BRAG selection>		<rationale for BRAG selection>	£...

Figure 14 Illustrative Options Appraisal Table

Final strategic options appraisal

Figure 15 shows the final strategic options appraisal in the context of the whole HND process.

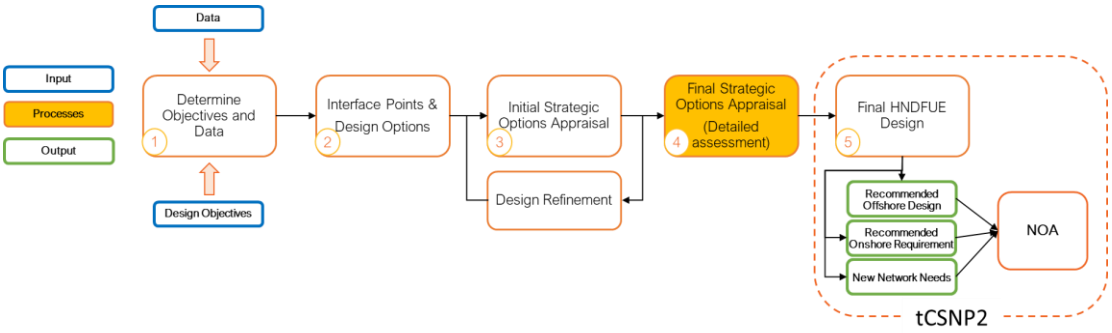


Figure 15 Final strategic options appraisal

64. The final strategic options appraisal builds on the initial strategic options appraisal and considers the same four design objectives. The main difference is that the final strategic options appraisal assesses the designs and impact on objectives in greater detail. The process involves:

    - Assessing further technical deliverability and operability difficulty of each option including updated cable routes.
    - More detailed assessments of required onshore reinforcements based on power flow studies.
    - More detailed assessments of environmental, community through BRAG assessments.
    - More detailed cost assessments associated with the build and operation of each design option.
    - Developing an understanding of mitigation actions that address environmental, community, deliverability, and operability challenges.

65. The additional detail produced at this step will allow the assessments against the four network design objectives to be re-evaluated. This will enable the final refined list of design options selected be compared and appraised in greater detail. The outcome of this process will produce the recommended offshore and onshore design.

Detailed deliverability and operability assessment

66. This will involve refining technical details that were assumed in the initial appraisal which will then be fed back into the optimiser to ensure option viability. In addition, options will be assessed against operability criteria such as power flow control, technology maturity and network security to understand how they perform under various power system conditions and ensuring they comply with the National Electricity Transmission System Security and Quality of Supply Standard (NETS SQSS).

67. SQSS rules govern the security of the transmission network from real time operation through to long term planning. In developing the optimised network design, some deviations from the current SQSS rules may prove to be efficient. The current SQSS for offshore generators has mostly been applied to radial connections as this is the current industry practice. However, in coordinated designs, multiple generators (e.g. windfarms) may share high voltage direct current (HVDC) or high voltage alternating current (HVAC) systems and offshore elements may become part of the Main Interconnected Transmission System (MITS)[11]. The current SQSS does allow for coordination, however it may benefit from review to reflect the latest technology and design options. There are currently no anticipated modifications beyond those recommended by HND1.

68. The SQSS infeed loss for planning and operating an offshore transmission system governs the maximum allowable disconnection of generation allowed. For the coordinated design the infeed loss will be increased from 1320 MW to 1800 MW for normal infeed loss risks. This increased infeed loss allows for a larger, more efficient design without negatively impacting customers.

[11] A MITS node is defined as a Grid Supply Point connection with 2+transmission circuits connecting at the site, or a node with more than 4 transmission circuits connecting at the site.

69. Power system studies are split into two parts: local connection assessment and wider system impact assessment. The local assessment ensures that designs that are proposed meet security standards and that customers can be connected in a safe and secure manner, accounting for any required network investment to achieve this. Wider system analysis looks to understand how collections of new generators connecting to the system affects wider system flows and whether additional network investment is warranted to operate the network in a safe, secure, and economical way.

70. Once power system studies have been completed for the shortlist of designs the data obtained will be fed back into the optimiser, updating the input data to ensure our assumptions in the initial options appraisal are accurate. In addition to updating the optimiser, each of the options will be compared from a deliverability and operability perspective to understand potential advantages and drawbacks to different design options which will be factored into the final strategic options appraisal.

Further environmental and community assessment

71. Following the refinement of the options to a shortlist of designs, a further review will occur for the environmental and community impact considerations and their BRAG ratings, which is consistent to what was used in the initial strategic options appraisal process. The Electricity System Operator's (ESO's) environmental consultants will undertake route refinement and more comprehensive analysis, to identify all the constraints along each route and to provide an overall summary of the constraints for each route. Constraint narrative will be broken down into offshore, landfall and onshore sections, along with a summary overview. This updated narrative will feed into the final strategic options appraisal.

72. As the onshore reinforcements will be known following the detailed technical analysis of the refined list of design options, the ESO will work with the Transmission Owners (TOs) will carry out an assessment of environmental and community impacts on these works. This will feed into the overall BRAG ratings of each option for this specific objective considering both the offshore and onshore impacts cumulatively. The final BRAG rating applied to a design option will consider what mitigations are feasible to minimize the impact on communities and the environment.

Final economic appraisal

73. The shortlist of design options that are the output of the initial strategic appraisal have their input data checked and revised, as outlined in the preceding part of this section. These options are then re-evaluated by the optimiser in the same way as described in the initial strategic options appraisal. The economic assessment will determine the costs of each shortlisted design.

74. The final output from the optimiser is the most economic offshore design and the associated onshore reinforcements considering operational and capital network costs. The other options put into the final strategic options appraisal will also be evaluated by the optimiser, these are the alternative designs. This will allow a comparison to be made between the most economic solution and alternative solutions, that may perform better against the other network design objectives.

75. The design objectives of the Holistic Network Design Follow-Up Exercise (HNDFUE) are broader than just economic cost. The results of the optimiser will therefore be reviewed in the final strategic options appraisal process in order to balance the four network design objectives equally. Alternative designs to the optimal economic design will be considered and compared against the most economic design to reach a final recommendation.

76. This will involve using the economic results for all the designs considered in the final strategic options appraisal. The following and potentially additional sensitivities will be considered and analysed:

    - Sensitivity of cost between different options
    - Removal of environmental or community sensitive design options to understand the economic effect of avoiding these environmental or community constraints
    - The effect of delivery timelines on HNDFUE recommendations; and
    - Significant delivery risks and alternative recommended options will be reviewed and, where they exist, alternative recommendations will be considered.

Options appraisal summary and recommended design

77. The output of the final strategic options appraisal process is an analysis of the implications of each option in the form of a final options appraisal summary table (OAST). This OAST will be an updated and more detailed version of the options appraisal table that was produced for the initial strategic options appraisal. The OAST will provide a summary of the main factors that have been considered in reaching a conclusion for each option.

78. Once all the information has been brought together in the OAST and a recommended option, a Design Review workshop will be held and options appraisal workshops with representatives from the Central Design Group (CDG). The purpose of the Design Review and Options Appraisal workshops is the same as the initial strategic options appraisal process but with the intention to feedback and approve the final recommended design.

Final HNDFUE Design

79. The final Holistic Network Design Follow-Up Exercise (HNDFUE) design will consist of the recommended offshore network design, the recommended onshore requirements, and any onshore new network needs that are an input to the Network Options Assessment (NOA). Figure 16 below shows how the final HNDFUE design fits into the overall process.

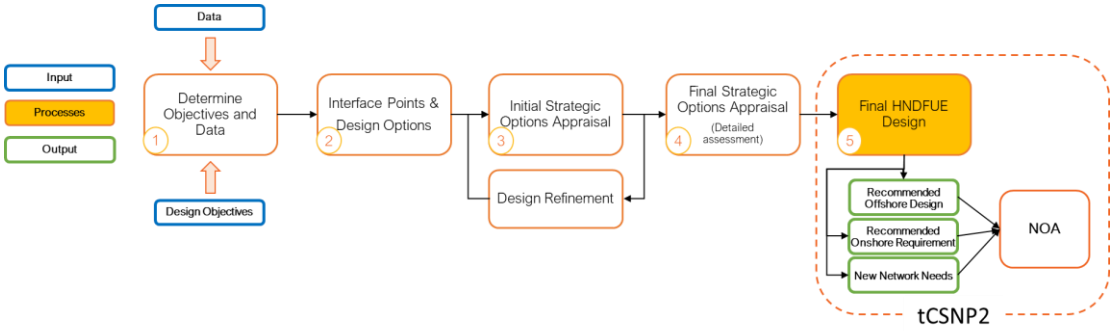


Figure 16 Final HNDFUE Recommendations

80. Although one final HNDFUE design will be recommended, if there have been significant challenges balancing the four network design objectives, multiple options may be put forward. In summary, the final HNDFUE design will include:

- Recommended offshore network and interface points (recommended offshore design).
- Recommended onshore requirements, which are known Transmission Owner (TO) planned onshore reinforcements.
- New network needs, which are new onshore reinforcements triggered by the HNDFUE that are required to support the offshore network design.

81. Further design refinement will be undertaken through the processes being developed as part of the Electricity Transmission Network Planning Review (ETNPR).

Final Options Appraisal Summary Tables (OAST)

82. A suite of OAST documents will be produced that will include detailed BRAG (Black, Red, Amber, Green) assessments against all four network design objectives to justify why the recommended design was chosen. This will form part of the final outcome of the HNDFUE process.

Recommendations for technical and commercial industry codes

83. In parallel to the work being undertaken to develop the HNDFUE, we are undertaking a review of technical and commercial industry codes and standards, and relevant licenses, in consultation with the Central Design Group (CDG). The aim of this review is to identify the additional impacts on codes, standards and licenses that will arise as a result of the HNDFUE, over and above the current impacts that are already being considered as a result from the HND. If any are found, these will form part of the final recommended design.

Final HNDFUE design review

84. The HNDFUE will follow a structured review process as shown in Figure 17. Once the final recommended design and accompanying OAST documents are complete, they will be reviewed internally within the Electricity System Operator (ESO). The documents will be updated based on feedback before sharing the final OAST with the CDG and Offshore Transmission Network Review (OTNR) governance. Following review and approval of the documents by the CDG and OTNR project management board, the documents will be issued to in scope developers, OTNR Working Group, Department for Business, Energy and Industrial Strategy (BEIS), Office of Gas and Electricity Markets (Ofgem), and the Expert Advisory Group (EAG).

85. More detail on the ESO Offshore Coordination Project, including timelines, can be found on the ESO website.[12]

Figure 17 Final HNDFUE design review process

[12] https://www.nationalgrideso.com/future-energy/the-pathway-2030-holistic-network-design/hnd

Link to tCSNP2 and NOA

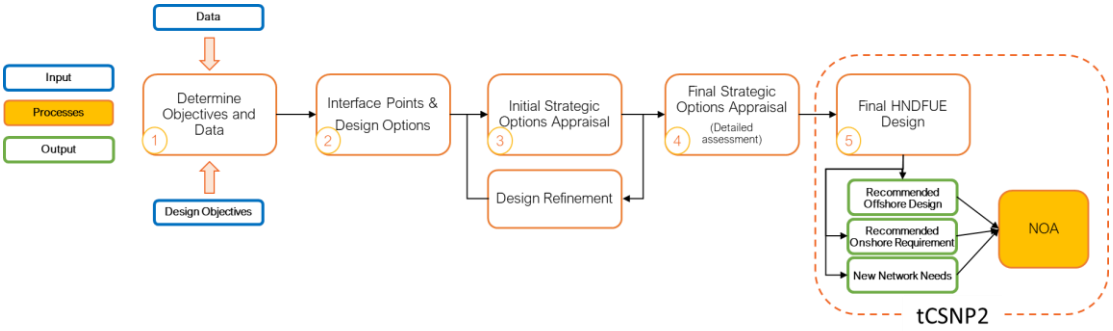


Figure 18 HNDFUE link to tCSNP2 and NOA

The first transitional Centralised Strategic Network Plan (tCSNP) comprised of the Holistic Network Design (HND) and the *NOA 2021/22 Refresh*. For the reasons outlined below, tCSNP2 will be structured differently.

The Holistic Network Design Follow-Up Exercise (HNDFUE) uses a generation background based on our latest view of the future energy landscape - Future Energy Scenarios 2022 (FES 2022). However, a full Network Options Assessment (NOA) has not yet been carried out using a FES 2022 dataset. This means that there cannot be a NOA refresh stage in the same way as HND1. Including a full NOA would add significant time to the process. Therefore, to ensure timely connection offers are made to in scope generators the final NOA Refresh stage has been replaced with a link to the decoupled NOA process.

The HNDFUE will continue to recommend onshore reinforcement requirements and will consider all known onshore reinforcement options. The Electricity System Operator (ESO) will also work collaboratively with the Transmission Owners (TOs) to refine further network requirements into *new network needs* as part of the HNDFUE. These *new network needs* will represent potential transmission solutions but due to their development being at a very early stage more work will be required to firm up the detail of these wider system requirements. The *new network needs* identified in the HNDFUE process will be included in connection offers but are subject to refinement following the NOA process.

The NOA process will embed the HNDFUE's offshore network recommendation and provide the onshore TOs the opportunity to further develop the *new network needs* whilst considering a range of alternative solutions. Through the NOA process a final set of wider system reinforcement recommendations will be made. Following this, connection offers will be updated replacing *the new network needs* with a final set of reinforcement works.

ESO

Appendix I - Stakeholder Feedback

In July 2022, we sought written feedback on the draft Follow-Up Exercise Holistic Network Design (HNDFUE) Methodology from stakeholders:

- The Central Design Group (CDG): this group acts as a vehicle for us to consult with the onshore Transmission Owners (TOs) as the HNDFUE is developed.
- The Environmental Subgroup (ESG): this subgroup brings together environmental stakeholders to provide advice to the CDG on the environmental impacts of the technically viable options being considered in developing the HNDFUE.
- Holistic Network Design (HND) developers: developers that had projects included in the HND were able to provide valuable feedback based on their experience of the HND.
- HNDFUE developers: the methodology of the HNDFUE directly affects those developers that are in scope for the follow-up exercise.

Furthermore, we have also taken into consideration the feedback received during the ESG, CDG meetings and the ScotWind workshop in August 2022. All of this valuable feedback received, combined with our lessons learnt from HND1, has informed and shaped changes that introduce process and efficiency improvements to the HNDFUE Methodology.

Stakeholders expressed gratitude for the opportunity to provide feedback on the methodology and many emphasised their support of the HNDFUE methodology and the ambition to provide a coordinated onshore and offshore design to meet the government objectives of connecting 50 GW of offshore wind by 2030.

The key themes from the feedback received along with our responses are summarised below:

	You said…	We did…
Deliverability	There is a risk that the design isn't deliverable by 2030.	We have produced a deliverability BRAG (Black, Red, Amber, Green) appraisal criteria which is outlined in *Table 2*. This allows for the assessment of possible risks and timelines for the deliverability of different aspects of the design. We have also formed a Deliverability Forum as outlined in the *Introduction*.
Engagement	How can stakeholders be more engaged throughout the process?	This has been reflected in our engagement plan which includes longer feedback windows and regional workshops with representation from developers, TOs and ESG members. In addition to the inclusion of developer representation at the CDG and subgroups to allow active developer input at the design stage.

ESO

	You said…	We did…
Environment	Can the environmental considerations be described in the design?	The environmental BRAG assessment outlined in *Table 1* will be described in the final Options Appraisal Summary Tables (OAST) as described in the *Final Holistic Network Design Follow-Up Exercise Design* section. We will continue to engage with environmental stakeholders via the ESG to align on our assessment and possible mitigation actions.
FES	Which FES scenario will be used for HNDFUE?	We will use the *FES 2022* Leading the Way scenario, which has been modified to align with the wind generation in scope for the HNDFUE.
Radial Design	Why will a radial counterfactual not be produced?	As outlined in *HNDFUE Methodology Changes*, we will consider radial design options alongside coordinated design options as part of a single process rather than separately. This is to accelerate the HNDFUE timeline.
Interaction with HND	How does the HND interact with the HNDFUE?	The HNDFUE methodology incorporates the learnings from HND. The HND design recommendation will not be reopened in the HNDFUE and the HND will be used as an input to the HNDFUE design process.
NOA	Will we be completing a NOA Refresh?	As outlined in *HNDFUE Methodology Changes*, we will include progression in the HNDFUE towards developing a new set of reinforcements to be considered in the next iteration of the NOA which will feed into the Transitional Centralised Strategic Network Plan (tCSNP2) to assess the most optimal delivery combinations and timings.

ESO

	You said…	We did…
Celtic Sea	How will the HNDFUE be completed for the Celtic Sea?	We will work closely with The Crown Estate to recommend a design for the Celtic Sea that is independent of the seabed lease winners.
Projects in scope	How where the projects in scope determined?	The *HNDFUE Terms of Reference* published by BEIS defines the scope for the follow-up exercise. These were carefully considered and agreed upon by OTNR partners.
Asset classification	That there is uncertainty around asset classification.	The HNDFUE, like the HND, will be agnostic of who delivers the design, and more certainty has been provided by Ofgem's *asset classification publication*.
Habitats Regulation Assessment	Can we include a Habitats Regulation Assessment (HRA) in the HNDFUE?	After careful consideration, we will not be conducting an HRA as part of the HNDFUE to remain consistent with the assessment carried out in the HND and to prevent delay to the recommended design outcomes. The ESO carrying out this role would represent a change to roles and responsibilities. However, HRA and Strategic Environmental Assessment (SEA) are being considered under the Future Framework.

Minor feedback on the phrasing and wording of the methodology has been actioned and implemented throughout the document.

Much of the feedback received has been confidential and therefore the changes reflected are not outlined in this summary.

We have carefully considered all the feedback received, however, there are cases where feedback has not been incorporated into the methodology. This was because the feedback was actioned independently of the methodology, it was out of scope of the HNDFUE or the suggestions could cause delay to the timeline. We have also looked to ensure that the HNDFUE Methodology is consistent with the HND Methodology. We have improved and optimised the HNDFUE methodology, where we have found inefficiencies and learnt lessons from stakeholders.

Appendix II - Detailed HNDFUE process outline

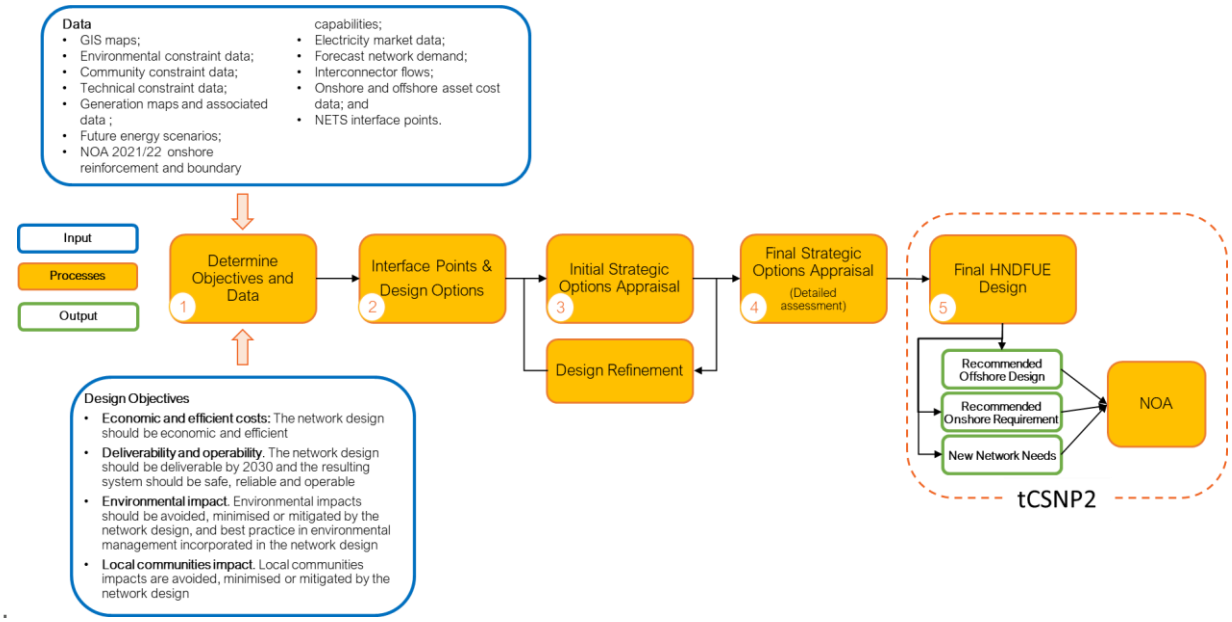


Figure 19 Detailed HNDFUE Process Outline

Appendix III - HNDFUE ToR

OTNR Pathway to 2030 Central Design Group and Network Design Terms of Reference[13]

I. Preamble to the Terms of Reference

The first Holistic Network Design (HND) published in July 2022 provided a set of recommendations to facilitate the connection of 50 GW of offshore wind by 2030, taking account of the four Network Design Objectives of economic and efficient, deliverable and operable, minimising environmental impact and minimising community impact. 23 GW of new offshore wind generation was in scope of the first HND process, which included some, but not all, ScotWind generation and assumptions on offshore generation in the forthcoming Celtic Sea leasing round.

These Terms of Reference (ToR) relate to the follow-up HND process being undertaken from July 2022 to produce a set of follow-up HND recommendations and inform development of associated follow-up Detailed Network Designs (DNDs).

The ToR, including the Network Design Objectives, set out in the following document, in no way limit the prerogative of the Office of Gas and Electricity Markets (Ofgem) or the Secretary of State to take decisions in their roles as independent decision makers.

In particular, neither the ToR nor network designs developed on the basis of the ToR prejudge any decision, either:

- By Ofgem, within the price control framework or on other matters,
- By the UK Government, in particular Department for Energy and Industrial Strategy (BEIS) and the Secretary of State, with regard to decisions on Development Consent Orders or on other matters, or
- By the Scottish and Welsh Governments.

In developing the follow-up HND and follow-up DNDs (as described in this document), all parties shall have regard to the existing legal obligations placed upon them, including their licence obligations.

The ToR and network designs developed based on the ToR are not intended to amend any existing frameworks and obligations (see outputs section on code or licence changes or derogations).

If the Offshore Transmission Network Review (OTNR) Project Board approves the ToR, after they have been discussed by the OTNR Working Group, the OTNR Project Board [14]will state its approval, and this will be noted in its session minutes, to highlight that the OTNR supports the ToR and the OTNR Pathway to 2030 Central Design Group (CDG) carrying out its works based on the ToR.

The ToR are only final when the OTNR Project Board has approved them. However, the CDG can begin work, including stakeholder engagement, in advance of approval.

Once the follow-up HND is completed, the Electricity System Operator (ESO), with the support of the CDG members as appropriate, will seek approval from the OTNR Project Board that the ToR of the follow-up HND have been met. This is expected to happen after the design has been discussed by the working group, and they are satisfied that the recommended design is in line with the requirements of the ToR. The Project Board will state that the follow-up HND is in line with the requirements of the ToR, and this will be noted in its session minutes, to highlight that the OTNR supports the follow-up HND.

Interactions with wider network planning

Ofgem is undertaking a wider Electricity Transmission Network Planning Review (ETNPR)[15] in parallel to the work of the CDG. Ofgem will coordinate the ETNPR and Offshore Transmission Network Review (OTNR)

13 The ESO are expecting a revised version of the ToR stating a change to the HND publication date now being June 2022.
14 For an overview on the OTNR governance fora please refer to slide 9 of this presentation: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/946574/presentation-17-10-20.pdf
15 The aim of the ETNPR is to ensure that planning and design of the GB electricity transmission network can efficiently support the delivery of net zero at lowest cost to consumers. The ETNPR will review approaches to analysis and decision making, including for anticipatory investment and integration of market solutions, whole system solutions and flexibility to resolve network problems. The ETNPR will also review roles and responsibilities of key parties in early development of solutions, as well as review incentives and legal duties to enable any change. The scope of the ETNPR is broader than the OTNR and any changes to network planning arrangements as a result of the ETNPR may be taken forward after the Central Design Group has produced its initial outputs.

workstreams to ensure that emerging findings align and are compatible as far as possible, to avoid duplication or other process inefficiencies.

This will include, for example, ensuring, as far as possible and appropriate, consistency in analysis and decision-making tools underpinning network plans and designs, as well as roles and responsibilities in developing those plans and designs – with the aim to ensure that the follow-up HND and follow-up DNDs are compatible with the wider network plans and designs resulting from the ETNPR (e.g. through the Transitional Centralised Strategic Network Plan (TCSNP), the Large Onshore Transmission Investments re-opener or other mechanisms).

The first TCSNP (TCSNP1) was the combination of the first HND and *the Network Options assessment (NOA) 2021/22 refresh* published in July 2022. The NOA 2021/22 refresh was undertaken towards the end of the first HND and was therefore incorporated as a final step within the first HND in order to ensure that the wider onshore network reinforcements recommended through the NOA refresh complemented the first HND.

The second TCSNP (TCSNP2) has wider objectives than TCSNP1, which include seeking whole energy system solutions that would not be possible within the current NOA process. The methodology for TCSNP2 is currently under development, but it is expected that TCSNP2 will not conclude until some months after the HND follow-up process. As such, these ToR reflect that the HND follow-up process will specify system needs and boundary capability requirements necessary to facilitate an economic, efficient, operable, and coordinated (Network Electricity Transmission System) NETS through TCSNP2. Where appropriate, the HND follow-up process may also specify solutions to these system needs and boundary capability requirements.

II. Terms of Reference for the Central Design Group and Pathway to 2030 Network Design for the HND follow-up process

Governance

1. Purpose

The follow-up HND will be delivered by the ESO in consultation with the CDG. The purpose of the follow-up HND is to provide design recommendations for in scope projects. This will be done in a holistic way, taking account of the four Network Design Objectives (economic and efficient, deliverable and operable, minimising environmental impact, minimising community impact). This will support the government ambition for 50 GW of offshore wind by 2030 for Great Britain including 5 GW of Great Britain's floating wind, as well as contributing to the Sixth Carbon Budget targets for 2035 and net-zero by 2050 for Great Britain and by 2045 for Scotland (Scottish Government target).

The purpose of the CDG is to act as a vehicle for the ESO to consult and collaborate with Transmission Owners (TOs) and other key stakeholders on the follow-up HND, and to consult with stakeholder groups as the follow-up HND is developed.

2. Objective

The ESO, in consultation with the CDG, will deliver a follow-up HND that facilitates an economic, efficient, operable, and coordinated National Electricity Transmission System (NETS) (including offshore and associated onshore assets required to connect in scope projects). The follow-up HND should minimise the impact on environment and communities (where possible) by considering different design options against the Network Design Objectives. This includes connections and associated system needs and boundary capability requirements necessary to connect in scope offshore generation to facilitate the pace and certainty required to deliver the ambitions and targets set out in Section 1 above.

Through considering the requirements for the NETS holistically, the follow-up HND should be economic and efficient, be deliverable and operable, minimise the impact on the environment, and minimise the impact on local communities.

For the avoidance of doubt each of these objectives have equal weight.

There are two parts of network design for both onshore and offshore as further described in Part B and Part C:

Follow-up HND, and

Follow-up DND

3. Scope

Prior to the assessment work beginning, the scope of the follow-up HND exercise will be agreed through existing OTNR governance arrangements. This will take the form of a list of specific projects or leasing rounds, where the final projects are yet to be defined. This can be found in Annex A along with high level reasoning for their inclusion.[16]

During the design process, where any deviation from the agreed scope is required, a proposal will be brought to the relevant OTNR governance forum for agreement and Annex A will be updated to reflect any changes, and the Terms of Reference republished.

[16] Further analysis will be carried out in September 2022 to determine whether any additional projects should be added to the scope of the follow-up HND. This will include consideration of the Innovation and Targeted Oil and Gas (INTOG) leasing round and wider oil and gas decarbonisation projects

4. Inputs

- A non-exhaustive list of inputs for the follow-up HND are given below.
- The first HND and the NOA 2021/22 refresh
- Contracted background and latest information on relevant connections, including where available, connection contract updates and developer build programmes as a result of recommendations from the first HND
- ESO 2022 Future Energy Scenario (FES) elements that meet ambition for 50 GW of Offshore Wind by 2030 and meet future Sixth Carbon Budget and net-zero targets, amended as appropriate to reflect new proposals
- NOA 2021/2022 refresh infrastructure schedule and project assumptions updated as appropriate, and where available, updated earliest in service dates for onshore transmission infrastructure to reflect British Energy Security Strategy (BESS) measures
- The draft revised National Policy Statements for Energy Infrastructure
- The Network Design Objectives (see below section D) for the follow-up HND
- English marine plans, Marine Scotland Sectoral Plan and Welsh National Marine Plan
- Leasing round updates from the Crown Estate (Celtic Sea) and from Crown Estate Scotland (ScotWind clearing round)
- Inputs from other stakeholders (including environmental stakeholders) to contribute to the overall CDG objective
- The methodology for the first HND as published in February 2022, with incremental improvements for the follow-up HND
- Industry technical and commercial codes and standards
- Pathway to 2030 industry code, Standard and Licence Recommendation Report
- Existing network design rules based on the Security and Quality of Supply Standard (SQSS) to guide the follow-up HND
- Ofgem's minded to decision on delivery models and asset classification determinations.

5. Output

- Follow-up HND recommendations, which will include offshore and associated onshore assets required to connect in scope projects. This may also include any notable alternative variations to design options within the HND follow-up if different design objectives drive different outcomes.
- Specification of system needs and boundary capability requirements necessary to facilitate an economic, efficient, operable, and coordinated NETS through TCSNP2. Where appropriate, the HND follow-up process may also specify solutions to these system needs and boundary capability requirements.
- If required, proposed network design rules based on the SQSS to guide the follow-up HND.
- If required, recommended changes to industry technical and commercial codes, standards and licence, or derogations the CDG considers are required in respect of the follow-up HND and proposals. This could include the trialling of any innovative approaches pending changes or derogations.

6. Logistics

The CDG meets at appropriate frequency to deliver outputs by agreed deadlines.

The CDG can decide to form sub-groups as appropriate; sub-group governance should be consistent with the CDG's governance.

At time of writing, there are the following sub-groups:

- HND working level sub-group
- Environmental sub-group
- Commercial sub-group (as required)
- Stakeholder and communication sub-group.

Options for virtual attendance will be available for all sessions.

7. Membership and attendees

Members:

- Representatives of the ESO, National Grid Electricity Transmission, Scottish and Southern Electricity Networks Transmission, SP Energy Networks
- A representative from in scope developers
- Relevant environmental sub-group and local communities' representatives

Observers:

- BEIS and Ofgem representatives
- Representatives of the Devolved Administrations.

Guests:

- The CDG can invite guests (for example in scope developers and/or The Crown Estate or Crown Estate Scotland) on a case-by-case basis to provide input on specific topics.
- The ESO will chair and provide a secretariat function for the meetings.

8. Delegates

Delegates must have appropriate authority to speak on behalf of their organisation.

9. Developer Forum

The developer forum meets at appropriate frequency to share early recommendations and gather feedback.

OTNR follow-up HND

Scope of work

Follow-up HND timing

The follow-up HND will aim to provide design recommendations for in scope projects by the end of March 2023, in consultation with the CDG.

Follow-up HND content

The follow-up HND must identify the requirements for network capacity on the NETS across Great Britain and in offshore waters in relation to in scope projects.

The follow-up HND should, as far as reasonably possible, include indications on the potential location of infrastructure such as onshore landing points and locations of new substations, as well as technology type (e.g., alternating current (AC) vs. direct current (DC)) and other key parts of the specification. It should provide developers with potential connection points and connection dates. The following additional points should be considered as part of this development:

- The follow-up HND should include a robust strategic desktop assessment of the different options available according to the published methodology, and any incremental improvements to that methodology, and taking into account the four Network Design Objectives.
- In particular, the desktop assessment of cumulative environmental and community impacts should be provided in a format that can be taken forward by relevant parties and feed into assessments of strategic impacts so that mitigations and compensation activities can be defined. It should be noted where this assessment aligns with or is similar to Habitats Regulation Assessment (HRA) requirements.
- In practice, the follow-up HND will cover the appropriate offshore and associated onshore network for in scope projects. This includes the interface between what is currently considered the 'offshore' network (assets owned by an Offshore Transmission Owner today), and 'onshore' network (assets owned by a Transmission Owner (TO) today).
- For those elements of the follow-up HND on the 'offshore' side of this interface, the follow-up HND should provide as much detail as reasonably possible, while considering that the follow-up DND will then set out the next level of detail (see below), in terms of both the electrical and spatial configuration of assets. A robust strategic options assessment should be applied cognisant of, and consistent with, the RIIO-T2 price control frameworks.
- Any solutions to system needs and boundary capability requirements on the onshore side of the interface that are in addition to those specified within the NOA 2021/22 Refresh, will be determined either through the HND follow-up process or through the wider TCSNP2 process. The ESO should take reasonable steps that, while remaining consistent with the Network Design Objectives, follow-up HND proposals and the outcome of the NOA 2021/22 Refresh align and where this is not the case the differences are justified. Where the follow-up HND aligns with existing onshore reinforcements in the NOA 2021/22 Refresh, the existing regulatory framework will apply, including any relevant changes as a result of the British Energy Security Strategy (BESS), and the four network design objectives will not be applied to these.
- The follow-up HND will consider the Network Design Objectives (cost, deliverability and operability, environmental impacts, and community impacts) on an equal footing.
- In developing the follow-up HND, the ESO (in its independent role, including in relation to and within the CDG), within these constraints, should seek to minimise the whole system cost to the consumer of the NETS while also meeting network planning and operational standards. The ESO should also take into account the Network Design Objectives when developing and evaluating design options, and in assessing the impacts of the design recommendations as a whole. Whole system costs must account for achieving the Government's net-zero targets, while appropriately managing social, environmental, and economic impacts to ensure clean, affordable and reliable energy to the consumer. Where a different balance of Network Design Objectives (in particular of total cost vs. other objectives) would result in a very different follow-up HND, the ESO should make this clear as part of the recommendation process and if appropriate show alternative options.

- The follow-up HND should provide a sufficient level of detail to allow the parties undertaking the follow-up DND to make decisions about the specific network assets that would fulfil the requirements of the follow-up HND. The follow-up HND should include a number of “fixed” design components, but it should not limit the ability of the parties undertaking the follow-up DND to exercise their engineering judgement or limit their ability to discharge their detailed planning and consenting obligations.

Roles and responsibilities for the follow-up HND development

- The ESO will be responsible for making an independent evaluation of the follow-up HND, including carrying out the strategic options assessment
- The ESO will be responsible for developing, delivering, and owning the follow-up HND.
- In developing the follow-up HND, the ESO should work closely with CDG participants[17], and take their views into account.
- If there is a divergence in opinion the ESO, the TOs and the other members of the CDG will seek to find agreement. If an agreement cannot be found, the ESO will take the final decision.
- The CDG should also take into account the views of in scope developers and as already stipulated by individual licences, environmental and community stakeholders, as far as is appropriate and reasonably practicable. This will include spatial planning, indicating where there are environmental constraints, land availability and interactions with other assets (including those not owned by TOs). In both cases the ESO should be able to demonstrate how those parties’ views have been addressed within the final follow-up HND.

[17] This could include relevant delivery bodies, where known. The Ofgem minded-to decision on delivery models to maintain the ‘very late competition generator build’ for Pathway to 2030 applies to all Crown Estate Leasing Round 4 projects, ScotWind projects and projects from an earlier leasing round that are in the scope of the first HND. The delivery model for Celtic Sea/other projects included in this exercise is yet to be decided. At the time of agreeing these terms of reference, Ofgem was in the process of considering responses to this consultation and therefore the final decision on the delivery model was not known.

OTNR follow-up DND

Scope of work

The Offshore follow-up DNDs, to be taken forward by the relevant delivery body, for both offshore and associated onshore assets (as defined in the follow-up HND and further confirmed in connection contract updates) should set out the next level of detail for the Network Assets based on the requirements set out in the follow-up HND. The follow-up DND should also seek to address the key environmental and cumulative impacts, indicated in the follow-up HND and therefore include mitigations and other measures required under the existing legislative and regulatory obligations (e.g., HRA or equivalent), as applicable in pursuit of planning consent in the relevant jurisdiction.

Interpretation

For the purposes of this document:

- Licence Area has the meaning given to it in the Electricity Transmission Licence.
- National Electricity Transmission System (NETS) has the meaning given to it in the standard conditions of the Electricity Transmission Licence.
- Network Assets has the meaning given to it in the Electricity Transmission Licence.
- Network Design Objectives are the ones listed in section E of this document.

Network Design Objectives

#	Name	Description	Notes
1	Economic and efficient costs	Network solution is economic and efficient	• Taking into account, amongst others, whole system costs and the requirements of license obligations • Least regrets investment decision that can be taken 'today', i.e., reinforcements that are required under all FES that are in optioneering to consultation stage in 2022 to meet 2030 ambition and contribute to delivery of CB6 and Net Zero in 2050
2	Deliverability and operability	Network solution that contributes to delivery of Sixth Carbon Budget and net zero ambition and the resulting system is safe, reliable and operable	• The aim is that the coordinated onshore and offshore network infrastructure connects in scope projects in a way that supports achieving government offshore wind ambition of 50GW by 2030 for Great Britain, including 5 GW of Great Britain's floating wind, and contributes to delivery of CB6 and Net Zero in 2050, while protecting system security, reliability, and resilience • Also, recommend offshore and associated onshore reinforcements and system needs and boundary capability requirements or solutions to manage constraints that are consistent with the Network Design Objectives • Taking into account, amongst others, planning consent requirements, value for money to the consumer and commercial acceptability from developers • This objective likely interacts with environmental impact and community impact
3	Environmental impact	Environmental impacts are avoided, minimised or mitigated by the network design, and best practice in environmental management is incorporated in the network design	• Cumulative environmental impacts of the design should be considered in addition to impacts in isolation, i.e., a high-level desktop assessment of key environmental impacts should be undertaken • Includes offshore and associated onshore environmental impacts, for example protected areas onshore and offshore, and further constraints • It should be considered that the connection of offshore wind as low carbon generation technology avoids carbon emissions compared to electricity generation with fossil fuels, but the follow-up HND should not inadvertently cause unnecessary damage to valuable ecosystems and contribute to biodiversity loss
4	Local communities impact	Local communities impacts are avoided, minimised or mitigated by the network design	• Encompasses communities affected by onshore and offshore grid infrastructure • Addressing the concerns of local communities which typically relate to: the number and size of onshore connection points and onshore infrastructure; cumulative impacts associated with multiple connections, substations and other infrastructure; coordinated / consolidated / integrated infrastructure is central to mitigating impacts