Beyond 2030: INTOG

Recommending the Final INTOG Design; Supplementary Report

December 2024

NESO
National Energy System Operator

Contents

Introduction 5
1.1 Report Structure 5
1.2 Background: Decarbonising Oil and Gas 6
1.3 A Holistic Approach 7
2 Overview of the Design Objectives and Assessment Approach 8
2.1 Projects In Scope 8
2.2 The Design Objectives 10
2.3 Determining Objectives and Data 11
2.3.1 Assessing the Designs Against the Design Objectives 12
2.3.2 Environment Impact 13
2.3.3 Community Impact 14
2.3.4 Deliverability and Operability Assessment 14
2.3.5 Economic and Efficient Assessment 15
2.4 Identifying and Assessing Initial Offshore Network Designs 16
2.5 Determining the Final Recommended Design 16
3 Identifying and Assessing Initial Offshore Network Designs 17
3.1 Interface Points and Availability 17
3.2 Offshore Design Option Creation 20
3.3 Design Sensitivities and Refinement 21
3.4 Determining Shortlisted Designs 23
3.4.1 Initial Strategic Options Appraisal – IN 24
3.5 Onshore Design Appraisal 26
4 Final Design Recommendation 27
4.1 Recommending Design TOG_R012U-NC 27
4.2 Recommending Design IN_002 30
5 Conclusion and Next Steps 31
Appendix A – Recommended Design Against Assessment Criteria 1
Economic and Efficient 1
Deliverability and Operability 2
Environment 2
Community 3
Recommending Design IN_002 4
Economic and Efficient 4
Deliverability and Operability 4

Environment 4
Community 5
Appendix B – Shortlisted Designs Against Assessment Criteria 1
Overall Rank Second: TOG_M010Y-NC 1
Economic and Efficient 2
Deliverability and Operability 2
Environment 3
Community 3
Overall Rank Third: TOG_M007X 4
Economic and Efficient 5
Deliverability and Operability 5
Environment 6
Community 6
Overall Rank Fourth: TOG_R010T 7
Economic and Efficient 8
Deliverability and Operability 8
Environment 9
Community 9
Overall rank Fifth: TOG_R007V-NC 10
Economic and Efficient 11
Deliverability and Operability 12
Environment 12
Community 12
Overall Rank Sixth: TOG_R003K-1a 14
Economic and Efficient 15
Deliverability and Operability 15
Environment 16
Community 16

Table of Figures

Figure 1: INTOG projects in scope of the HNDFUE INTOG process 8
Figure 2: Overview of the design process 11
Figure 3: Scale of severity ratings 13
Figure 4: Interface points evaluated for INTOG 18
Figure 5: TOG design nomenclature 21
Figure 6: Recommended TOG design TOG_R012U-NC 28
Figure 7: Recommended IN design IN_002 30

Table of Tables

Table 1: Projects in scope 9
Table 2: Transmission Interface point availability 19
Table 3: Network design assessment overview – shortlisted designs 23
Table 4: IN ISOA longlist of options 25
Table 5: Indicative onshore works 27
Table 6: TOG Design assessment overview comparison 29
Table 7: IN design assessment overview and comparison 31

Introduction

This document is a supplementary report to the *Beyond 2030: INTOG publication*. It expands on the publication by providing additional insights and detailed analysis, explaining the assessment process, the offshore and onshore design options considered and how we came to the final recommendation.

As the National Energy System Operator (NESO), we are responsible for moving electricity around Great Britain to keep homes and businesses supplied with the energy they need. One of our key responsibilities is to assess Great Britain's future energy supply and demand needs and then recommend an electricity network design that can meet those needs in a safe, efficient, and affordable way.

As part of the Holistic Network Design Follow Up Exercise (HNDFUE) processes, we have developed and published recommended designs for several offshore wind projects. Further information on these publications is available as follows:

- In 2020, we developed the *Offshore Coordination Phase 1 Final Report*[1], which assessed the costs and benefits of a coordinated offshore transmission network.
- In July 2022, we published our *Holistic Network Design (HND) recommendation*[2] for connecting 23 GW of offshore wind to the onshore transmission network.
- In March 2024, we published *HNDFUE; Beyond 2030*[3] which facilitated the connection of an additional 21 GW of offshore wind as a result of the Scottish leasing round.
- In August 2024, we published *HNDFUE; Celtic Sea*[4] which recommended a design for 4.5 GW of offshore wind from the Celtic Sea leasing round.

1.1 Report Structure

This annex covers three main sections described below:

- **Overview of the design objectives and assessment approach**: an explanation of the key factors considered in assessing designs and the phased approach to determining the final recommendation.

[1] nationalgridNESO.com/document/183031/download
[2] nationalgridNESO.com/document/262676/download
[3] nationalgridNESO.com/document/304756/download
[4] Beyond 2030: Celtic Sea

- **Identifying and assessing initial offshore network designs**: an explanation of the iterative process followed to identify and assess offshore designs while considering the high-level onshore network impact.
- **Determining the final recommendation for connecting offshore wind farms**: an explanation of how we determined the recommended offshore network design and considered the impact of onshore network reinforcements.

1.2 Background: Decarbonising Oil and Gas

In April 2022 the UK Government published the *British Energy Security Strategy*[5], aiming to deploy up to 50 GW of offshore wind capacity in the UK, with an additional 4.5 GW set out for Innovation & Targeted Oil and Gas (INTOG) projects where a more coordinated approach to electricity transmission network planning is essential.

The INTOG leasing round by Crown Estate Scotland (CES) aims to boost offshore wind farm innovation, and reduce carbon emissions from oil and gas production, in line with the targets in the North Sea Transition Deal (NSTD). INTOG projects are categorised as either Innovation (IN) or Targeted Oil and Gas (TOG) projects. The IN projects are smaller scale innovation projects of 100 MW. These projects will seek to trial innovations within the offshore wind sector, such as floating wind installations. The TOG projects are projects supplying electricity to oil and gas platforms in the North Sea, to reduce their carbon emissions. A total of 12 areas were leased for INTOG by CES, however, for this exercise we investigated the coordination for the six projects that were less progressed in their development.

A key goal of the NSTD is to decarbonise North Sea oil and gas platforms. One of the ways to achieve this is with renewable electricity provided to the platforms to provide heat and power. The NSTD includes a specific target to achieve oil and gas electrification by 2030, and this is therefore a keen focus of the INTOG design process.

This INTOG specific requirement differentiates them from previous HNDFUE process. The TOG projects anticipate their demand will reduce during the 2030s as the platforms curtail output before eventually undergoing decommissioning. This will overall result in additional offshore wind generation output flowing into the transmission system.

[5] gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy

1.3 A Holistic Approach

A holistic network design takes a more integrated approach than the pre-existing network planning process in assessing future network needs. It considers both the offshore and onshore network needs of the National Electricity Transmission System (NETS) to ensure a comprehensive and coordinated planning strategy.

Our analysis has recommended a network design for connecting the INTOG offshore wind farms, taking into account a representative set of onshore reinforcement and offshore infrastructure needs. The three Transmission Owners (TOs); National Grid Electricity Transmission (NGET), Scottish and Southern Electricity Networks Transmission (SSENT) and Scottish Power Transmission (SPT) advised on indicative onshore works to facilitate the connections, based on their understanding of the infrastructure required from the Beyond 2030 works and ongoing ScotWind analysis.

We have used four network design objectives to ensure we are considering a broad range of factors in planning our future networks responsibly. These network design objectives are economic and efficient; minimising environmental impact; minimising local community impact; and maximising deliverability and operability and are further described in section 2.2.

We developed the *INTOG publication* with a range of stakeholders including:

- UK Government departments
- TOs
- CES
- Ofgem
- INTOG developers
- Environmental and community representatives.

Feedback from our stakeholders has helped to shape our final recommendation. More details on this stakeholder engagement can be found in *Part 1* of the *Beyond 2030 publication*.

2 Overview of the Design Objectives and Assessment Approach

2.1 Projects In Scope

Crown Estate Scotland (CES) leased a total of 12 Innovation and Targeted Oil and Gas (INTOG) projects, these ranged from small singular turbine projects of 3 MW to large offshore windfarms in excess of 1,000 MW. For our Holistic Network Design Follow Up Exercise (HNDFUE) INTOG process, the projects were included if they were seeking a connection to the transmission system and were at an earlier stage of their development. Out of the 12 INTOG projects, we have included two Innovation (IN) sites of 100 MW each and four Targeted Oil and Gas (TOG) projects. These projects are shown below in Figure 1:

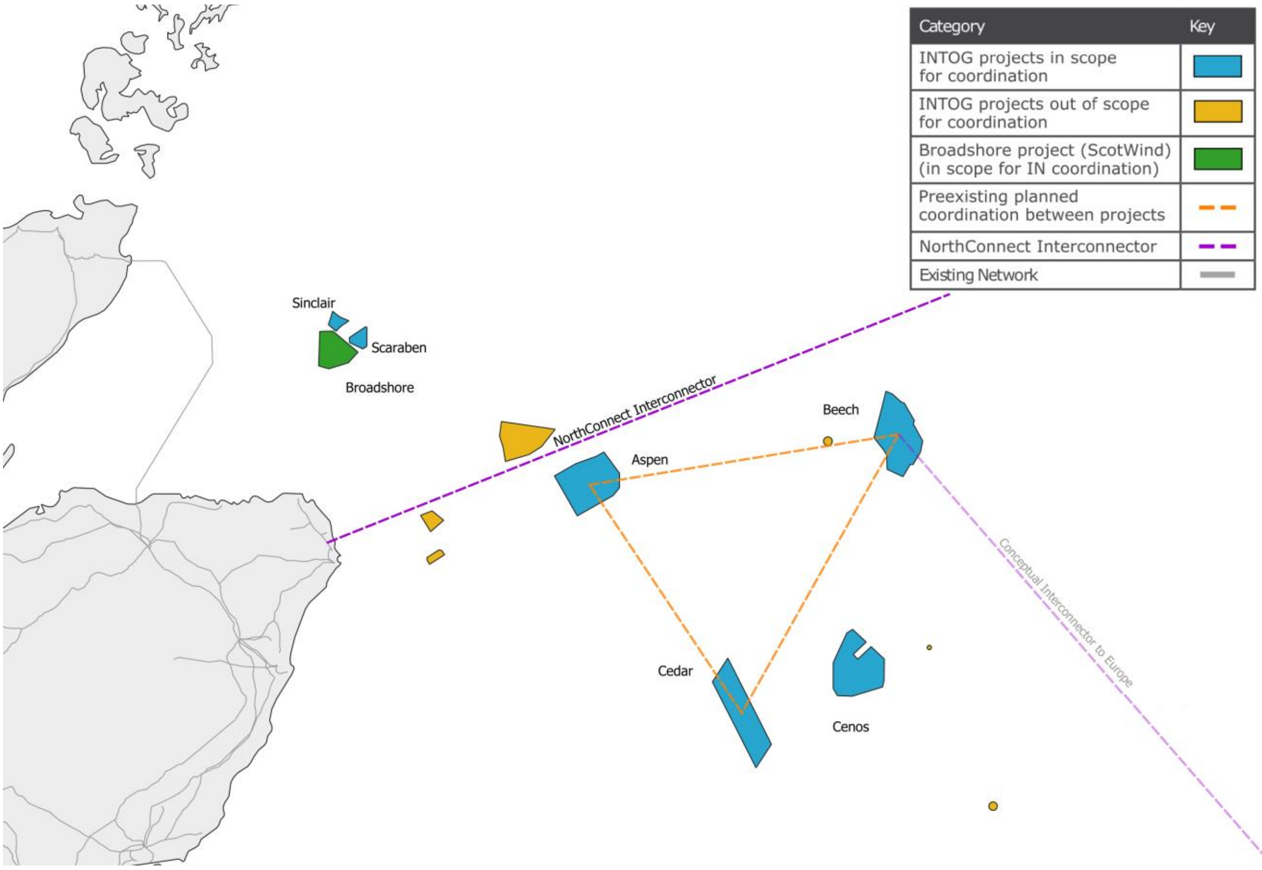

Figure 1: INTOG projects in scope of the HNDFUE INTOG process

With the two IN projects in scope, both projects are being developed by the same partnership of developers, which allows for greater potential coordination between the two projects, from mesh interconnection to less complicated cable corridor sharing.

While Figure 1 shows these projects geographically, the developer has since indicated that the two IN projects will be situated closer together, however this change has not been reflected in these figures as they would not cause any change in our appraisals. These projects are also close to the Broadshore (SW_NE6) project, assessed in the HNDFUE ScotWind design process connecting to Longside 400 kV. This project is held by the same developer partnership, and therefore was also considered for coordination with the two IN projects.

The TOG projects in scope for INTOG are shown in Table 1 below and detail each project's planned generation capacity and maximum demand requirements. The demand requirement for the TOG projects would supply heat and power to the oil and gas platforms would first be supplied by the onshore transmission system in early 2030 then as the offshore wind farm is constructed, demand would start to be supplied by the wind farm until the oil and gas platforms are ultimately decommissioned. The offshore wind farm would remain generating power to export into the transmission system.

The Aspen, Beech and Cedar projects are being developed by the same developer, and this developer currently has plans to link the three project areas via high voltage alternating current (HVAC) cables to form a coordinated ring of projects to feed their oil and gas platform demand. This was taken into consideration at the design drafting stage and therefore forms a constant feature in all designs and presented in the shortlisted designs shown later in this document. This design feature was still assessed and included in all analysis in the same manner as the other offshore elements of each design.

Table 1: Projects in scope

Project Name	Developer	Generation Capacity (max)	Max Demand Requirement
Aspen	Cerulean Winds	1,000 MW	600 MW total across all three projects
Beech	Cerulean Winds	1,000 MW	
Cedar	Cerulean Winds	1,000 MW	
Cenos	Flotation Energy	1,350 MW	270 MW
Sinclair	Bluefloat and Renantis	100 MW	N/A
Scaraben	Bluefloat and Renantis	100 MW	N/A

Following discussions with the Office of Gas and Electricity Markets (Ofgem) and the Department for Energy Security and Net Zero (DESNZ), and with approval from the Transmission Networks Board, the NorthConnect interconnector was also added to the scope of this design process. To fully evaluate the effectiveness of coordination between the in scope projects and NorthConnect, designs were drafted both with and without it in scope for coordination.

The developer of the Aspen, Beech and Cedar projects (Cerulean Winds) also presented a concept to construct an offshore hybrid asset (OHA) link from the Beech wind farm to Germany at the beginning of the HNDFUE INTOG process. This has been included in the background of the economic modelling, but it does not form part of our final recommended design.

2.2 The Design Objectives

The holistic network design (HND) process considers the four design objectives to determine the viability of a proposed design. For each design, we considered the impacts of each criteria on an equal footing both for both offshore and onshore elements. The four design objectives considered in this approach includes:

- **Economic and efficient**: We used economic assessment tools to determine the optimal economic design from a wide range of proposed options, ensuring the best value for consumers.
- **Deliverability and operability**: We applied a deliverability assessment framework that considered a range of factors including supply chain of technologies, construction timeframes and consenting challenges ensuring our design is delivered in a timely and practical way.
- **Environmental impact**: We conducted assessments of environmental constraints using a range of geospatial data sources to determine the location and sensitivity of environmental constraints. We did this in consultation with Statutory Nature Conservation Bodies (SNCBs) ensuring our design minimises the impact, where possible, on the natural environment.
- **Local community impact**: We conducted assessments of community constraints using a range of geospatial data sources to determine the location and the sensitivity of community constraints, ensuring our designs minimise the impact, where possible, on local communities that host this infrastructure.

The design objectives above were set by the Offshore Transmission Network Review (OTNR) Project Board and documented in the HNDFUE Terms of Reference (ToR)[6].

The design process involved evaluating various network designs before recommending a final recommended design. The design process consists of five key steps, as shown in Figure 2. This process has been developed in collaboration with Transmission Owners (TOs), developers, environmental and community representatives, and considered feedback from stakeholders, particularly those involved in developing the earlier Holistic Network Design (HND) and the first element of the HNDFUE.

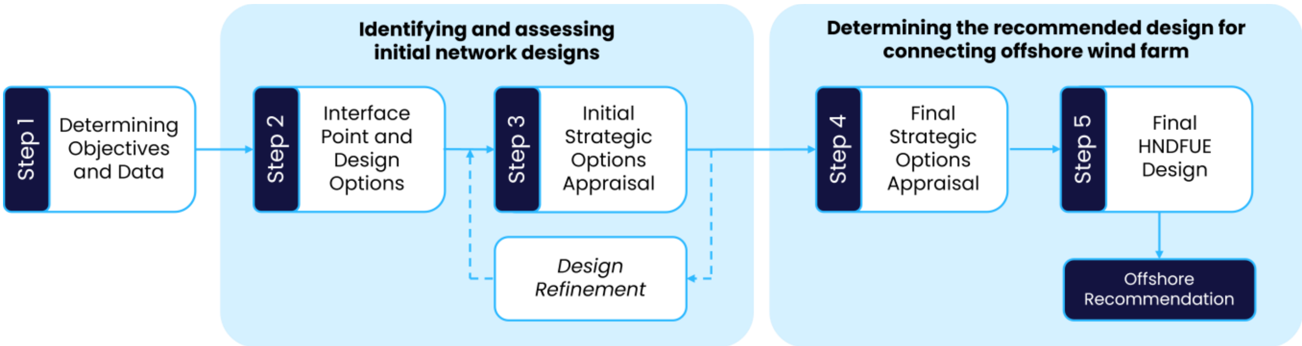

Figure 2: Overview of the design process

2.3 Determining Objectives and Data

The first step in developing the HNDFUE involved establishing the scope of the study, geographic area, and necessary background data. This includes setting design objectives and gathering relevant data.

Key input data for the HNDFUE development includes (this list is non-exhaustive):

- Identification of the HNDFUE background scenario.
- Initial HND outcome.
- Cost model for onshore and offshore assets.
- Design rules and technology assumptions.
- Environmental, community and technical constraint geographic information system (GIS) dataset.

[6] assets.publishing.service.gov.uk/media/64ef6dc513ae15000d6e30de/otnr-hnd-fue-tor.pdf

2.3.1 Assessing the Designs Against the Design Objectives

The assessment process considered the design objectives on equal footing across the onshore and offshore network. The approach to assessing objectives is 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 criteria that must be considered when recommending a final design.

The community, environmental, deliverability and operability impacts were assessed using a BRAG (Black, Red, Amber, Green) assessment process. The economic assessment is not assigned a BRAG status as the costs are quantified with scenario-based forecasts. It uses a combination of financial information about the designs, such as capital infrastructure costs and operational costs to determine the value of each design in terms of net present value (NPV). The NPV enabled us to compare the economic performance across each design.

To determine the BRAG status of designs, they were appraised by subject matter experts (SMEs) for each design objective. The definitions for each BRAG rating are explained:

- **Black rating** – the design is significantly constrained from an environmental/community/deliverability and operability perspective and is unlikely to be viable due to environmental/community/deliverability issues.
- **Red rating** – the design is heavily constrained from an environmental/community/deliverability and operability perspective and is potentially viable, however will have to overcome many environmental/community/deliverability issues.
- **Amber rating** – the design is moderately constrained from an environmental/community/deliverability and operability perspective and is likely to be viable, however may have to overcome some environmental/community/deliverability issues.
- **Green rating** – the design is lightly constrained from an environmental/community/deliverability and operability perspective and is likely to be viable without any major environmental/community/ deliverability issues.

At the final strategic options appraisal (FSOA) stage, these BRAG ratings were each supplemented with a severity rating, from 1-5. This rating indicated the severity of the relevant constraints to each objective and allowed designs with the same colour of BRAG rating to be compared in more detail. Figure 3 shows how the severity ratings provide subdivisions within each BRAG rating, while still showing a scale of increasing constraint. Black BRAG ratings did not receive a severity rating, as this rating indicates that the design is unviable.

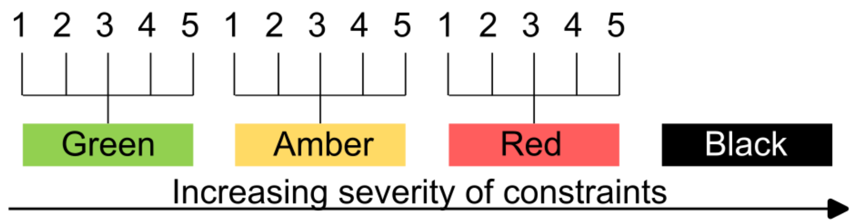

Figure 3: Scale of severity ratings

2.3.2 Environment Impact

A key part of the appraisal was to review the environmental impacts that were assessed based on relevant features and constraints along the offshore cable route corridors. This assessment focused on:

- Determining feasible cable route corridors to an interface point.
- Assessing the feasibility of a particular offshore design, considering the locations of onshore connection works and offshore infrastructure required.
- The type of data required for the offshore constraint mapping included:
  - Water depths.
  - Planning datasets e.g. Marine Planning Areas (MPAs), Water Framework Directive (WFD) water bodies.
  - Information of renewable energy projects, existing and consented sites and cable routes.
  - Information on oil and gas infrastructure, including pipelines.
  - Nature conservation information.
  - Information on marine cables.
  - Aggregate/dredging areas.
  - Information on seabed habitats.

- Geological information, near surface and sub-surface.
- Marine mammal data.

This was a high-level, desktop based, strategic options appraisal and was not intended to identify a route corridor for detailed network design, consenting and construction, or the final siting of any infrastructure. The output of this stage was an environmental BRAG assessment for potential route corridors. These individual assessments formed the basis for assessing the interaction of designs with environmental and community constraints – and the associated anticipated risk to consenting – for the design option, which consist of multiple offshore cable routes. The consolidated allocation of an environmental BRAG rating for a design option were assigned based on expert judgement considering the BRAG ratings of the cable routes.

2.3.3 Community Impact

A key part of the appraisal was to review the community impacts were assessed based on relevant features and constraints along the offshore cable route corridors. This assessment focused on:

- Determining feasible cable route corridors to an interface point.
- Assessing the feasibility of a particular offshore design, considering the locations of onshore connection works and offshore infrastructure required.
- The type of data required for the offshore constraint mapping included:
    - Information on aquaculture
    - Shipping data and Information of wrecks
    - Locations of disposal sites, current and historic
    - Aggregate/dredging areas
    - Defence activity exclusion zones
    - Information on fishing activity.

2.3.4 Deliverability and Operability Assessment

Several criteria were used to ascertain the overall BRAG status against the deliverability and operability objective, some of which includes:

- **Design complexity**: technical difficulty in realising a design i.e. interface/landing points, interconnectivity of sites, offshore cabling, and/or offshore substation.

- **Construction complexity**: to realise the design including potential risks of a particular design option for both onshore connection works and offshore infrastructure.
- **Technology readiness level**: high voltage alternating current (HVAC) is proven design whereas high voltage direct current (HVDC) connections are less mature.
- **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.
- **Planning and consenting**: High-level issues arising from a design i.e. overhead lines (OHLs), new landing sites that require specific consents that are separate from environmental considerations.

Specific to the INTOG process, we had to also consider which TO connection points would be available for connection by 2030 to supply TOG demand from shore. As such, preference was given to either existing substations, planned extensions or already planned new substations that would meet as far as possible this timeline.

2.3.5 Economic and Efficient Assessment

The economic assessment focused on evaluating the total costs associated with building and operating the infrastructure needed to connect the offshore wind farms to the selected interface points. The evaluation includes the costs of reinforcing the onshore network, delivering power to where it is needed based on expected additional power transfer requirements between key boundaries across the UK and an estimate (£/GW) of the associated cost to enable this transfer. The economic optimisation model assessed the cost of design options and provided the total capital and ongoing operational cost of design options and the costs of operating the market once the wind farms and associated infrastructure are in place.

Economics was not assigned a BRAG rating, instead the NPV was used as a comparison between designs:

- NPV: the differential in cost between the design in question, and the most economic shortlisted design. The NPV is a combination of the following three cost components:
- Offshore infrastructure costs: estimated cost of building, operating, and maintaining the offshore network (including infrastructure between the interface point and offshore wind farms, in addition to costs associated with each interface point).

- Onshore infrastructure costs: estimated cost of reinforcing the onshore transmission network to facilitate connection of the wind farm.
- **Market costs:** includes the approximate dispatch costs (approximate running costs) of thermal generation that is in merit, and the redispatch of the entire of Great Britain's system (cost of bids and offers due to thermal constraints, and cost of taking actions on interconnectors), over a 40-year period. These costs are based on a single snapshot year as modelled in the optimiser. The input costs that the optimiser uses to calculate this are consistent with those used in some of our other economic modelling, for example, Network Options Assessment (NOA).

2.4 Identifying and Assessing Initial Offshore Network Designs

A crucial aspect of the design process was determining the transmission interface points (TIPs) or substations where the wind farms would connect to the onshore network. These connections could be made to existing substations or new substations planned by the TO, either for existing customers or specifically triggered by this HNDFUE exercise.

Once feasible TIPs are established by the TO, we then identify and assess various ways to connect the offshore generation to these points.

Following the environmental, community, deliverability and operability, and economic assessments by our SMEs, design options were refined to better align with the design objectives. This iterative process, conducted in collaboration with the TO, led to an improved set of high performing designs that were taken forward for detailed assessment in the final strategic options appraisal stage.

The objective of the initial network design appraisal was to determine the best performing design options using high-level assumptions. This approach was taken without waiting for all the required data concerning onshore reinforcement works, and detailed assessment of offshore works. Following the assessment of the options, seven high-performing designs were shortlisted for further development and assessment.

2.5 Determining the Final Recommended Design

The next phase built on the initial strategic options assessment phase by delving deeper into the shortlisted designs, with a particular focus on assessing their onshore requirements, while continuing more detailed evaluation of the offshore designs against the four design objectives.

The necessary onshore reinforcement requirements to facilitate the connections were considered for each shortlisted design to ensure a robust and reliable link to the onshore transmission network, and these reinforcements were factored into the overall performance evaluation.

Each design was compared and ranked on their overall performance, considering how well they met the design objectives for their offshore and onshore requirements.

Following a thorough comparison and ranking process, which incorporated feedback from various stakeholders, a final design was selected. This design represents the optimal balance across all four design objectives, for their offshore and onshore component.

3 Identifying and Assessing Initial Offshore Network Designs

The purpose of this phase was to identify network designs that connect the offshore wind farms to the onshore transmission network and assess these against the design objectives. This phase aimed to shortlist a range of suitable designs that could be assessed in further detail in the next phase of the process.

3.1 Interface Points and Availability

Transmission interface points (TIPs) were identified at the start of the INTOG process provided by the TOs. Each interface point was assessed based on its capacity for additional connection, relevant features and constraints along the offshore landfall site, and onshore cable route corridors to the interface point. Figure 4 shows an overview of the transmission interface points provided by the TOs.

A key constraint was substation bay availability of the transmission interface points due to the specific target to achieve oil and gas electrification by 2030. While this target date is key driver for the demand element of TOG projects, it was not explicitly considered as an additional decision making factor outside of the four design objectives.

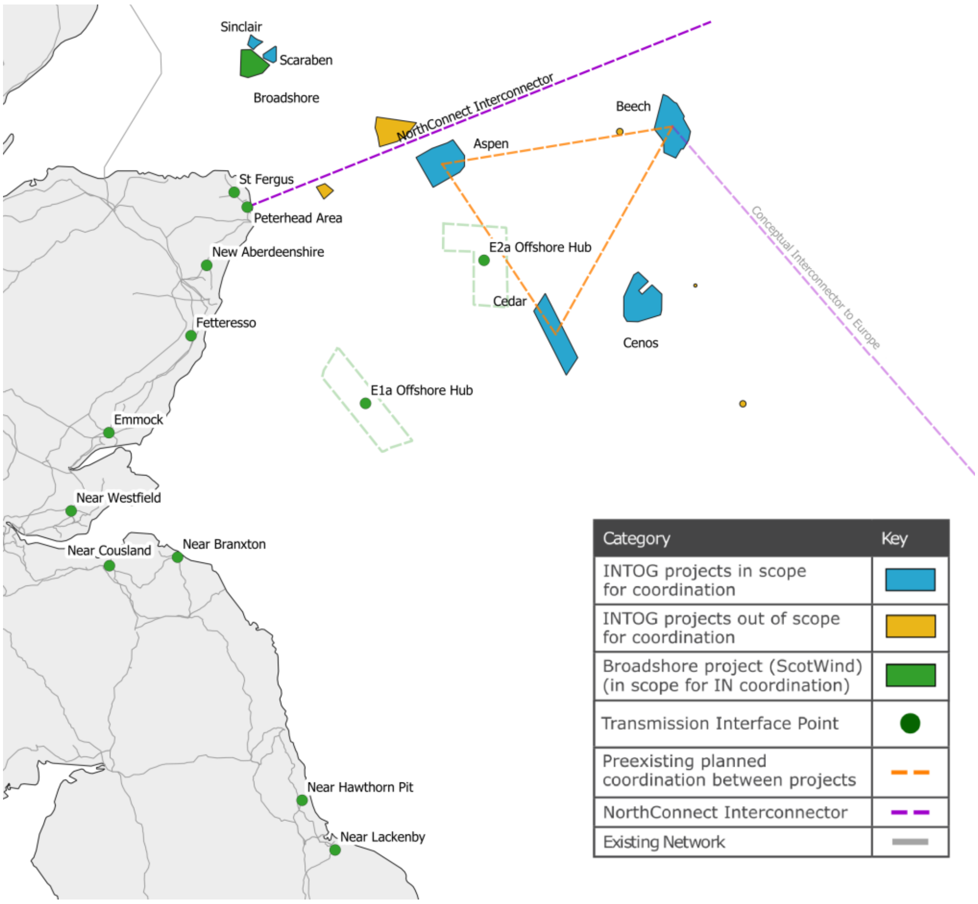

Figure 4: Interface points evaluated for INTOG

Table 2 shows the TIP sites which were prioritised for the INTOG process and whether they are new, existing or already planned developments. The dates presented in the table are indicative availability dates, hence are subject to change due to planning process and consenting challenges.

Two TIP locations were appraised in National Grid Electricity Transmission's (NGET's)area; Near Hawthorn Pit and Near Lackenby using information provided during the Holistic Network Design Follow Up Exercise (HNDFUE) Scotwind. Offshore interface points were also considered at this stage, where supplied by the TOs. An offshore interface point is an offshore platform that is part of a coordinated offshore design (such as HND or HNDFUE ScotWind) but has been classified as a TO asset by Ofgem's asset classification process.

Other TIP locations were also investigated during the ISOA stage but were less favourable due to either their later availability dates, costs, location or environmental topographical constraints at landfall for export cables. There are no interface points supplied further south than the North East England as they did not meet the North Sea Transition Deal (NSTD) timescales.

Only one TIP location; Longside was investigated for the two innovation sites. This was because the TO already had bays allocated at Longside 132 kV voltage level for these projects.

Table 2: Transmission Interface point availability

Interface Point (400 kV)	Existing/Planned/New [indicative year]	Assessment against TOG demand objective
St. Fergus	New [2035]	Shorter route to shore for northern TOG sites, however indicative year do not meet NSTD timescales.
Peterhead	Existing [2028]	Early availability, but only possible for a NorthConnect connection as no additional bays are available.
Longside	Planned [2031]	Planned upgrade and extension to Peterhead 400 kV now formally known as a new planned substation. Longside 132 kV available for Innovation (IN) sites.
New Aberdeenshire	Planned [2033]	Shorter route to shore for northern TOG sites, however indicative year do not meet NSTD timescales.
Fetteresso	Existing	Potentially available by 2030 as this is an existing site, some extension required for an additional bay. Provides a relatively short route from most TOG sites.
Emmock	Planned [2030]	Potentially available by 2030, site in development.
Near Branxton	New [2031]	Available by 2031, suitable for secondary connection site.
Near Hawthorn Pit	New [2033]	Indicative year do not meet NSTD timescales.
Near Lackenby	New [2033]	Indicative year do not meet NSTD timescales.

Two interface points were also supplied in England, Near Hawthorn Pit and Lackenby. Although these interface points would not meet the desirable dates for connection, they were included to assess the impact on the onshore element of each design of connecting further south. This was to test whether an interface point in England would mitigate against additional Scottish onshore reinforcements in this instance.

3.2 Offshore Design Option Creation

After identifying the best performing interface points, we explored different offshore configurations to connect the offshore wind generation to the main transmission system considering the four design objectives.

Each offshore design was appraised individually against the community, environment, deliverability and operability, and economic design objectives. Design review workshops were held to review the designs collectively, ensuring all objectives were given equal consideration. Based on their performance, we decided whether to progress a design, iterate the design by changing certain features (e.g. change to interface point, or design configuration), or discount the design.

During the initial design development, we identified six different types of offshore network variations.

- Radial designs, with NorthConnect out of scope for coordination.
- Radial designs, with NorthConnect in scope for coordination.
- Radial designs, with NorthConnect out of scope for coordination, featuring southern connections.
- Radial designs, with NorthConnect in scope for coordination, featuring southern connections.
- Mesh designs, with NorthConnect out of scope for coordination.
- Mesh designs, with NorthConnect in scope for coordination.

To keep track of the variations, each design received a unique design reference. These design names followed a set nomenclature, illustrated in Figure 5 and detailed below for TOG designs. IN designs were named with the prefix 'IN', and numbered incrementally as there were less design options drafted for IN projects due to the relative simplicity of this element of INTOG.

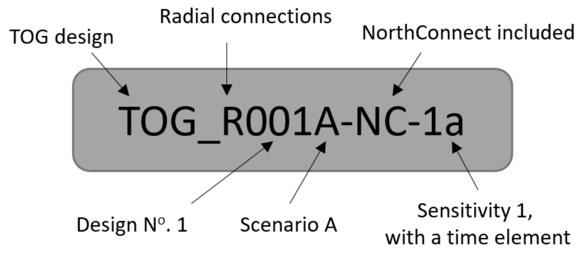

Figure 5: TOG design nomenclature

All TOG designs started with the prefix 'TOG_', to differentiate them from designs for IN projects.

The next letter denoted the type of design, with 'R' for radial, and 'M' for mesh designs. Each design would then be assigned a number, incremented as designs were produced. A letter would follow the number, indicating the scenario being used. This was linked to when demand or generation could be connected in each design. If the design included coordination with the NorthConnect interconnector, the additional letters 'NC' were applied.

Lastly, an additional number may be added as a suffix, indicating that the design is a sensitivity study on an existing design. A letter 'a' may also be added at this point to indicate a time element to the sensitivity.

3.3 Design Sensitivities and Refinement

A longlist of designs was created during the ISOA stage which were each appraised against each network design objective, in line with the HNDFUE INTOG methodology. The longlist of designs was created to test three key factors in designs: topology type, coordination with NorthConnect, and connections to North East England.

The topology types tested here were radial designs, where projects connect directly to shore without interacting or coordinating with projects from other developers, or mesh designs, where there is coordination and interaction between developers and their respective projects. Coordination with the NorthConnect interconnector was also tested here to determine and quantify any benefit, exploring the impact on both connection timescales and the ability to export power to additional markets. Lastly, designs with links to North East England were assessed to determine whether it would have a beneficial impact on the onshore reinforcements required in Scotland.

Internal design workshops with subject matter experts (SMEs) were conducted to compare the performance of the design and to seek improvements. The purpose was to arrive at a shortlist that represented the variety of connection options available and the best performing design across the four objectives. Within each category of designs, the process began by first identifying any designs to be discounted. Designs were immediately discounted if they featured any Black BRAG (Black, Red, Amber, Green) ratings, as this would indicate significant constraints that would likely make the design unviable. Nine designs were discounted due to Black deliverability and operability ratings, the Black rating primarily from constraints at an interface point. Two designs were then also discounted due to Red deliverability and operability ratings, given due to high levels of offshore complexity in each design. These designs were discounted as there were sufficient alternative designs in the category that performed better in this objective.

Elements within a design that performed well were implemented into additional designs to understand their impact. Similarly, less favourable elements due to any design criteria were refined to see if improvements could be made for subsequent offshore designs.

Throughout this process certain factors were identified as strongly contributing to the performance of designs, and therefore those designs either being shortlisted or not being shortlisted:

- **Length of cable** – designs with longer offshore cable lengths have higher CAPEX costs. Shorter offshore routes are an economic advantage if onshore reinforcement costs are same.
- **Complexity of offshore network** – designs with increased numbers of cables connecting to any individual project resulted in poorer deliverability and operability ratings, as this results in either more platforms offshore, or more complex platform arrangements.
- **Combinations of onshore landing locations** – designs that connected to interface points with environmental or community constraints resulted in poorer environmental or community ratings when these routes to shore made up the majority of offshore routes. Designs that therefore minimised the number of onshore landing points also performed well as the chance of an Amber rated interface point being used was reduced.

3.4 Determining Shortlisted Designs

A shortlisted design was then identified by comparing designs on their economic values and BRAG ratings and identifying the best performing design when comparing the objectives on an equal footing. Input to this process was continually provided by SMEs within each of the design objectives to ensure an informed decision.

Table 3 below shows the shortlist of designs produced by the ISOA process, and includes the BRAG assessment outcomes for the community, environment, and deliverability and operability network design objectives. In addition, the table includes the economic assessment results for each design, shown as cost variance versus the cheapest design in the longlist, and a ranking produced from these figures.

Table 3: Network design assessment overview – shortlisted designs

Design	Description	BRAG assessment			Economic costs	
		Environment	Community	Deliverability & Operability	Rank	NPV Variance vs best (£bn)
R010T	Three links total with one each to Fetteresso (Cenos), Emmock and Near Branxton (Cerulean).	Amber	Green	Green	5	4.44
R003K-1a	Three links total with one each to Lackenby (Cenos), Fetteresso and New Aberdeenshire (Cerulean).	Green	Amber	Green	6	5.46
R012U-NC	Three links total with one each to Peterhead (Cenos), Fetteresso and Near Branxton (Cerulean). NorthConnect is coordinated with Cenos.	Green	Green	Green	2	2.46
R007V-NC	Three links total with one each to Hawthorn Pit (Cenos), Near Branxton and Fetteresso (Cerulean) NorthConnect is coordinated with Cenos.	Green	Amber	Amber	4	3.07

Design	Description	BRAG assessment			Economic costs	
		Environment	Community	Deliverability & Operability	Rank	NPV Variance vs best (£bn)
M007X	Mesh design coordinating all projects through an AC link between Cenos and Cedar. Three links total with one each to Fetteresso, Emmock (Cerulean) and Near Branxton (Cenos).	Amber	Green	Amber	3	2.84
M010Y-NC	Mesh design coordinating all projects through an AC link between Cenos and Cedar. NorthConnect is primarily coordinated with Cenos. Three links to shore total, one to Peterhead (Cenos) and two to Near Branxton (Cerulean).	Green	Green	Amber	1	0

The assessment at this stage considered the economic, environmental, deliverability and operability, and community constraints between the offshore wind farms and onshore substations. It did not account for the impacts of any further onshore works other than with high-level notional reinforcement.

3.4.1 Initial Strategic Options Appraisal – IN

In a similar manner to the TOG designs, a longlist of designs was generated for the IN projects. Due to the IN element of the process being a much more concentrated design process, a singular interface point considered for this design exercise which is Longside 400/132 kV. This was due to the Longside 132 kV site being the planned connection for the two IN projects, and the 400 kV site being the existing planned connection for Broadshore, which would be used in the event of coordination with this wind farm.

Table 4 below shows the designs considered in the ISOA process, and includes the BRAG assessment outcomes for the community, environment, and deliverability and operability network design objectives and the economic NPV results for each design.

The shortlist for the IN designs came about by first discounting the two designs IN_001 and IN_003 that scored a Black rating on deliverability and operability due to constraints at the Longside interface point. Similarly, IN_000 was then also discounted due to a Red environmental rating around concerns in the Southern Trench MPA.

The design IN_005 did not attain an economic assessment thus could not be evaluated in accordance with our methodology. This design explored the possibility of using array cabling to connect the IN projects and the Broadshore (SW_NE6) wind farm, therefore reducing the requirement for additional platforms in the sea. As array cable costs are attributed to the project, this design was not taken further.

Based on this analysis, designs IN_002 and IN_004 were then shortlisted. By shortlisting these two designs, the final strategic options appraisal (FSOA) process for the IN design would therefore test the benefit of coordinating the projects with the ScotWind Broadshore project or separating them but coordinating them with each other and following a separate path to shore.

Table 4: IN ISOA longlist of options

Design	Description	BRAG assessment			Economic costs	
		Environment	Community	Deliverability & Operability	Rank	Cost Variance vs best (£m)
IN_000	Pure radial design, one connection from each project to Longside 132 kV.	Red	Green	Green	4	366
IN_001	Coordination between each project and Broadshore, using the existing planned 1 GW link to Longside 400 kV.	Green	Green	Black	1	0
IN_002	Coordination between the two Innovation projects and a single link to Longside 132 kV.	Amber	Green	Green	2	164
IN_003	Coordination between each project and Broadshore, upgrading the existing planned link to a HVDC symmetric monopole.	Amber	Green	Black	5	1901
IN_004	Coordination between each project and Broadshore, upgrading the existing planned link with an additional cable to allow for the full capacity of all projects.	Amber	Green	Green	3	170

Design	Description	BRAG assessment			Economic costs	
		Environment	Community	Deliverability & Operability	Rank	Cost Variance vs best (£m)
IN_005	Coordination between each project and Broadshore using array cabling only, upgrading the existing planned link with an additional cable to allow for the full capacity of all projects.	Amber	Green	Green	N/A	N/A

Further explanation on how each of the shortlisted designs ranked against their design criteria is available in Appendix B

3.5 Onshore Design Appraisal

At the shortlisted designs stage, we undertook another round of internal design workshops with SMEs to assess both offshore and onshore aspects of the design. In addition, we liaised with the impacted TOs to understand the extent of onshore works required to enable the shortlisted designs. This stage included:

- Feedback from TOs to determine required onshore reinforcements for each of the shortlisted options.
- Appraising the technical deliverability and operability of each option including onshore reinforcement.
- Further detailed assessments of environmental and community impact using BRAG assessments considering both offshore and onshore impact of each option.
- More detailed cost assessments associated with building and operating each design option, considering the offshore and onshore component of each option.

The TOs provided information reinforcement paths for each shortlisted design. Due to the ongoing TO work for the Scotwind connections, most of the onshore reinforcement schemes included have already been triggered as necessary and have been published in *Beyond 2030*.

Table Table 5 shows the works required across all shortlisted designs in Scotland. Reinforcements in additional to these were also required for the designs featuring southern connections which is further described in Appendix B.

Table 5: Indicative onshore works

Description	Category	New / Existing Recommendation
Upgrade the existing network to a higher voltage between Blackhillock and Kintore.	Existing network upgrade	Recommended in the Beyond 2030 publication
New circuit from North East Scotland to the Central Belt.	New onshore circuit	Recommended in the Beyond 2030 publication
Upgrade and/or rebuild the circuits and equipment between Longside, Peterhead, Persley, Kintore, Fetteresso, Alyth, Kincardine.	Existing network upgrade	Recommended in the Beyond 2030 publication
Pathway to 2030: Holistic Network Design Offshore Network.	New offshore circuits	Recommended in the Beyond 2030 publication
Beyond 2030: Holistic Network Design Follow Up Exercise Offshore Network.	New offshore circuits	Recommended in the Beyond 2030 publication

Each shortlisted design was individually re-assessed to create a combined offshore and onshore BRAG rating on each design criteria alongside a severity rating was added to help further distinguish between the designs.

4 Final Design Recommendation

This section provides detail on both the Innovation and Targeted Oil and Gas (INTOG) elements of the Final Recommended Design for the Holistic Network Design Follow Up Exercise (HNDFUE) INTOG process, and our rationale behind the selection of these design elements when compared to the other shortlisted designs.

4.1 Recommending Design TOG_R012U-NC

When considering the four network design objectives on an equal footing, design TOG_R012U-NC performs well across each and provides the best overall performance across the shortlist of Targeted Oil and Gas (TOG) designs. Shown in Figure 6 below, this design has three high voltage direct current (HVDC) connections from the in scope TOG projects to shore. The Cerulean projects Aspen and Cedar connect to Fetteresso and Near Branxton respectively, and the NorthConnect interconnector coordinates with the Cenos project and forms a coordinated solution connecting to Peterhead. This design was initially shortlisted in the initial strategic options appraisal (ISOA) due to having the lowest costs in its category, while performing equally well with other designs on the remaining objectives.

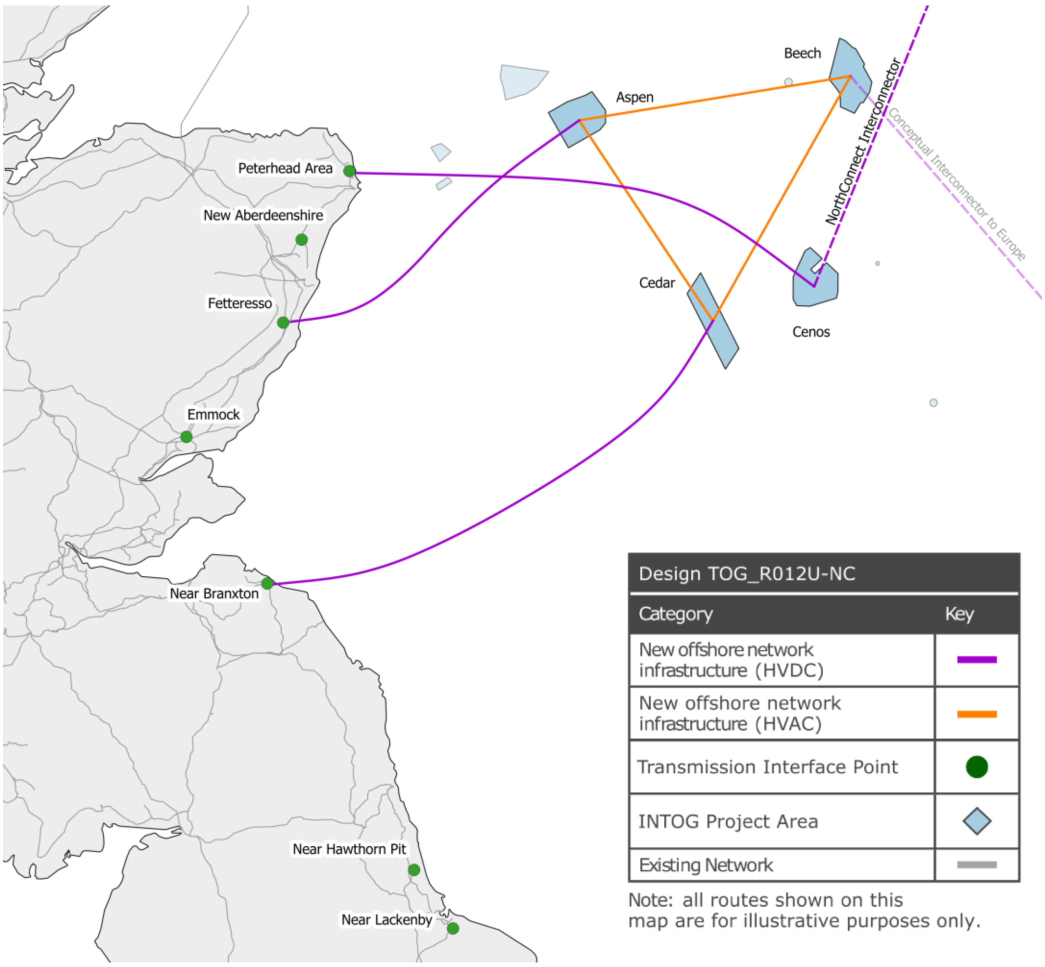

Figure 6: Recommended TOG design TOG_R012U-NC

This design performs relatively well across both environment and community, due to fewer cables making landfall and a lower proportion of interface points in sensitive areas. This design was therefore ranked joint first in both objectives when compared with other designs in the shortlist. This design also performs well economically, due to the benefits of coordination with NorthConnect. The benefits of an earlier connection for both projects also result in substantial carbon cost savings, where the projects can support decarbonisation of the oil and gas platforms, and coordination with

NorthConnect allows an additional export path for generation. This design performed second best out of all the shortlisted designs, second only to design TOG_M010Y-NC in this regard. This design also performs well in deliverability and operability due to lower offshore complexity when compared to mesh designs and was ranked first in this objective.

The indicative onshore works identified for this design are shown in

Table above. There were three individual works identified for this design: one new onshore circuit and two upgrades of existing circuits. These works enable greater power flow along the north east coast of Scotland, enabling the additional power from these projects to be transported further south to demand centres. The coordinated offshore networks recommended in the first HND and HNDFUE ScotWind design processes were also identified as indicative works for this design. The high-capacity offshore links in these designs enable the transfer of this power further south to demand centres in England. These indicative onshore works will mean that the generation element of the TOG projects will not be able to export generation onto the transmission network until their completion in late 2030s.

This design therefore performs best, or joint best in three out of the four network design objectives and was the second-best performing design economically behind design TOG_M010Y-NC as shown in *Table 6*Further information on how it scored against each design criteria is available in Appendices A and B.

Table 6: TOG Design assessment overview comparison

Overall Rank	Design	Economic & Efficient			Environment		Community		Deliverability & Operability	
		Offshore NPV Delta (£b)	Market Cost Delta (£b)	Total NPV Variance (£b)	Onshore BRAG	Offshore BRAG	Onshore BRAG	Offshore BRAG	Onshore BRAG	Offshore BRAG
1st	**R012U-NC**	(1.1)	(1.5)	(2.5)	**Red 2**	**Green 5**	**Red 2**	**Green 3**	**Amber 2**	**Green 3**
2nd	M010Y-NC	(0)	(0.1)	(0)	Red 2	Green 5	Red 2	Green 3	Amber 4	Amber 5
3rd	M007X	(2.9)	(0)	(2.8)	Red 2	Amber 2	Red 2	Green 3	Amber 2	Amber 4
4th	R010T	(2.8)	(1.7)	(4.4)	Red 2	Amber 2	Red 2	Green 3	Amber 2	Green 5
5th	R007V-NC	(1.9)	(1.3)	(3.3)	Red 4	Green 5	Red 3	Amber 2	Amber 4	Amber 1
6th	R003K-1a	(3.4)	(2.2)	(5.7)	Red 3	Green 5	Red 3	Amber 2	Amber 4	Amber 1

4.2 Recommending Design IN_002

Design IN_002 performs well across each design objective and provides the best overall performance across both the shortlist and longlist of Innovation (IN) designs. Shown in Figure 7 and Table 7 below, this design features coordination between the two IN projects, but then does not coordinate with Broadshore.

Design IN_002 was recommended based on two key factors. Firstly, the slightly better performance across the design objectives demonstrated that it would represent a marginally better solution than IN_004. Secondly, it was determined during the course of the final strategic options appraisal (FSOA) analysis that developing the additional cable required in both designs as a separate link, rather than a bundled solution, would allow the project to proceed with more flexibility when both constructing and operating the IN projects. Further information on how it scored against each design criteria is available in Appendix A.

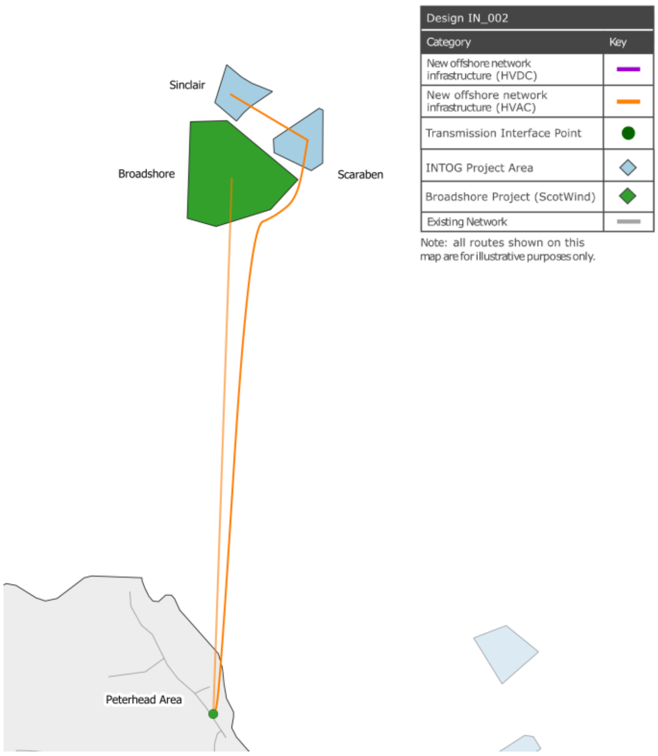

Figure 7: Recommended IN design IN_002

Table 7: IN design assessment overview and comparison

Design	Description	BRAG assessment			Economic costs	
		Environment	Community	Deliverability & Operability	Rank	Cost Variance (vs best) (£m)
IN_002	**Coordination between the two Innovation projects and a single link to Longside 132 kV.**	**Amber 3**	**Green 2**	**Green 3**	**1**	**0**
IN_004	Coordination between each project and SW_NE6, upgrading the existing planned link with an additional cable to allow for the full capacity of all projects.	Amber 4	Green 3	Green 4	2	6

This stage of the process provided a recommended offshore network configuration, which connects offshore wind farms to interface points. The recommendation considered the onshore network needs; however, these studies do not reflect the works necessary to meet the full requirements of the security and quality of supply standards (SQSS) and further onshore reinforcement analysis needs to be conducted, considering a range of future energy scenarios.

5 Conclusion and Next Steps

Following the release of this recommendation, we will continue to work with the Transmission Owners (TOs), Crown Estate Scotland (CES) and relevant governmental and regulatory stakeholders to support this recommendation as it proceeds through the detailed network design (DND) phase.

Where frameworks are still in development for elements of the design, such as offshore hybrid assets (OHA), we will continue to work with the Office of Gas and Electricity Markets (Ofgem) to develop these and with the TOs to apply them to the relevant areas of the recommended design.

The next step for the projects in scope of the Holistic Network Design Follow Up Exercise (HNDFUE) Innovation and Targeted Oil and Gas (INTOG) design exercise is to now update the current connection contracts to those that match the final design. This process will be led by our customer connections teams and will feature input and coordination from the developers and TOs.

The generation and demand elements of the INTOG projects will be subject to connection assessments which will determine their connection dates. As NESO, we are coordinating an industry-wide connection reform under which these projects will be assessed in 2025.

We were commissioned by the Secretary of State for Energy Security and Net Zero to provide advice on how clean power can be delivered by 2030. The INTOG design was developed prior to this commission. INTOG remains a key enabler of a low-carbon energy future in 2030 and beyond, and our recommended design enables these benefits in a rapid, yet holistic manner.

Appendix A – Recommended Design Against Assessment Criteria

The recommended design R012U-NC performs well across both environment and community, due to fewer cables making landfall and a lower proportion of interface points in sensitive areas. This design was therefore ranked joint first in both objectives when compared with other designs in the shortlist. This design also performs well economically, due to the benefits of coordination with NorthConnect. The benefits of an earlier connection for both projects also result in substantial carbon cost savings, where the projects can support decarbonisation of the oil and gas platforms, and coordination with NorthConnect allows an additional export path for generation. This design performed second best out of all the shortlisted designs, second only to design TOG_M010Y-NC in this regard. This design also performs well in deliverability and operability due to lower offshore complexity when compared to mesh designs and was ranked first in this objective.

Economic and Efficient

Of the six designs considered in the Targeted Oil and Gas (TOG) final strategic options appraisal (FSOA), R012U-NC is ranked as the second-best option from an economic perspective. It evaluates to a net present value (NPV) relative to the most economical design, M010Y-NC, of -£2.5 billion.

The components of the economic evaluation include offshore costs, market costs (including network constraints) and onshore costs. For all shortlisted designs the onshore costs were approximately the same, leaving the main causes of differentiation to be the performances of the offshore and market costings.

The main driver of the strong economic performance of this design is due to its relatively low offshore costs, which is £1.1 billion more expensive than M010Y-NC. This design ranks as the second-best option from this perspective, mainly due to it having the shortest total circuit lengths compared to the other designs. The offshore cost is higher than M010Y-NC, mainly because the high voltage direct current (HVDC) link from Cedar to Emmock has a relatively larger capacity of 2 GW.

It also has medium market costs at £1.5 billion more expensive than M007X, which are driven by the mid-range network constraints and its low-carbon savings from oil and gas platforms, due to the later coordinated connection for Cenos and Cerulean.

Deliverability and Operability

The R012U-NC design is ranked first across the shortlisted designs with a Green BRAG severity 3 rating. This design has several advantages that improved the overall deliverability rating, this included; using existing interface point locations to help facilitate the demand connects, shorter cable lengths to available connection locations, no coordination between the two TOG developers, coordination between Cenos project and NorthConnect to reduce an additional link to shore, use of HVDC symmetrical monopole assets which are deemed more readily available in supply chain issues compared to HVDC Bipole solutions.

The other shortlisted options increase in deliverability severity ratings due to increasing complexity in the offshore designs such as coordination between TOG developers, longer connections to shore and increasing onshore works which are ranked fifth and sixth due to the above Beyond 2030 onshore works required within National Grid Electricity Transmission's (NGET's) licensed area.

The onshore works required for the shortlisted designs are broadly the same, with additional works required for designs with connections outside Scotland. Due to the required works described in Beyond 2030, it is currently estimated the earliest in service dates for the generation export of the TOG projects in the late 2030s.

Environment

Overall, this offshore design is lightly constrained (BRAG rating Green 5).

The key constraints are mainly found on the route from Cenos to Peterhead, which interacts with a number of environmental sites including Buchan Ness to Collieston Coast special area of conservation (SAC), marine protected area (MPA) and special protection area (SPA)and the Southern Trench MPA.

None of these sites are designated for features specifically sensitive to cabling. Additionally, given that the inshore route (i.e. no further than 12 nm from the coast), has already been consented as part of the North Connect connection, this route is considered to be only moderately constrained (Amber) overall. The Cenos wind farm site is situated within East of Gannet and Montrose Fields MPA, so this constraint is unavoidable in connecting the site.

Across the other routes, the main unavoidable constraints include some areas of Annex 1 Reef, as well as the Outer Firth of Forth and St Andrews Bay Complex SPA and MPA (Cedar to Near Branxton) and two sites of special scientific interest (SSSIs) (Aspen to Fetteresso). None of the offshore-to-offshore routes (i.e. those coordinating between developments) interact with environmental sites, with the exception of North Connect to Cenos, due to Cenos' location within the East of Gannet and Montrose Fields MPA.

Overall, the combination of eight routes which make up this design include only two which have been appraised as Amber (moderately constrained), with all the rest rated Green (lightly constrained). The conclusion is that R012U-NC is rated Green 5 – lightly constrained, but with a high severity score within the BRAG rating, to reflect the presence of some Amber routes.

The onshore BRAG and severity rating is the equal lowest across the shortlisted designs. Based on the information available – which is subject to confirmation through further connections studies – no new reinforcements are required above those already identified, appraised and recommended in the *Beyond 2030 publication*. The BRAG and severity rating should therefore be considered in terms of a wider context than this project alone.

Community

R012U-NC ranked in the highest category for community having a Green 3 rating offshore and a Red 2 rating onshore. This design has the ability to avoid all community constraints offshore and has the lowest offshore routeing length across all shortlisted designs. Onshore it was identified that there are no further works required other than those proposed in the *Beyond 2030 Report*, however it is important to note that this is subject to confirmation following connection studies.

Recommending Design IN_002

This design was then compared to design IN_004 in the FSOA analysis. IN_004 consisted of coordination between each project and SW_NE6 but included an upgrade of the existing planned link with an additional cable to allow for the full capacity of all projects. When comparing the designs, this shared feature of an additional cable from the project areas to Longside substation was a key component in determining any differences between the two. Due to this similar feature, both designs performed similarly on the environment, community, and deliverability and operability objectives.

Economic and Efficient

Design IN_002 performed better against IN_004 from an economic perspective by £6 million. This is due to the slight difference on circuits cost.

Deliverability and Operability

The Innovation developer had previously applied for a 132 kV connection in the Peterhead substation area for each of the innovation projects, this became the counterfactual design assessed in the longlist with a separate connection for each project. The Transmission Owner (TO) had provided substation bay information at the start of the process which would permit their total capacity at the connection point. The deliverability of the shortlisted designs is similar as each entails reducing the total number of circuits from the three grouped projects. The final design IN_002 was determined to have a better deliverability rating than IN_004 due to improvement on potential infrequent security of supply issues by coordinating all three nearby projects.

Environment

This design is rated Amber 3. While the route between Sinclair and Scaraben avoids environmental sites, the route from Scaraben to Peterhead interacts with the Southern Trench MPA, and the Loch of Strathbeg SSSI. The route to Peterhead is new, and while coordination with the Broadshore connection to Peterhead is assumed, it nevertheless introduces an additional trench into an already congested designated site. It is considered that the route through the Southern Trench MPA can avoid sensitive habitats within the site (burrowed mud and shelfs) and so this route is considered moderately constrained. This is the major route for the design, and therefore overall, the offshore design is rated Amber 3.

Community

IN_002 performed well overall for community scoring an offshore BRAG rating of Green 4. The only community constraints identified included the Formartine and Buchan Way national trail which cannot be avoided when connecting to Longside 132 kV.

Appendix B – Shortlisted Designs Against Assessment Criteria

The following section provides an overview of the seven other Targeted Oil and Gas (TOG) designs that were considered at the final strategic options appraisal (FSOA) stage but were ultimately not recommended as the final design. This section provides detail on the performance of each design against the network design objectives, including the outcome of the detailed FSOA level appraisals.

Overall Rank Second: TOG_M010Y-NC

This design was a mesh design, featuring coordination between different TOG developers, as well as the NorthConnect interconnector in scope for coordination. The design provides a connection to Near Branxton for the Cerulean project Cedar. The NorthConnect interconnector coordinates with the Cenos project and forms a coordinated solution connecting to Peterhead. The topology of this design, indicative onshore works identified and this design's performance relative to the other designs in the shortlist is shown in the figure and tables below. The indicative onshore works identified for this design will mean that the generation element of the TOG projects will not be able to export generation onto the transmission network until their completion, which is currently estimated to be in 2030s.

This design was shortlisted due having the lowest costs in its category, while performing equally well with other designs on the remaining objectives.

This design performs well across both environment and community, primarily due to a reduction in cables making landfall and therefore a reduced impact on protected areas. This design also performs extremely well economically, with the lowest costs in the shortlist. This is due to several benefits being shared across all projects: efficient power flow, an earlier demand connection at Peterhead and several export paths for generation.

While this design performed extremely well on the environment, community, and economic objectives, it was ranked second due to deliverability and operability concerns, primarily over the feasibility of complex offshore platform arrangements at Cenos and Cedar.

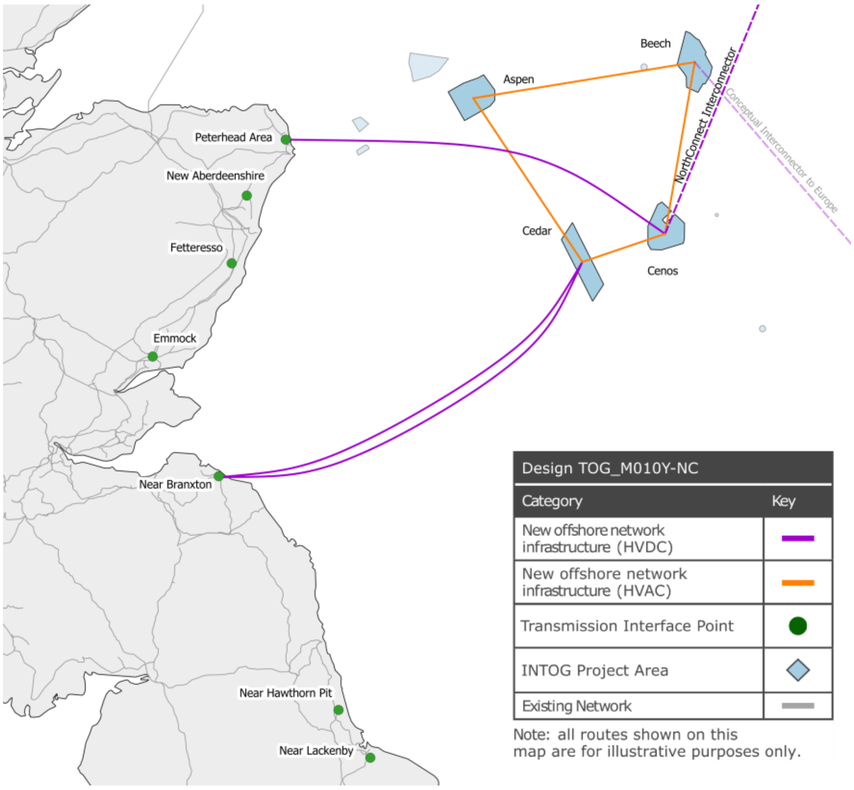

Figure B1: design TOG_M010Y-NC schematic

Economic and Efficient

Of the six designs considered in the TOG FSOA, M010Y-NC is ranked as the best option from an economic perspective.

The offshore cost is lowest across all shortlisted designs, mainly because of a combination of short cable lengths and lower cable capacity.

It also has lower market costs with £0.1 billion more expensive than M007X, which are driven by the lowest network constraints and its large carbon savings from oil and gas platforms, due to the earlier coordinated connection for Cenos and Cerulean.

Deliverability and Operability

The M010Y-NC design is ranked fourth across the shortlisted designs with an offshore Amber BRAG (Black, Red, Amber, Green), severity 5 rating. This design has several complexities that affected overall deliverability rating, including the meshed offshore network between all developers. While this would enable the demand connection requirement earlier, there would be challenges in developing a staged approach for the mesh network with potentially large non-standard platform arrangements or multiple smaller platforms interconnected at or nearby the Cedar and Cenos projects.

The onshore works were indicated to be the same for the other designs which solely land in Scotland, thereby attaining an Amber severity 1 rating.

Environment

The offshore design is rated Green 5. It utilises two landing points, which is fewer than alternative shortlisted designs. Landing points featured in this design are two of the three which make up the recommended design (Peterhead and Near Branxton). Both are rated Amber (moderately constrained). Near Branxton in this design will require two cables/trenches, one of which replaces the Fetteresso connection in R012U-NC.

The key constraints are therefore – on the approach to Peterhead – Buchan Ness to Collieston Coast special area of conservation (SAC), marine protected area (MPA) and special protection area (SPA) and the Southern Trench MPA, and – on the approach to Near Branxton – areas of Annex 1 Reef, as well as the Outer Firth of Forth and St Andrews Bay Complex SPA and MPA (Cedar to Near Branxton).

Additionally, as is common to all designs, routes to Cenos will need to pass through the East of Gannet and Montrose Fields MPA, as the wind farm is situated within this designated site.

Onshore, there is no difference between the requirements to facilitate the recommended design.

Both designs have same offshore and onshore BRAG and severity ratings. One slight nuance which makes R012U-NC marginally preferable is the replacement of the connection to Fetteresso (rated Green for the individual route) with an additional connection to Near Branxton (rated Amber). With coordination between the two Near Branxton connections, a proportion of this difference can be mitigated (hence the identical BRAG/severity rating.

Community

M010Y-NC ranked in the highest category for community having a Green 3 rating offshore and a Red 2 rating onshore. This design has the ability to avoid all community constraints offshore and has the second-lowest offshore length across all shortlisted designs. Onshore it was identified that there are no further works required.

Overall Rank Third: TOG_M007X

This design was a mesh design, featuring coordination between different TOG developers and NorthConnect considered out of scope for coordination. The design provides a connection to Fetteresso for Cenos. Cerulean projects Aspen and Cedar connect to Emmock and Near Branxton respectively. The AC ring between the Cerulean projects is widened to include the Cenos project through an extra link. The NorthConnect interconnector does not coordinate with any projects in this design and connects as per its current position. The topology of this design, indicative onshore works identified and this design's performance relative to the other designs in the shortlist is shown in the figure and tables below. The indicative onshore works identified for this design will mean that the generation element of the TOG projects will not be able to export generation onto the transmission network until their completion, which is currently estimated to be in 2030s.

This design was shortlisted due to strong economic performance in its category, while performing similarly to other designs on the remaining objectives.

This design performed poorly on the environmental objective, ranking joint last due to the increased environmental impact of the nearshore approach and onshore landing point of several routes. This performance is similar to R010T (ranked fourth), as these designs share many features. This design then performed relatively well on the remaining objectives, with rankings in the middle of the shortlist. When compared to R010T, it ranks slightly lower due to the increased complexity of a mesh solution, but this is countered by an increase in economic performance due to more efficient power flow between all projects.

Due to its relatively balanced performance, this design was ranked third, making it the best performing design with NorthConnect out of scope for coordination.

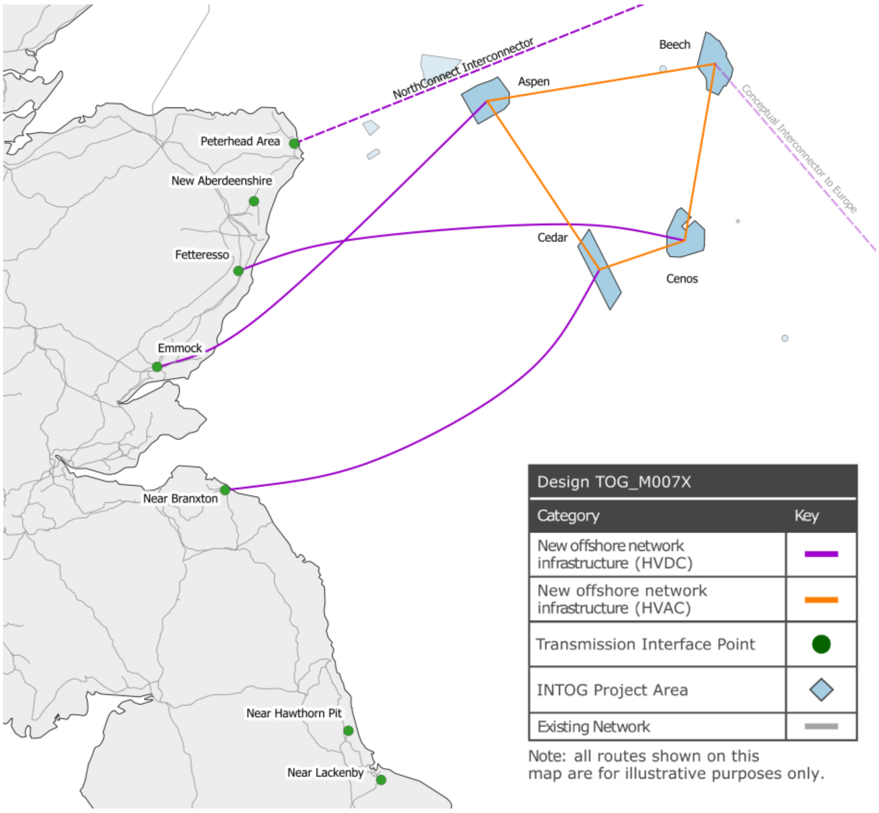

Figure B2: design TOG_M007X schematic

Economic and Efficient

Of the six designs considered in the TOG final strategic options appraisal (FSOA), M007X is ranked as the third best option from an economic perspective. It evaluates to a net present value relative to the most economical design, M010Y-NC, of -£2.8 billion.

The offshore cost is high with £2.9 billion more expensive than M010Y-NC, mainly because of the longer length of high voltage direct current (HVDC) cables across all shortlisted designs.

It also has the lowest market costs which are driven by its large carbon savings from oil and gas platforms, due to the earlier coordinated connection for Cenos and Cerulean.

Deliverability and Operability

The M007X design is ranked third across the shortlisted designs with an offshore Amber BRAG, severity 4 rating. This design mitigates against some complexities on the M010Y-NC design. There is a reduced meshed offshore network as NorthConnect is not included in the mesh and the links are separated between Cerulean projects instead of being solely in the Cedar location. There would be challenges in developing a staged approach for the mesh network and without NorthConnect coordinating with another project, the number and lengths of the links increased overall.

The onshore works were indicated to be the same for the other designs which solely land in Scotland, thereby attaining an Amber severity 1 rating.

Environment

The offshore design is rated Amber 2. Within this design, the combination of connections includes Cedar to Near Branxton as well as Aspen to Emmock. Due to the location of the interface points and the wind farm sites, this leads to two separate and unconnected routes through the Outer Firth of Forth and St Andrews Bay Complex SPA and areas of Annex 1 Reef. The individual routes to Near Branxton and Emmock are both rated Amber. These, in combination with the direct route for the interconnector into Peterhead (rated Amber, although already consented) and the route to Fetteresso make M007X one of two Amber rated offshore designs in the shortlist. While this means a moderately constrained design, it is nevertheless the equal worst-scoring in terms of environmental factors.

Onshore, as is the case for the top and second ranked options, based on the information available – which is subject to confirmation through further connections studies – no new reinforcements are required above those already identified, appraised, and recommended in the *Beyond 2030 publication.*

However, environmentally, M007X still remains one of the more constrained options considered.

Community

M007X ranked in the highest performing category for community having a Green 3 rating offshore and a Red 2 rating onshore. This design could avoid all community constraints offshore however this design had the highest overall offshore route length across the shortlisted designs. Onshore it was identified that there are no further works required other than those proposed in the *Beyond 2030 Report*, however it is important to note that this is subject to confirmation following connection studies.

Overall Rank Fourth: TOG_R010T

This design is a radial design, featuring less interaction between developers, and the NorthConnect interconnector is out of scope for coordination. The design provides a connection to Fetteresso for Cenos. Cerulean projects Aspen and Cedar connect to Emmock and Near Branxton respectively. The NorthConnect interconnector does not coordinate with any projects in this design and connects as per its current position. The topology of this design, indicative onshore works identified and this design's performance relative to the other designs in the shortlist is shown in the figure and tables below. The indicative onshore works identified for this design will mean that the generation element of the TOG projects will not be able to export generation onto the transmission network until their completion, which is currently estimated to be in 2030s.

This design was shortlisted due to offering earlier bay availability than other designs in its category, while providing benefits to the community and deliverability and operability objectives.

This design performed poorly on the environmental objective, ranking joint last due to the increased environmental impact of the nearshore approach and onshore landing point of several routes.

While this design did perform well in the community and deliverability objectives, the poorer economic performance resulting from less efficient power flow resulted in it being ranked fourth overall and was not recommended to proceed.

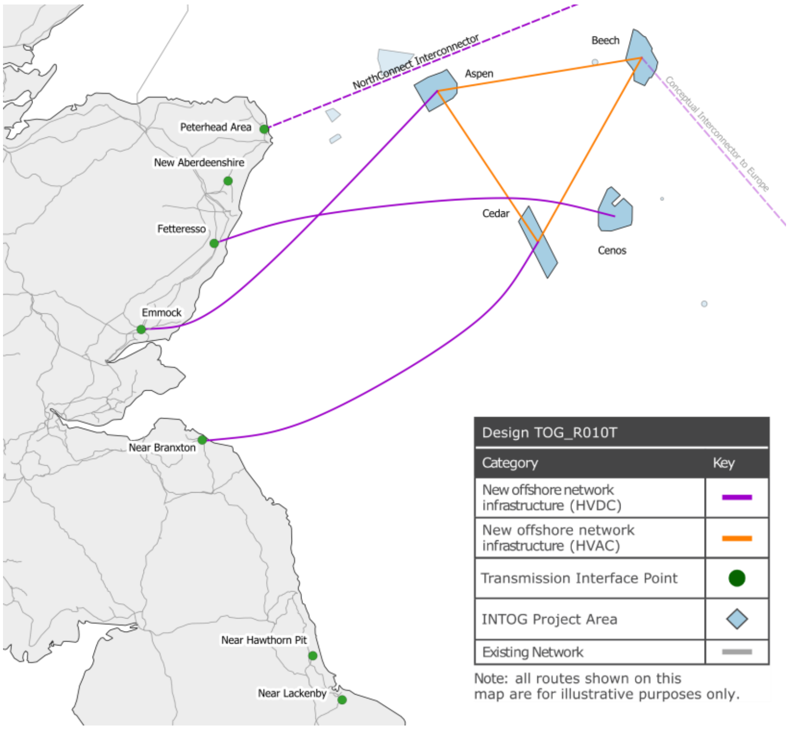

Figure B3: design TOG_R010T schematic

Economic and Efficient

Of the six designs considered in the TOG FSOA, R010T is ranked as the fifth-best option from an economic perspective. It evaluates to an NPV relative to the most economical design, M010Y-NC, of -£4.4 billion.

The offshore cost is high with £2.8 billion more expensive than M010Y-NC, mainly because of the longer length of HVDC cables across all shortlisted. It also has medium market costs with £1.7 billion more expensive than M007X, which are driven by its medium carbon savings from oil and gas platforms.

Deliverability and Operability

The R010T design is ranked second across the shortlisted designs with an offshore Green BRAG, severity 5 rating. This design has some advantages that improved the overall deliverability rating, this included using existing interface point locations to help facilitate the demand connects, no coordination between the two TOG developers, use of HVDC symmetrical monopole assets which are deemed more readily available in supply chain issues compared to HVDC bipole solutions. However, it increases the number of connections onshore as there is no coordination between a TOG project and

NorthConnect, this also had the effect of increasing a connection link from a project to the next available interface point location.

Environment

This offshore design is rated Amber 2 for environment. Routes connecting the offshore wind farm sites to transmission interface points are the same as the coordinated M007X design. Consequently, the environmental constraints encountered are virtually identical. These are the interaction with the Outer Firth of Forth and St Andrews Bay Complex SPA and areas of Annex 1 Reef (via two separate and unconnected routes). The individual routes to Near Branxton and Emmock are both rated Amber. These – in combination with the direct route for the interconnector into Peterhead (rated Amber, although already consented) and the route to Fetteresso (rated Green) combine into an overall Amber 2 rating offshore.

Onshore – as is the case across all the higher ranked designs, no further works in addition to those proposed in the *Beyond 2030 Report* are required.

This design achieves the same score as M007X overall and is the joint-last ranked design in terms of the environmental objective, alongside M007X.

Community

R010T ranked in the highest performing category for community having a Green 3 rating offshore and a Red 2 rating onshore. This design could avoid all community constraints offshore however it ranked fifth in terms of offshore routeing length across the six shortlisted designs. Onshore it was identified that there are no further works required other than those proposed in the *Beyond 2030 Report*, however it is important to note that this is subject to confirmation following connection studies.

Overall rank Fifth: TOG_R007V-NC

This design is a radial design, featuring less interaction between developers and the NorthConnect interconnector is in scope for coordination. The design provides a connection to Fetteresso and Near Branxton for the Cerulean projects Aspen and Cedar. The NorthConnect interconnector coordinates with the Cenos project and forms a coordinated solution connecting to Hawthorn Pit. The indicative onshore works identified for this design will mean that the generation element of the TOG projects will not be able to export generation onto the transmission network until their completion, which is currently estimated to be 2030s.

This design was ranked second to last in the deliverability and operability ratings, due to additional onshore works required in the North East of England, and longer offshore links required. This was the second of two designs that triggered additional works above the Beyond 2030 works, and again would have a substantially increased onshore impact when compared to other designs that did not trigger these additional works. This design performed slightly better economically than the previous design, due to the NorthConnect interconnector providing an export path for power from the North East of England.

Due to slightly better economic performance when compared to design R003K-1a, but still poor performance overall, this design was ranked fifth and was not recommended to proceed.

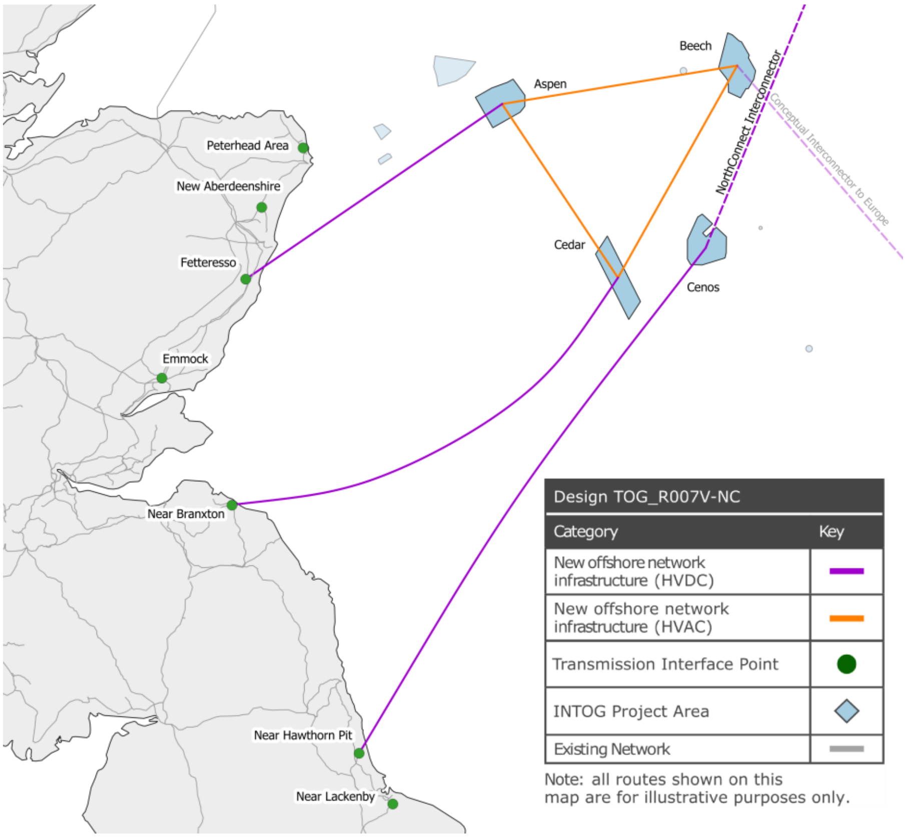

Figure B4: design TOG_R007V-NC schematic

Economic and Efficient

Of the six designs considered in the TOG FSOA, R007V-NC is ranked as the fourth-best option from an economic perspective. It evaluates to an NPV relative to the most economical design, M010Y-NC, of -£3.3 billion.

The offshore cost is medium with £1.9 billion more expensive than M010Y-NC, mainly because of the average length of HVDC cables across all shortlisted.

It also has medium market costs with £1.7 billion more expensive than M007X, which are driven by its medium carbon savings from oil and gas platforms.

While for most designs the onshore network costs did not lead to the differentiation in their rankings, in this case the slightly higher onshore reinforcements cost for this design contributed to the total cost.

Deliverability and Operability

The R007V-NC design is ranked fifth across the shortlisted designs with an offshore Amber BRAG, severity 1 rating. This uses existing interface point locations to help facilitate the demand connections for the Cerulean projects, there is no coordination between the two TOG developers but there is coordination between Cenos project and NorthConnect to reduce an additional link to shore. However, the coordinated NorthConnect and Cenos to Hawthorn Pit area is a long link to the interface point and there is an additional risk due to onshore works, consenting issues that likely not meet the required demand connection date which is why the overall ranking is low within the shortlist. It ranks Amber severity 4 in onshore deliverability due to further onshore works required above Beyond 2030 within National Grid Electricity Transmission's (NGET's) licensed area.

Environment

In terms of the offshore design, this option is rated Green 5. It incorporates three interface points, and scores favourably due to avoiding the multiple constraints and competition for space seen at Peterhead. The route to Near Branxton encounters the Outer Firth of Forth and St Andrews Bay Complex SPA and Firth of Forth Banks Complex MPA as well as Annex I Reefs. Meanwhile, the route to Hawthorn Pit cannot avoid the Durham Coast SAC and SSSI and Annex 1 Reef. These are moderate constraints, although not designated for habitats sensitive to cabling.

To facilitate the link to Hawthorn Pit, the onshore element of this option appears – based on the information available at this time – to require two new additional onshore circuits, not currently proposed in Beyond 2030. These new circuits have themselves been appraised by the Transmission Owner (TO) as Red for environment. This increases the onshore environmental impact of the design, due to a large number of environmentally designated sites, including (but not limited to) SACs, SPAs, Ramsar sites and special sites of scientific interest (SSSIs) within the study areas for each, and the cumulative risk of the interaction between each project and these sites.

Overall, the additional onshore works associated with this design mean it is one of the lower-ranked designs for environment.

Community

R007V-NC had a higher onshore and offshore BRAG rating than four of the other shortlisted design having a severity rating of Red 3 onshore and Amber 3 offshore,

offshore this design had the worst BRAG rating out of all shortlisted designs. The higher offshore BRAG rating is due to the routes connecting to Hawthorn Pit where the Durham Heritage Coast and areas of National Trust land cannot be avoided, all other significant constraints offshore can be avoided. This design also required two additional onshore reinforcements on top of the Beyond 2030 works, having an increased impact on the community.

Overall Rank Sixth: TOG_R003K-1a

This design is a radial design, featuring less interaction between developers, and the NorthConnect interconnector is out of scope for coordination. The design provides a connection to Lackenby for Cenos. Cerulean projects Aspen and Cedar connect to New Aberdeenshire and Fetteresso respectively. The NorthConnect interconnector does not coordinate with any projects in this design and connects as per its current position. The indicative onshore works identified for this design will mean that the generation element of the TOG projects will not be able to export generation onto the transmission network until their completion, which is currently estimated to by late 2030s.

This design was shortlisted to investigate the onshore impact of a connection to NGET's region, with the aim of relieving constraints in the North East of Scotland.

This design was ranked last in the deliverability and operability ratings, due to additional onshore works required in the North East of England, and longer offshore links required. This was also one of two designs that triggered additional onshore works above the Beyond 2030 works, and so would have a substantially increased onshore impact when compared to other designs that did not trigger these additional works. This design was also ranked last in the economic ratings, due to the increased cost of longer offshore links, and the additional onshore works.

Due to these factors, this design was ranked sixth and was not recommended to proceed.

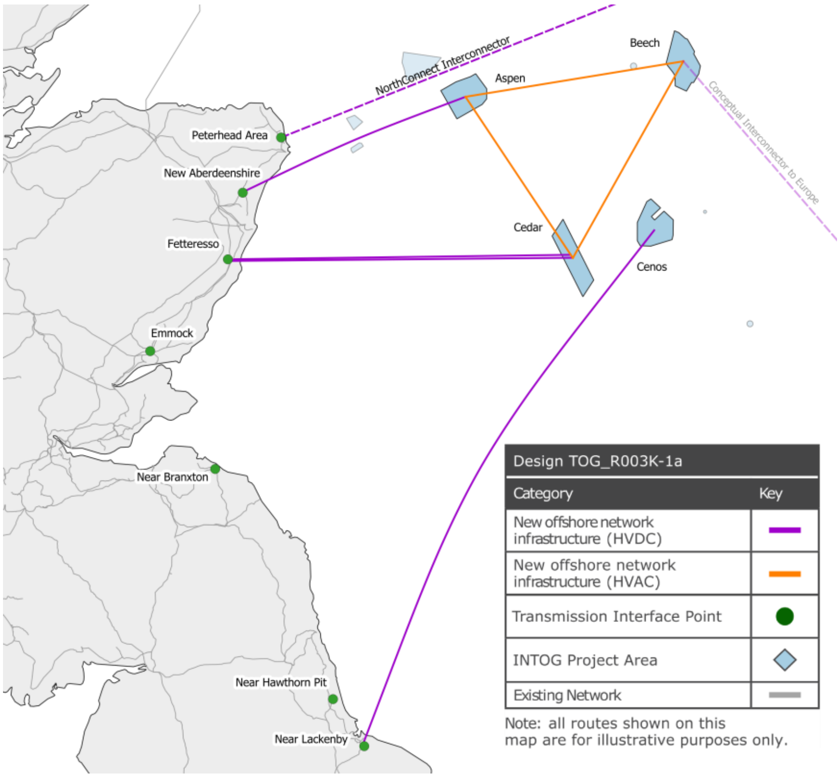

Figure B5: design TOG_R003K-1a schematic

Economic and Efficient

Of the six designs considered in the TOG FSOA, R003K-1a is ranked as the most expensive option from an economic perspective. It evaluates to an NPV relative to the most economical design, M010Y-NC, of -£5.7 billion.

The offshore cost is the highest with £3.4 billion more expensive than M010Y-NC, mainly because of the longest length of HVDC cables across all shortlisted. It also has highest market costs with £2.2 billion more expensive than M007X which are driven by very low-carbon savings from oil and gas platforms due to relatively late connection dates.

While for most designs the onshore network costs did not lead to the differentiation in their rankings, in this case the slightly higher onshore reinforcements cost for this design contributed to the total cost.

Deliverability and Operability

The R003K-1a design is ranked sixth across the shortlisted designs with an offshore Amber BRAG, severity 1 rating. This uses existing interface point locations to help facilitate the demand connections for the Cerulean projects, there is no coordination between the two TOG developers or coordination between Cenos project and NorthConnect. Cenos to Near Lackenby indicated the pre-INTOG existing Connection Offer for the project. This results in a long link to the interface point and there is an additional risk due to onshore works, consenting issues that likely not meet the required demand connection date which is why the overall ranking is low within the shortlist. It ranks Amber severity 4 in onshore deliverability due to further onshore works required above Beyond 2030 within the NGET licensed area.

Environment

This design is rated Green 5 for the offshore element. It incorporates a route to Peterhead, and its associated constraints (Southern Trench MPA, Buchan Ness to Collieston SAC, MPA and SPA, Bullers of Buchan Coast SSSI and Annex I Reefs. Also included is a route to Lackenby, which encounters Annex I Reef as well as the East of Gannet and Montrose Fields MPA. In total there are four landing/interface points featured in the design. The other two (New Aberdeenshire and Fetteresso), also both encounter environmental designations, Ythan Estuary, Sands of Forvie and Meikle Loch SPA at New Aberdeenshire, and two SSSIs enroute to Fetteresso.

Similar to R007V-NC, this option appears to require two new additional onshore circuits, not currently proposed in Beyond 2030. These new circuits have themselves been appraised by the TO as Red for environment, due to a large number of environmentally designated sites, including (but not limited to) SACs, SPAs, Ramsar sites and SSSIs within the study areas for each, and the cumulative risk of the interaction between each project and these sites.

Community

R003K-1a had a higher onshore and offshore BRAG rating than other shortlisted designs having a severity rating of Red 3 onshore and Amber 2 offshore, offshore this design ranked second last in terms of BRAG ratings. The higher offshore BRAG rating is due to significant community constraints such as urban areas at landfall within the route to Lackenby area, which are difficult to avoid due to the cliffs at landfall. This design also has similar constraints to several other designs such as the Formartine and Buchan Way National Trail cannot be avoided for the routes into New Aberdeenshire. Additionally, the North Yorkshire and Cleveland Heritage Coast and Cleveland Way National Trail cannot be fully avoided in the route to Lackenby area. Onshore this design also required two further onshore reinforcements which will have an increased impact on the community.