East Coast Grid Spatial Study

Main Report
April 2021

Prepared for:

Project Partners:

Quality information

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Revision history

Revision	Revision date	Details	Authorized	Name	Position
v0.1	Dec 2020	Draft final report for client review	FF	Frank Fortune	Technical Director
V0.2	Feb 2021	Revised following client review	FF	Frank Fortune	Technical Director
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V0.4	Apr 2021	Re-structured and re-formatted	DR	David Ritchie	Technical Director

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Executive Summary

AECOM was commissioned by The Crown Estate, in partnership with National Grid Electricity Transmission, National Grid Electricity System Operator and the Marine Management Organisation to consider the influence of spatial constraints on approaches to the connection of future offshore wind farms to the electricity transmission system along the east coast of England from the Humber Estuary in the north to Thames Estuary.

This technical study aims to identify key terrestrial and marine spatial constraints within the east coast region establishing an understanding of the study area's spatial context; to identify and assess the risks that these constraints may present to future offshore wind grid connections under a radial approach; and to consider the extent to which a coordinated model of connection could mitigate these risks.

Two key activities were undertaken:

(i) Strategic constraints mapping to characterise the study area and identify key terrestrial and marine spatial constraints, risks and opportunities; and

(ii) Development and assessment of hypothetical offshore wind development and grid connection scenarios to evaluate radial and coordinated approaches to connection.

This report includes:

- High level characterisation of the East Coast study area.
- Key findings from the analysis of alternative grid connection scenarios.
- Spatial characterisation work and scenario assessments; and
- Conclusions and recommendations.

Spatial constraints vary widely across the region. However, they all potentially influence development of grid connection infrastructure, particularly in terms of the availability of suitable landfalls or proximity of potential grid connection points within coastal areas. Whilst these issues are common to both radial and coordinated models, prolonging the radial model will be less sustainable in the long term given that radial connection, by its nature demands more landing sites for the same capacity of offshore wind when compared to coordinated solutions. Therefore, long-term availability of suitable landfall sites was identified as a risk to future offshore wind deployment, although the significance of this risk varies across the study area.

Several approaches to coordinated grid connection were considered and compared to the radial approach. In all coordinated scenarios, the amount of physical infrastructure required was reduced compared to the radial model. However, depending on the approach adopted, coordination may require additional infrastructure not required in a radial model, including offshore 'hubs', coastal 'nodes' and additional subsea cable routes connecting offshore wind farms to 'hubs' or 'nodes'.

A coordinated model of infrastructure development will have spatial benefits compared to the radial model. Transitioning to such an approach over the medium to longer term could more effectively support the future deployment of offshore wind as it would facilitate a reduced spatial impact, particularly in inshore and coastal parts of the study area. However, radial models may continue to play a role while technological and regulatory barriers to more coordinated designs are overcome. Furthermore, the location and timing of future offshore wind development will also determine the availability of opportunities for coordinated approaches.

Further work, beyond this study, could help remove barriers to development coordinated offshore grid connections and transmission infrastructure, including improved spatial planning with links to future leasing rounds.

1. Introduction

1.1 Background to the Study

1.1.1 Role of offshore wind in achieving Net Zero

Development of offshore wind is expected to play an integral role in achieving the UK's legal target to reach Net Zero by 2050 (The Climate Change Act 2008, Section 1)[1]. Reflecting the importance of offshore wind, recent governmental announcements pledged to work toward an increased target 40 gigawatts (GW) of installed capacity by 2030, as an important step on the way to net zero whilst the Climate Change Committee have cited Offshore Wind as having the potential to become the 'backbone of the whole UK energy system'[2.] However, the achievement of net zero largely based on offshore wind would potentially require at least 100 GW of installed capacity to be in place by 2050 (Committee on Climate Change, 2020[3]).

To achieve 40 GW total installed capacity across the UK, taking into consideration the amount of offshore wind already consented or in planning, potentially requires the installation (or at least consenting) of an additional 25 – 30 GW of offshore wind in the next 10 years.

All offshore wind projects constructed to date as well as those currently in planning are connected on an individual basis, with point to point or 'radial' connection between the offshore wind farm and the grid. While this approach has been successful to date, with the significant increase of offshore wind development anticipated to 2030, an increasing level of constraint with other infrastructure, other users and other offshore wind projects is anticipated during the period to 2050 and net zero. For this reason, strategic consideration is being given to the need for, and practicality of, adoption of an alternative approach to grid connection, with increased levels of coordination between offshore wind projects and infrastructure managers.

In July 2020, the Department for Business, Energy and Industrial Strategy (BEIS) launched the Offshore Transmission Network Review (OTNR)[4]. That review brings together the key stakeholders involved in the timing, siting, design and delivery of offshore wind, to consider all aspects of the existing regime and how this influences the design and delivery of transmission infrastructure. Its terms of reference focus on identifying tactical near-term actions that can be taken and early opportunities for coordination for projects in the short- to medium-term, plus a longer-term strategic review to develop a new regime that can ensure a more coordinated approach for the future.

In parallel with these reviews, National Grid ESO (NGESO) has been progressing its Offshore Coordination Project with support from Ofgem and BEIS. Between 30 September and 28 October 2020, NGESO carried out consultation across industry and within; a Phase 1 report has now been published which includes details of progress and consultation so far[5]. That project plans to recommend potential changes to how offshore wind connects to the onshore network underpinned by:

- Conceptual integrated designs which are technically feasible and compliant with grid requirements.
- Cost benefit analysis of different designs, considering the benefits for consumers and communities, and informed by stakeholder engagement.
- Identification of the barriers to implementing the recommended approaches. Including regimes, policy frameworks, network codes and the roles and responsibilities of different participants in the processes.

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[1] https://www.legislation.gov.uk/ukpga/2008/27/section/1
[2] Climate Change Committee, *Building back better – Raising the UK's climate ambitions for 2035 will put Net Zero within reach and change the UK for the better*, December 2020 (Available here)
[3] https://www.theccc.org.uk/2020/12/09/building-back-better-raising-the-uks-climate-ambitions-for-2035-will-put-net-zero-within-reach-and-change-the-uk-for-the-better/
[4] https://www.gov.uk/government/publications/offshore-transmission-network-review
[5] National Grid ESO, *Phase 1 Final Report,* December 2020 (Available here)

1.1.2 Offshore wind pipeline

At present just under 40 GW of offshore wind capacity has secured seabed rights in the UK. Around 10 GW of this is operating capacity, with the remainder in various stages of the development process, as shown in Figure 1-1 below.

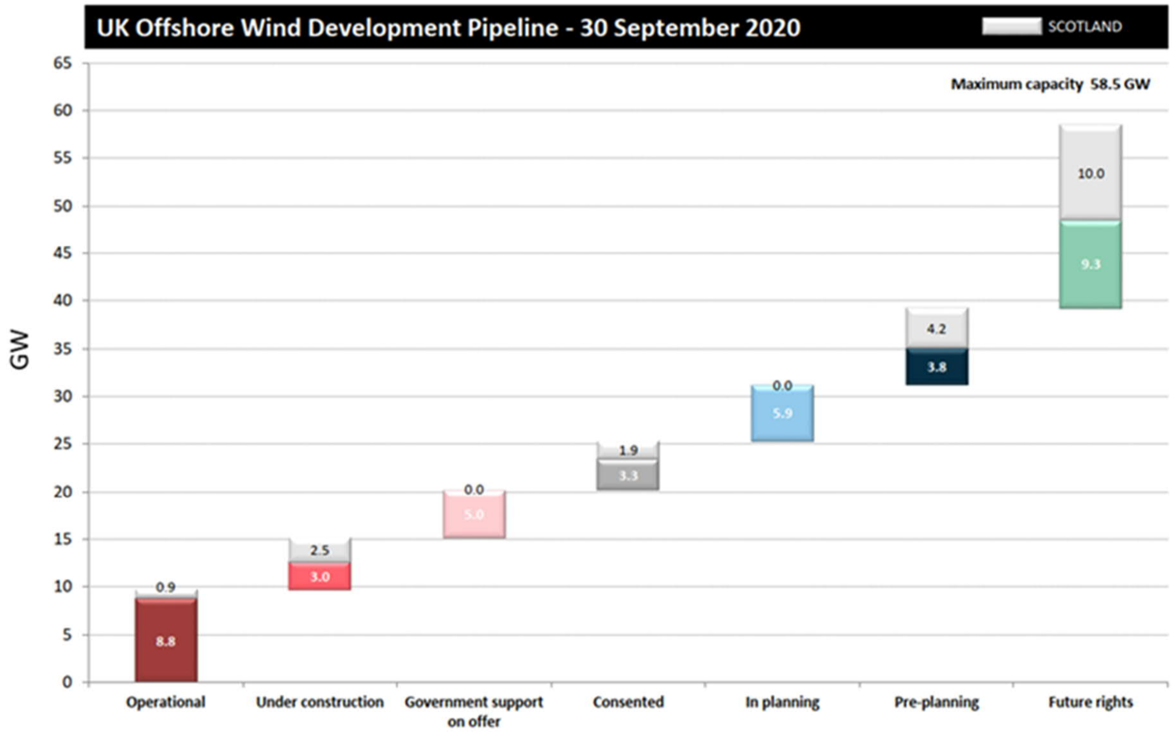

Figure 1-1 TCE Offshore Wind Development Pipeline as of 30th September 2020

Up to a further 19.3 GW of capacity could be granted future seabed rights through current leasing processes underway across the UK via The Crown Estate (TCE) and the Crown Estate Scotland (CES). The Round 4 leasing round was completed in February 2021, awarding 6 new potential offshore wind projects offering up to 8GW of new offshore wind capacity[6]. In Scotland the CES recently completed a review of its ScotWind leasing round and an updated closing date for applications has been set as 16th July 2021[7].

1.2 This Study

1.2.1 Overview

In the context of the UK's ambitious target for Net Zero and the importance of increased offshore wind generation capacity in achieving that target, the potential for spatial considerations to affect the achievement of those targets was identified. AECOM was commissioned by TCE, in partnership with National Grid Electricity Transmission (NGET), NGESO and the Marine Management Organisation (MMO) to consider the spatial context, in particular the constraints and opportunities, which could influence the way in which future offshore wind farms could connect to the electricity transmission system along the east coast of England. This collaborative approach brings together several organisations with a strategic interest in the future approach to connection of offshore wind projects.

[6] https://www.thecrownestate.co.uk/en-gb/what-we-do/on-the-seabed/offshore-wind-leasing-round-4/
[7] https://www.crownestatescotland.com/media-and-notices/news-media-releases-opinion/crown-estate-scotland-completes-scotwind-leasing-review

As noted above with reference to the OTNR and Offshore Coordination Project, this study is one of several underway on behalf of governmental, regulatory and industry bodies which review approaches to the connection of future offshore wind development to the transmission system. While the other studies have a focus on technology or cost benefit aspects of different connection approaches, this study considers the implication of spatial constraints and risks. This study seeks to add to the evidence base being established through the parallel studies, enabling development to come forward with reduced consenting risk and potentially more rapidly.

1.2.2 Aims of the Study

The key aims of the study were to:

(i) Develop an understanding of potential terrestrial and marine constraints that may affect future offshore wind farms connecting into the east coast of England using a radial connection,

(ii) Assess the risks and issues to future offshore wind farm deployment that terrestrial and marine constraints could present, and

(iii) Consider if adopting a more coordinated or integrated approach to offshore wind grid connections in this region could mitigate these risks and issues.

It should be noted at the outset that this study is not a roadmap for development or a prediction or recommendation where future development will take place. Instead it presents several indicative potential scenarios for offshore wind development for the purpose of testing the risks associated with radial and coordinated approaches to connection of each of those deployments. This study was also separate from the Round 4 Leasing process and did not have any role in, or access to, that process, beyond publicly available information.

1.2.3 Report Structure

The structure of the remainder of this report is summarised below in Table 1-1.

Section	Description of Contents
Section 2. Approach to the Study	This section sets out an overview of the approach adopted in setting out the broad parameters of the study.
Section 3. The Study Area	This section sets out and describes the study area, identifying key terrestrial and marine spatial constraints.
Section 4. Spatial Assessment	This section provides spatial assessment of study area highlighting key risks and sensitivities to offshore wind grid connection infrastructure.
Section 5. Offshore Wind and Grid connection Scenarios	This section describes how alternative scenarios have been developed for purpose of testing radial and coordinated approaches.
Section 6. Grid Connection Scenario Analysis	This section analyses each scenario and provides a comparative assessment of alternative radial and coordinated approaches.
Section 7. Conclusions & Recommendations	This section sets out the conclusions of the study and sets out recommendations to take forward.

Table 1-1 Report Structure

2. Approach to the Study

2.1 General Approach

The study approach taken to the study area involved the following steps, with each step having a series of sequential sub-steps:

- Study Area Characterisation:
  - Strategic-Scale Review of the Study Area
  - Spatial Assessment of the Study Area
- Scenario Development and Assessment:
  - Conceptual Offshore Wind Development
  - Definition of alternative Grid Connection Scenarios
  - Analysis of Grid Connection Scenarios

The approach taken to each of the steps is summarised in **Table 2-1**, with signposting of locations within the report where steps and sub-steps of the approach are undertaken.

Step	Description	Signposting
Strategic-Scale Review (Study Aim (i))	A strategic scale review of the Study Area has been undertaken. This focuses on the inshore and nearshore area, potential landfall locations and onshore connections to the existing transmission system.	**Sections 3.3 to 3.10:** Characterisation of the Study Area and Subregional assessment of marine and terrestrial constrains within the Study Area.
Spatial Assessment (Study Aim (ii))	A sub-regional spatial assessment has been carried out to understand the relative level of potential constraints across the Study Area and potential implications for future offshore wind grid connections.	**Section 4:** Spatial Assessment.
Conceptual Offshore Wind Development (Study Aim (ii))	A hypothetical Offshore Wind Development Scenario has been identified within the East Coast study area in order to test radial and alternative coordinated grid connection scenarios.	**Section 5.2:** Offshore Wind Development Scenario.
Definition of alternative Grid Connection Scenarios (Study Aim (ii))	Radial and alternative coordinated approaches to connecting the hypothetical Offshore Wind Development Scenario have been defined and taking into account the review of the Study Area.	**Section 5.3:** Potential Landfalls. **Section 5.4:** Potential Grid Connection Points. **Section 5.5**: Grid Connection Scenarios.
Analysis of Connection Scenarios (Study Aim (iii))	An analysis of the relative strengths and weaknesses of the alternative approaches to connection has been undertaken; this is informed by consideration of terrestrial and marine constraints.	**Section 6:** Grid Connection Scenario Analysis.

Table 2-1 Approach to study and Study Aims signposting

2.2 Study Area Characterisation

2.2.1 Strategic-Scale Review of the Study Area

Strategic scale constraints mapping has been undertaken in the terrestrial and marine environments across the Study Area. Publicly available hard and soft constraints data have been used to characterise the Study Area in terms of the distribution of key environmental, physical and socio-economic spatial constraints, with focus on those constraints with potential to affect development of grid connection infrastructure for future offshore wind projects.

2.2.2 Spatial Assessment of the Study Area

The Study Area has been subdivided into four sub-regions, and a simple RAG (Red, Amber, Green) appraisal made as to the potential for the mapped constraints to impact the deployment of the various components of connection infrastructure.

2.3 Scenario Development and Assessment

2.3.1 Conceptual Offshore Wind Development

Working with TCE and the project partners, a hypothetical scenario for the East Coast region has been developed which considers potential offshore wind generation and connection points to the transmission system. This includes:

- Development of an offshore wind scenario in the region which is consistent with delivering the national target of 40GW by 2030. This scenario takes account of 'in pipeline' projects and makes hypothetical assumptions on potential deployment outside the Round 4 leasing process and outcomes; and
- Identification of potential connection points based on the existing onshore transmission system and information relating to the planned development of the transmission system. This considers the recommendations of Network Options Assessment (NOA) and advice from the project partners.

2.3.2 Definition of Alternative Grid Connection Scenarios

Informed by the baseline described above we have undertaken a strategic scale routeing study for new offshore wind generation, to better understand how future projects could pragmatically connect to the onshore transmission system, while allowing for existing and planned infrastructure, as well as environmental constraints.

Indicative cable and infrastructure corridors have been identified from offshore windfarm to grid connection points, including landfalls and all stages in between, for several indicative development scenarios, including a continuation of the current point to point, or radial connection approach (the 'business as usual') scenario as well as several approaches to coordinated connection.

Technology assumptions for the grid connection scenarios considered in this report are based on currently deployed technologies, or those technologies expected to be available by 2030. This has been informed by the ESO Offshore Coordination Project and its supporting technical reports. Further detail is provided in **Appendix A**.

2.3.3 Analysis of Grid Connection Scenarios

The cable and infrastructure corridors identified are influenced by the spatial distribution of environmental and other constraints (for example infrastructure). However, there are some specific types of issues affecting routeing for the offshore, onshore and landfall in the scenarios considered, as follows:

- Offshore infrastructure corridor: - Physical parameters such as availability of suitable ground conditions for burial. Hard constraints such as current and 'in pipeline' offshore wind projects or aggregate extraction areas. Soft constraints such as fishing areas, navigation areas and designated sites for nature conservation, or landscape.
- Landfall area: - Physical parameters such as topography and elevation, as well as stability of the foreshore. Hard constrains such as existing cable landfalls and coastal flood protection works. Soft constraints such as proximity to designated sites and recreational use.
- Onshore infrastructure corridor: - Physical characteristics such as distance to grid connection. Hard constraints including major infrastructure such as railways, road and utilities. Soft constraints including designations and recreational areas.

Consideration of the risks and opportunities associated with connecting conceptual offshore wind projects under radial and coordinated approaches is detailed in Section 6 of this report and considers aspects of the scale and characteristics of the technology.

Comparison is drawn between the level of constraint associated with infrastructure corridors for each of the scenarios, to identify those scenarios that are less constrained, and identify opportunities for reducing their levels constraint.

It should be noted that all the current 'in pipeline' offshore wind projects are connected on a point to point, radial basis, forming a key part of the baseline for all of the scenarios assessed.

A comparative assessment is undertaken of the scenarios and their identified risks and mitigations using a simple analysis of the Strengths, Weaknesses, Opportunities and Threats (SWOT) associated with each of the scenarios assessed. The SWOT is presented in **Appendix E**.

2.3.4 Radial approach to connection

This is the 'business as usual' scenario, and all future projects are also connected radially, each with individual export cable route, landfall, onshore cable route and grid connection infrastructure. This radial approach to connection is applied to all future offshore wind projects in a way which realistically maximises the number of new projects connected to grid on an individual basis.

2.3.5 Coordinated approach to connection

Three main coordinated scenarios for the Study Area are considered, each with different technology approaches to coordination and including consideration of shared route corridors and landfalls as well as nodes or hubs, located onshore (generally at the coast or inshore waters) or offshore waters, which would connect multiple offshore wind developments.

A fourth subregional coordinated scenario is considered, which allows the consequences of intensified and highly focussed subregional development to be considered.

Finally, consideration is also given the potential outcomes of coordinated connection of new offshore wind look beyond 2030 targets as the UK continues to work towards Net Zero.

2.3.6 Risks and mitigation measures

For each of the scenarios, risks and potential mitigations are considered.

2.4 Stakeholder Engagement

Briefings on the project, its scope and timeframe for reporting were provided to stakeholders through the following processes:

- Email briefing to a 'long list' of stakeholders.

- 'One to one' presentation of mains study elements.

The objective of this engagement was primarily to raise awareness of the study and discuss the approach so that feedback, including key terrestrial and marine spatial constraints of concern were addressed in the study.

3. The Study Area

3.1 Overview

The eastern region of England has been the subject of significant offshore wind development to date and it is anticipated that further development will occur through Round 4 and beyond. In addition, the region also hosts several other elements of significant non-renewable energy related offshore and coastal infrastructure, including, but not limited to major ports and harbours; oil and gas structures; power generation including nuclear power stations; electricity interconnectors; onshore electricity infrastructure; roads; rail and; coastal defence works.

The Study Area allows for consideration of the spatial planning context in the east of England region from the Humber Estuary in the north to the Thames Estuary in the south incorporating Lincolnshire, Norfolk, Suffolk and Essex.

Key aspects of the Study Area are:

- It encompasses the marine area inshore from the Humber Estuary to the Thames Estuary and includes the Eastern Regions Bidding Area from The Crown Estate's Offshore Wind Leasing Round 4[8];
- In the marine environment, the study area encompasses all inshore waters (within the 12 nautical mile (nm) limit) and extends out to a maximum distance of approximately 200 nm; and
- In the terrestrial environment the study area extends inland to encompass the nearest point on the existing transmission system.

The Study Area is illustrated in **Figure 3-1** at the end of this section.

3.2 Characterisation of the Study Area

3.2.1 Overview

Given the size and scale of the Study Area, for the purposes of this study it has been broken down into four subregions. The sub-regions identified align with English County boundaries of Lincolnshire, Norfolk, Suffolk and Essex (Figure 3-1 above), with these boundaries extrapolated to include inshore waters within the 12nm limit.

Potential environmental, socio-economic, physical and infrastructure constraints have been identified where they have the potential to affect or restrict future development within the Study Area, with a particular focus on the nearshore environment (to the 12nm limit), and terrestrially to the nearest point on the existing onshore transmission network. It is noted that the extent to which these constraints present a risk to future development is dependent on the proximity of proposed infrastructure, the scale and form of infrastructure, and the specific features for which the areas are of interest.

3.2.2 Terrestrial and Marine Spatial Considerations

Table 3-1 below describes the range of terrestrial and marine constraints and considerations which were identified as part of the study area characterisation. Subsequent sections provide a summary of key spatial constraints and considerations for each sub-region within the east coast study area.

Themes	Example Terrestrial Spatial Constraints and Considerations	Example Marine Spatial Constraints and Considerations
Biological Environment	This includes designated sites or areas including Special Protection	This includes designated sites or areas including Special Protection

[8] https://www.thecrownestate.co.uk/en-gb/what-we-do/on-the-seabed/offshore-wind-leasing-round-4/. The analysis for this study was undertaken before The Crown Estate's Round 4 tender process concluded, as announced on 8 February 2021.

Themes	Example Terrestrial Spatial Constraints and Considerations	Example Marine Spatial Constraints and Considerations
	Areas (SPAs), Special Areas of Conservation (SACs) and Sites of Special Scientific Interest (SSSIs)	Areas (SPAs), Special Areas of Conservation (SACs) and Marine Conservation Zones (MCZs)
Historic Environment	This includes designated sites including Scheduled Monuments and Listed Buildings.	This includes protected wrecks.
Physical Environment	This includes consideration of physical features such as landform, topography and coastal erosion as well as rivers and flood risk.	This includes consideration of physical features such as bathymetry, seabed geology/characteristics for example sand waves.
Landscape / Seascape	This includes designated sites including Areas of Outstanding Natural Beauty (AONBs) and National Parks.	This includes coastal landscape designations including AONBs and National Parks.
Other Land / Sea Users	This includes the existing transmission system and more general land use including agricultural land use.	This includes other offshore infrastructure including offshore wind farms, aggregate extraction areas, other cables and pipelines and oil and gas installations as well as other sea-users such as commercial fisheries.
Settlements	This includes settlements and coastal communities ranging from cities to towns and villages.	- Not applicable

Table 3-1 Marine and Terrestrial Constraints and Considerations

The following sections provide a summary of the existing baseline constraints as per the above constraint 'themes' within each of the sub-regions**. Tables 3-2** to **3-9** and **Figures 3-2** to **3-5** detail the characterisation of the study area including the scale, location and distribution of the following constraints both offshore and onshore:

- Biological Environmental Constraints.
- Physical Environmental Constraints.
- Historic Environmental Constraints.
- Other Users / Other Infrastructure.
- Landscape Constraints.

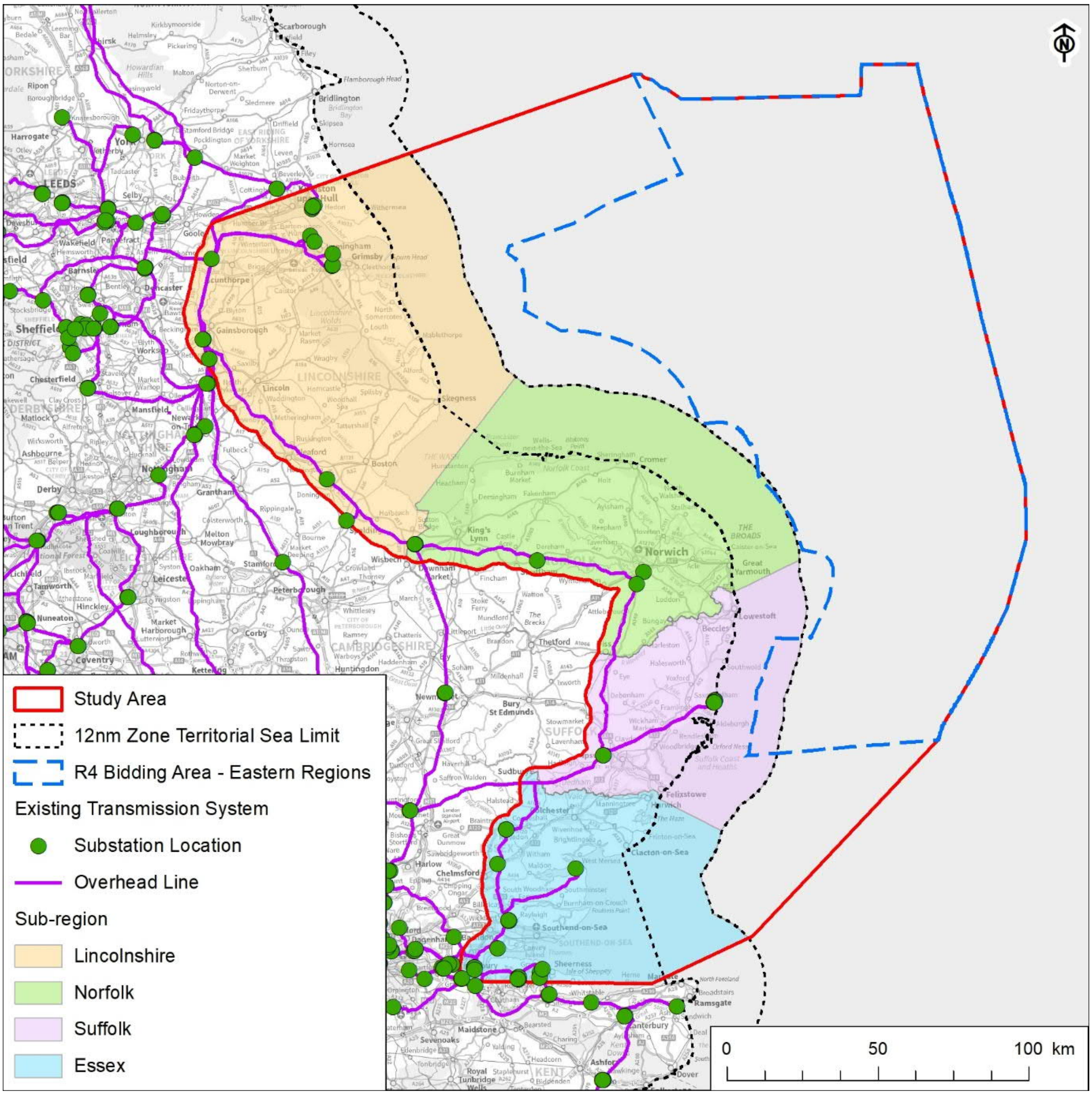

Figure 3-1 – Study Area

3.3 Lincolnshire Sub-region Marine Constraints and Considerations

Biological Environment	Physical Environment	Historic Environment	Other Sea Users
• At the north of the sub-region is the Humber Estuary SAC, SPA, Ramsar, and SSSI which extends down the Lincolnshire coastline to Saltfleet, which also overlaps with the Saltfleetby-Theddlethorpe Dunes SAC. • In the marine environment to the north of the Study Area is the Holderness Inshore MCZ, the southern half of which overlaps with the study area. • At the northern end of the study area, but further offshore is the Holderness Offshore MCZ • Throughout the Lincolnshire coastline, and much of the area to the 12nm boundary, is the Greater Wash SPA. • At the south of the sub-region, there are multiple statutory nature conservation designations including the Inner Dowsing, Race Bank, and North Ridge SAC which extends from the coast at Skegness beyond the 12nm limit, as well as the Gibraltar Point and the Greater Wash and North Norfolk Coast SACs which cover the Lincolnshire coastline to the south.	• Predominantly characterised by lengthy sandy beaches, shifting sands and intertidal muds backed largely by sloping dunes. • The Shoreline Management Plan (SMP) policy adopted for the majority of the region is 'Hold the Line' with some section of No Active Intervention to the north of the Humber Estuary. • In terms of underlying geology, alluvium and chalk tend to dominate the sub-region. • The inshore 12nm zone is predominantly sand and gravel with some muds; to the north of the sub-region, there are also notable volumes of river silt arising from the Humber Estuary.	• Spurn heritage coast is located to the north of the study area. • Multiple listed buildings although almost entirely terrestrial. • Multiple features of local heritage interest throughout the region contribute to the character of this coastal region. • There are no protected wreck sites or other designated heritage assets in the marine environment within the Lincolnshire region.	• Humber Estuary including fisheries, port operations (including freight and passenger transport) and operation and maintenance for offshore wind projects. • Immingham / Grimsby, there is a Major offshore wind farm (OWF) Operations and Maintenance (O&M) facility. • Fishing effort • Vessel densities vary across the sub-region but reach peak levels (up to ~50,000 movements per year) within the approaches to the Humber Estuary and inside the Estuary itself • Seaward, there are several restricted areas for defence use including the Donna Nook practice area to the north of the sub-region • Several large licenced aggregate extraction in the region including Humber 1-4, Off Salfleet, Humber Overfalls, Humber Estuary and Inner Dowsing, located off the coast from around Mablethorpe • There are also multiple oil and gas assets within the sub-region • At the south of the region the Triton Knoll, Inner Dowsing and Lincs OWFs represent major investment and development of renewable energy in the area, as well as the Viking Link interconnector which makes landfall south of Mablethorpe.

Table 3-2 Lincolnshire Marine Constraints and Considerations

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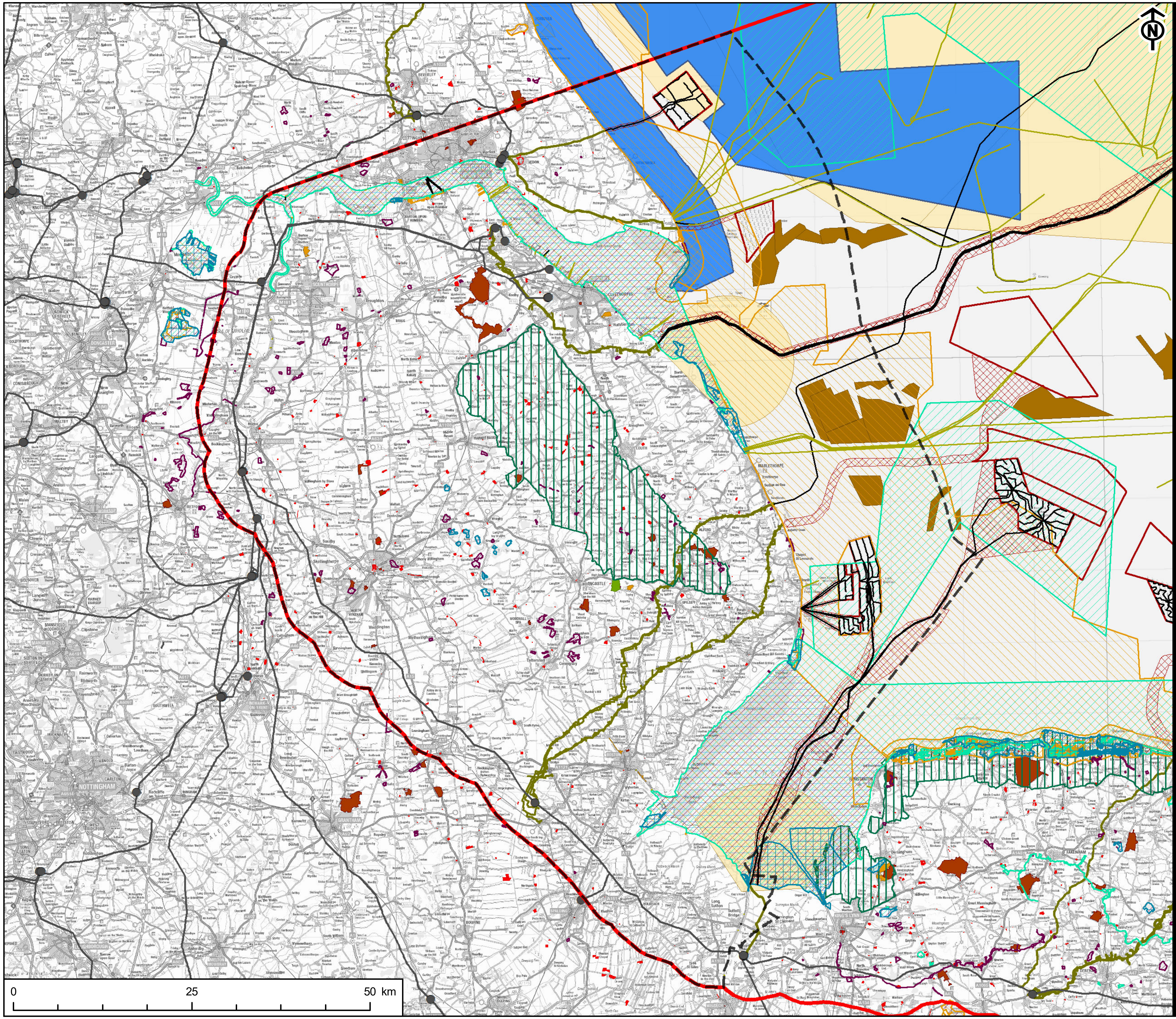
3.4 Lincolnshire Sub-region Terrestrial Constraints and Considerations

Biological Environment	Physical Environment	Historic Environment	Landscape and Seascape	Land Use Constraints and Settlements
• Between Saltfleetby and Theddlethorpe, the sand dunes are also designated as a SAC and SSSI. • There are various designations further south including the Gibraltar Point (SAC, SPA, Ramsar, SSSI and NNR), and The Wash (SAC, SPA, Ramsar, SSSI and NNR). • To the south of Louth, and to the east and southeast of Lincoln there are frequent pockets of ancient woodland.	• From the coast, the landform through Lincolnshire is very flat through much of the region. • The area is predominantly good/ moderate agricultural land (Grade 3 Agricultural Land Classification (ALC). • Due to the area being flat and low-lying, especially around the coast there is a broad area of higher susceptibility to flooding (Flood Zone 3, 1 in 200 annual probability from flooding from the sea).	• There are numerous Scheduled Monuments within the Lincolnshire Wolds AONB, but are more disparate through the remainder of the region. • There are also several Registered Parks and Gardens, the largest of these is Brocklesby Park (Grade I) located between Immingham and the north of the Lincolnshire Wolds. • There are multiple Designated Military Remains	• Through the centre of Lincolnshire is the Lincolnshire Wolds Area of Outstanding Natural Beauty. • The region is largely rural, agricultural land. Main settlements are located on the outer fringes along the existing transmission network, from Grimsby and Immingham on the industrialised banks of the Humber Estuary, to Scunthorpe to the west and then south through Gainsborough, Lincoln on to Boston and Spalding. • The coastline through Lincolnshire comprises extensive areas of exposed sandy beaches, which attract large volumes of visitors particularly in the summer. • Seaward, there are stretching coastal views within the region but also considerable marine activity around the Humber Estuary.	• The northern part of the region is heavily industrialised, along the southern bank of the Humber estuary, and along the M180 corridor to Scunthorpe. • The remainder of the region is largely agricultural. • The gas terminal at Theddlethorpe is notable and connects to a gas site at Hatton which includes a number of other pipeline connections. • In the north of region, the export cables for Hornsea 1 and 2 OWFs make landfall at North Cotes. In south Lincolnshire, the export cable for Triton Knoll OWF and the underground cable for the Viking Link interconnector (both currently under construction) make landfall south of Mablethorpe. • Population density is lower than other parts of the wider study area. There are larger settlements to the north associated with the industrial areas around the Humber. To the south and inland settlements are smaller and more spread out. Settlements in coastal areas, particularly to the south, are generally associated with tourism.

Table 3-3 Lincolnshire Terrestrial Constraints and Considerations



Project Management Initials: DR Designer: LC Checked: FF Approved: DR

Scale @ A3 1:500,000

AECOM

PROJECT
EAST COAST GRID STUDY

CLIENT
THE CROWN ESTATE

KEY
- Study Area
- Lincolnshire Sub-region
- Existing Overhead Line
- Cable
- Pipeline
- National Nature Reserve
- Special Area of Conservation
- Special Protection Area
- Site of Special Scientific Interest
- Ramsar Site
- Marine Conservation Zone
- Scheduled Monument
- Registered Battlefield
- Registered Park and Garden
- Heritage Coast
- Area of Outstanding Natural Beauty
- Country Park
- Military Practice Area
- Marine Aggregates Site
- Onshore Major Infrastructure
- Offshore Wind Site
- Offshore Wind Cable Agreement

TITLE
FIGURE 3-2
STUDY AREA CHARACTERISATION
LINCOLNSHIRE SUB-REGION

REFERENCE
ECGS_210318_SR_A_v1

SHEET NUMBER: 1 of 4

DATE: 18/03/2021

Coordinate System: WGS 1984 Zone 30N

3.5 Norfolk Sub-region Marine Constraints and Considerations

Biological Environment	Physical Environment	Historic Environment	Other Sea Users
• At the north of the sub-region lie the Wash and North Norfolk Coast SAC, the Greater Wash SPA, Ramsar, and SSSI extending south from the Wash. • The North Norfolk Coast SPA extends along the coast 40km from Holme to Weybourne. • East of Blakeney Point is the Cromer Shoal Chalk Beds MCZ. • The Southern North Sea SAC straddles the 12mile limit, as does the Hammond and Winterton SAC.	• Varied and includes a combination of lengthy sandy beaches, shifting sands and intertidal lagoons in addition to some large sections of saltmarsh and extensive mudflat. • Underlying geology is characterised by alluvium/chalk till and glacial sand / gravel. • Large sections of this region fall under the Shoreline Management Plan Policy is 'Hold The Line'. However, there are also sections of Managed Realignment and No Active Intervention.	• North Norfolk Coast Heritage Coast. • There are no Protected Wreck sites within the Norfolk coastline and wider inshore 12nm zone. • The majority of scheduled monuments in the region are coastal (terrestrial) sites however there are two marine scheduled monuments located within the 12nm inshore zone – 'Xanthe' and 'The Seagull'.	• To the far west of the sub-region, the Holbeach Military Practice area fills much on the nearshore area of The Wash. • There are few fishing ports within the region, however, there are sporadic beach-launch fisheries throughout the area. • Great Yarmouth and Lowestoft are notable in terms of their operation as major support hubs for both the oil and gas and offshore wind industries. • Sheringham Shoal, Lynn, Lincs and Inner Dowsing OWFs. • There are some Oil and Gas assets in the sub-region, most notably at Bacton where there approximately 14 individual gas, gas interconnector and chemical and lines

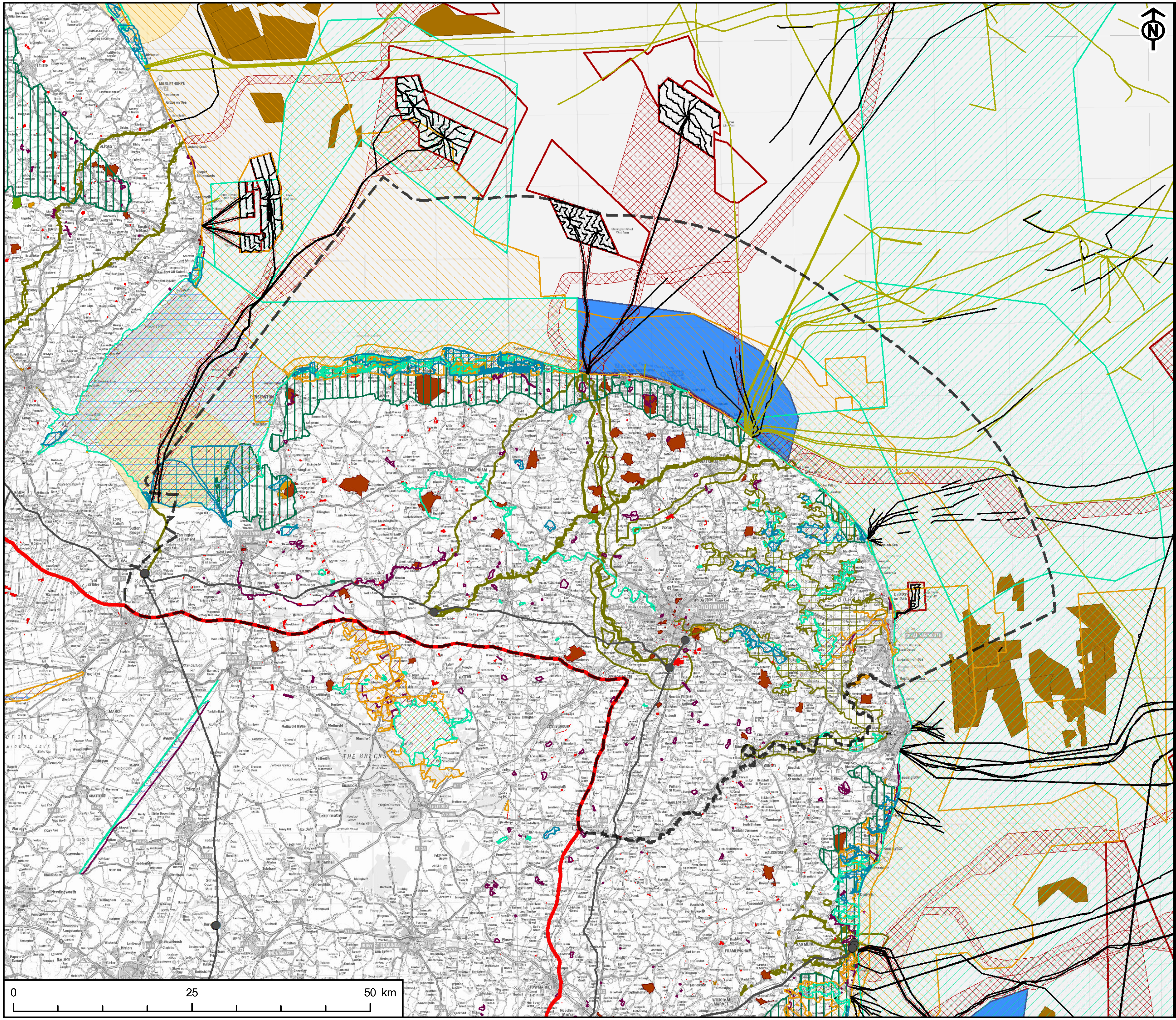
Table 3-4 Norfolk Marine Constraints and Considerations

3.6 Norfolk Sub-region Terrestrial Constraints and Considerations

Biological Environment	Physical Environment	Historic Environment	Landscape and Seascape	Land Use Constraints and Settlements
• The Wash designation extends around the north Norfolk coast to Holme next the Sea and is immediately abutted by the North Norfolk Coast designations (SAC, SPA, Ramsar, SSSI and NNR). • From Weybourne to the east of Mundesley, there are coastal cliffs designated as SSSIs. • To the east of the Norfolk, designations are largely orientated around The Broads National Park which covers most of the areas east of Norwich, and includes SACs (The Broads and Winterton-Horsey Dunes), SPAs (Broadland, Great Yarmouth North Denes and Breydon Water), Ramsar sites (Broadland and Breydon Water) as well as numerous SSSIs and NNRs. • Further inland, Norfolk includes various other designations including the River Wensum SAC and SSSI and River Nar SSSI.	• The landform is generally raised from the coastal cliffs and is gentle undulating throughout the region. • The Broads at the east of the region is generally flat. These areas are predominantly good/ moderate agricultural land (in regard to versatility and yield for productivity) to the west of the region, and good or excellent to the west. • The low-lying coastal areas in the west (at Kings Lynn), and east (The Broads) include broad areas of higher susceptibility to flooding (Flood Zone 3, 1 in 200 annual probability from flooding from the sea).	• There are a considerable number of Registered Parks and Gardens through the region, although these are predominantly located within the Lincolnshire Wolds AONB. • There are multiple Scheduled Monuments, however these are much smaller in scale. • There are also multiple Designated Military Remains, reflective of major defensive development during World War II within this region.	• The Norfolk Coast AONB covers approximately 90km of coastline between King's Lynn and Bacton, and a further 10km between Sea Palling and Winterton on Sea. • The area between Holme next the Sea and Weybourne is also designated as a Heritage Coast. • The Broads National Park further dominates the region to the east of Norwich. • There are Country Parks also located within the region including at Holt, Dersingham and Norwich. • The region (within the Study Area) is largely rural, agricultural land. • There are various recreational routes and paths of interest through the region • Seaward, there are distant views of some operational OWFs such as Lynn and Lincs OWF from the northwest coast, Sheringham Shoal from the north coast around Blakeney Point, Weybourne and Sheringham, and Scroby Sands from the east coast at Caistor-on-Sea	• The region is largely agricultural, beyond only a few populated areas – namely King's Lynn and Norwich. The region does also include the Cotlishall Airfield (RAF Coltishall) and Norwick International Airport. • At Mundesley is a gas terminal with five pipelines extending across the King's Lynn and south to the west and east of Norwich. This also includes the landfall for the Boreas and Vanguard OWF export cable connecting at Necton. • The Weybourne landfall currently includes the Dudgeon, Sheringham Shoal, and Hornsea 3 OWF export cables, and may potentially also include the Dudgeon and Sheringham Shoal extension OWF export cable. • The coastline and associated hinterland are well developed with settlements present throughout much of the area. This includes small and moderate sized towns as well as small villages. Further inland the largest settlement is the city of Norwich.

Table 3-5 Norfolk Terrestrial Constraints and Considerations

Project Management Initials: DR Designer: LC Checked: FF Approved: DR



Scale @ A3 1:500,000

Coordinate System: WGS 1984 Zone 30N

AECOM

PROJECT
EAST COAST GRID STUDY

CLIENT
THE CROWN ESTATE

KEY
- Study Area
- Norfolk Sub-region
- Existing Overhead Line
- Cable
- Pipeline
- National Nature Reserve
- Special Area of Conservation
- Special Protection Area
- Site of Special Scientific Interest
- Ramsar Site
- Marine Conservation Zone
- Scheduled Monument
- Registered Battlefield
- Registered Park and Garden
- Heritage Coast
- Protected Wreck
- Area of Outstanding Natural Beauty
- National Park
- Country Park
- Military Practice Area
- Marine Aggregates Site
- Onshore Major Infrastructure
- Offshore Wind Site
- Offshore Wind Cable Agreement

TITLE
FIGURE 3-3
STUDY AREA CHARACTERISATION
NORFOLK SUB-REGION

REFERENCE
ECGS_210318_SR_A_v1

SHEET NUMBER
2 of 4

DATE
18/03/2021

3.7 Suffolk Sub-region Marine Constraints and Considerations

Biological Environment	Physical Environment	Historic Environment	Other Sea Users
• Further south, there are additional designations: the Alde, Ore and Butley Estuaries SAC; the Orfordness - Shingle Street SAC; Deben Estuary SPA; Stour and Orwell Estuaries SPA; Alde-Ore Estuary SPAs; and the Southern North Sea SAC. • The Orford Inshore MCZ straddles the 12nm inshore limit. • The northern edge of the Outer Thames Estuary SPA extends into the southern edge of the Suffolk region.	• The Suffolk intertidal foreshore is dominated by sand and gravel in the north, changing to a gravelly substrate for ~23km encompassing the mouths of the Alde-Ore and Deben Estuaries. There are also some additional areas of coastal saltmarsh and vegetated shingle. • The Shoreline Management Plan policies for the area are variable with multiple sections of 'Hold The Line', No Active Intervention, Managed Realignment and two isolated examples of Advance The Line to the north of Southwold. • Underlying geology is characterised by till, mudstone/sandstone, sand and clay within the northern and central areas of the sub-region whilst further south, there is emergence of London Clay. • South of Shingle Street, there are various built coastal defence systems from the southern breakwater of Harwich Harbour, much of Harwich is protected by a series of seawalls, rock armour and beach groynes.	• Multiple listed buildings although almost entirely terrestrial. • Dunwich Bank is a protected wreck located ~0.5km off the coast of Dunwich Heath. • Multiple features of local heritage interest throughout the region contribute to the character of this coastal region.	• The inshore 12nm zone hosts some fishing effort, primarily undertaken by <10m vessels. • Multiple aggregate extraction areas including Yarmouth / Yarmouth expansions and the four 'Shipwash' sites. • The East Anglia One North and East Anglia Two OWF export cable routes are located within this region. • Lowestoft is a major operational and maintenance hub for Galloper OWF • At Sizewell, cooling water infrastructure for the (legacy) Sizewell A and (operational) Sizewell B Nuclear Power Stations extend into the inshore 12nm zone. Further south, there are notable major port facilities at Felixstowe Dock. • Felixstowe / Harwich Haven is surrounded by multiple traffic separation schemes, restriction areas and much of the inshore 12nm zone east of Felixstowe falls under the Harwich Harbour Area.

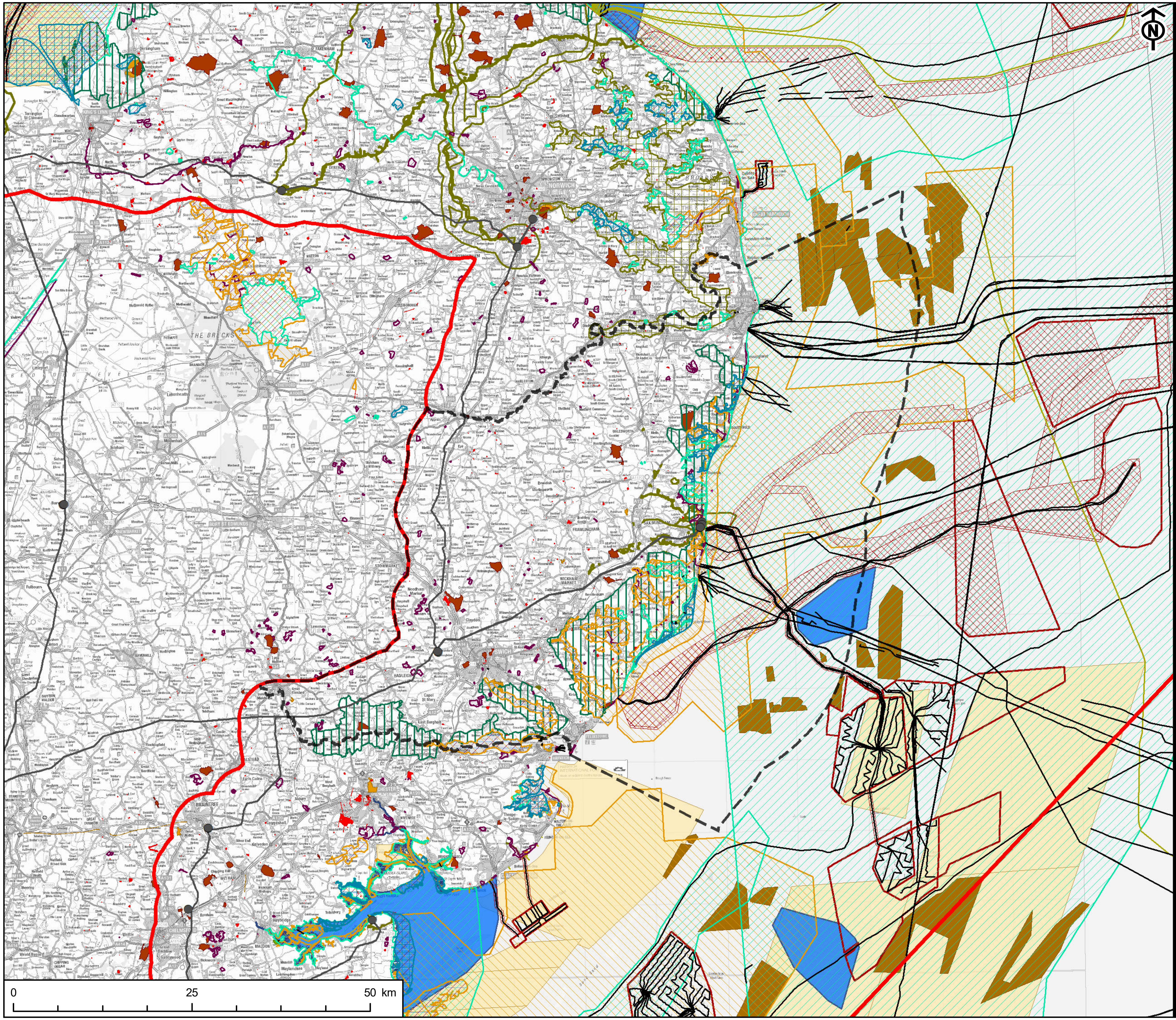
Table 3-6 Suffolk Marine Constraints and Considerations

3.8 Suffolk Sub-region Terrestrial Constraints and Considerations

Biological Environment	Physical Environment	Historic Environment	Landscape and Seascape	Land Use Constraints and Settlements
• The Minsmere-Walberswick SPA lies on the Suffolk coast between Southwold and Sizewell. • Through the Suffolk coast there are a series of coastal lagoons, estuaries and marshes which are internationally designated (SPA, SAC, Ramsar site) and stretch through the majority of the coastline save some short sections between. • Whilst there are some designated areas located further inland between the coast and the existing transmission network, these are smaller in scale and scattered spatially.	• The landform through Suffolk is gentle undulating throughout the region, with sporadic taller summits generally to the south of the region (north of Ipswich). • These areas are predominantly good/ moderate agricultural land (regarding versatility and yield for productivity) to the west of the region, and good or excellent in river valleys. • Areas at greater risk of flooding (Flood Zone 3, 1 in 200 annual probability from flooding from the sea) are typically highly localised to river valleys and estuaries.	• There are 11 Registered Parks and Gardens through the region. • There are relatively few Scheduled Monuments through of the region. • There are also multiple Designated Military Remains, reflective of major defensive development during World War II within this region.	• Suffolk heritage coast extends throughout much of the region. • The Suffolk Coast & Heaths AONB covers almost the entire coastline of Suffolk – stretching between Kessington just south of Lowestoft to the River Orwell valley (excluding Felixstowe). • The region is largely rural, agricultural land spread across a relatively flat plateau that dips towards the sandy heathlands along the coast. • Population within the region is predominantly around a few larger settlements at the north (Lowestoft) and the south (Felixstowe and Ipswich), • There are various recreational routes and paths of interest through the region • There are currently no OWF within the inshore environment that are visible from the coast, however cooling water infrastructure associated with Sizewell A and B is currently visible.	• The region is largely agricultural, beyond only a few populated areas. • Infrastructure within the region is largely focused around the Sizewell area – which includes the proposed Sizewell C nuclear site, as well as the East Anglia One and Two OWF export cables. • The main settlement is Ipswich at the south extent of the sub-region, with the main coastal settlements at Lowestoft at the north of the sub-region. South of Lowestoft several smaller coastal settlements are present including Southwold, Aldeburgh, and Orford. The coastline is more developed further south in the vicinity of Felixstowe.

Table 3-7 Suffolk Terrestrial Constraints and Considerations

Project Management Initials: DR Designer: LC Checked: FF Approved: DR



Scale @ A3 1:500,000

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PROJECT
EAST COAST GRID STUDY

CLIENT
THE CROWN ESTATE

KEY
- Study Area
- Suffolk Sub-region
- Existing Overhead Line
- Cable
- Pipeline
- National Nature Reserve
- Special Area of Conservation
- Special Protection Area
- Site of Special Scientific Interest
- Ramsar Site
- Marine Conservation Zone
- Scheduled Monument
- Registered Battlefield
- Registered Park and Garden
- Heritage Coast
- Protected Wreck
- Area of Outstanding Natural Beauty
- National Park
- Country Park
- Military Practice Area
- Marine Aggregates Site
- Traffic Separation & Deep Water Channel
- Onshore Major Infrastructure
- Offshore Wind Site
- Offshore Wind Cable Agreement

TITLE
FIGURE 3-4
STUDY AREA CHARACTERISATION
SUFFOLK SUB-REGION

REFERENCE
ECGS_210318_SR_A_v1

SHEET NUMBER 3 of 4

DATE 18/03/2021

Coordinate System: WGS 1984 Zone 30N

3.9 Essex Sub-region Marine Constraints and Considerations

Biological Environment	Physical Environment	Historic Environment	Other Sea Users
• The Essex coastline is heavily designated; this includes: Essex Estuaries SAC; Stour and Orwell Estuaries SPA; Hamford Water SPA; Colne Estuary Ramsar site and SPA; Blackwater Estuary Ramsar and SPA; Crouch and Roach Estuaries SPA; and Colne Estuaries MCZ. • Southern North Sea SAC, Margate and Long Sands SAC and the Outer Thames Estuary SPA are also located within the region.	• The Essex intertidal foreshore is largely mud, with some patchy muddy gravel. • The Shoreline Management Plan policy for the region is mainly 'Hold The Line' but with various pockets of 'No Active Intervention', 'Managed Realignment' and a number of isolated sections of 'Managed Realignment' to the west of Harwich Haven. • Much of the frontage in the region is backed by extensive coastal defences which stretch along much of the peninsula.	• The maritime wreck, believed to be the "London", a second rate 'large ship', is located at The Nore, Thames Estuary, off Southend-on-Sea. • The remains of a wreck thought to be that of a Swedish cargo vessel dating from 1787 to the early nineteenth-century, resides in the South Edinburgh Channel. This site is designated under the Protection of Wrecks Act 1973, for protection from unauthorised interference. • Multiple listed buildings exist although these are almost entirely terrestrial.	• There is some limited fishing effort within the 12nm zone along the Essex coast (primarily understood to be <10m vessels). • South east of the inshore 12nm zone are Gunfleet Sands I, II and Demo OWFs and Longsand aggregate extraction area. • The Neuconnect interconnector route is at the 12nm limit of the inshore zone and further to the south east is the London Array OWF. • Walton and Frinton Yacht Club, Titchmarsh Marina and The Naze Marine Holiday Park are notable recreational feature of the locality.

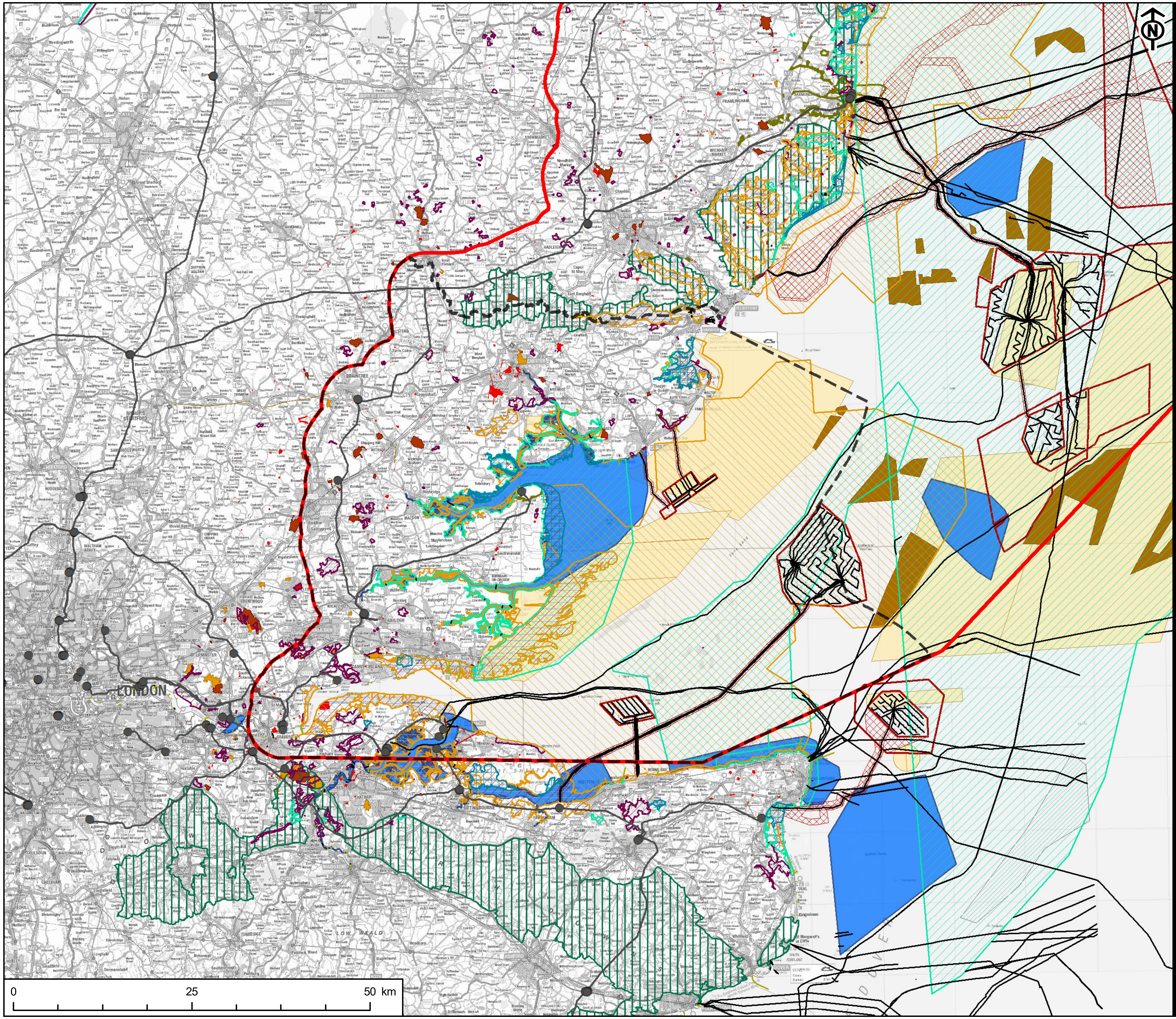
Table 3-8 Essex Marine Constraints and Considerations

3.10 Essex Sub-region Terrestrial Constraints and Considerations

Biological Environment	Physical Environment	Historic Environment	Landscape and Seascape	Land Use Constraints and Settlements
• Coastal designations include Dengie Ramsar site and SPA; Foulness Ramsar site and SPA; and Benfleet & Southend Marshes Ramsar and SPA. • To the south, the coastline through Essex is dominated by river estuaries, almost all of which are internationally designated. • Most of the wider Essex coastline is also internationally designated. • As with Lincolnshire and Suffolk, whilst there are some nationally designated sites further inland (such as Abberton Reservoir and Chalkney Wood, and pockets of ancient woodland along the A12 corridor) these areas are more discrete and spatially separate.	• The landform through the Essex region of the Study Area is heavily dominated by the low-lying coastal areas and large and numerous estuaries. • The more coastal areas – within the boundary of the A12 – are generally good/ moderate agricultural land (regarding versatility and yield for productivity), and good or excellent inland of the A12. • Areas at greater risk of flooding (Flood Zone 3, 1 in 200 annual probability from flooding from the sea) are typically highly localised to river valleys and estuaries.	• There are 15 Registered Parks and Gardens through the region, which are predominantly located around the settlements of Chelmsford, Witham and Colchester. • There are relatively few Scheduled Monuments throughout the region. • There are multiple Designated Military Remains, few of which are located around the coast. The greatest density of these are pillboxes adjacent to the A130 south of Chelmsford	• The Suffolk Coast & Heaths AONB extends over the county boundary to Essex in the north. • The Dedham Vale AONB extends across the entire valley of the River Stour between Brantham and Bure. • The coastal landscape is relatively unpopulated; further inland, the landscape is slightly more populated and dominated by arable agriculture. • Aside from infrastructure and traffic associated with Harwich Harbour/Harwich Haven, there are largely unconstrained views of the coast. • Gunfleet Sands I and II OWFs are also prominent in the seascape from Clacton on Sea and Frinton-on-sea. • Dependent on conditions, distant views of London Array are also possible from the coast in southern parts of the county.	• Land use is largely agricultural beyond the low-lying marshlands which extend throughout the coastline. • Existing and proposed infrastructure within the region is also limited. Bradwell B is proposed adjacent to the existing site north of Bradwell on Sea. • There is also the landfall of the export cable of the Gunfleet Sands OWF which land immediately north of Clacton on Sea. • The coastal environment is less densely populated or developed than inland areas. Main settlements are Colchester, in the north (situated several kilometres inland), Southend on Sea and Tilbury. Several smaller settlements are present on the coast including Frinton on Sea, Clacton, Maldon and Burnham on Crouch, as well as Sheerness and Eastchurch on the Isle of Sheppey.

Table 3-9 Essex Terrestrial Constraints and Considerations

Project Management Initials: DR Designer: LC Checked: FF Approved: DR



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Coordinate System: WGS 1984 Zone 30N

AECOM

PROJECT
EAST COAST GRID STUDY

CLIENT
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KEY
- Study Area
- Essex Sub-region
- Existing Overhead Line
- Cable
- Pipeline
- National Nature Reserve
- Special Area of Conservation
- Special Protection Area
- Site of Special Scientific Interest
- Ramsar Site
- Marine Conservation Zone
- Scheduled Monument
- Registered Battlefield
- Registered Park and Garden
- Heritage Coast
- Protected Wreck
- Area of Outstanding Natural Beauty
- Country Park
- Military Practice Area
- Marine Aggregates Site
- Traffic Separation & Deep Water Channel
- Onshore Major Infrastructure
- Offshore Wind Site
- Offshore Wind Cable Agreement

TITLE
FIGURE 3-5
STUDY AREA CHARACTERISATION
ESSEX SUB-REGION

REFERENCE
ECGS_210318_SR_A_v1

SHEET NUMBER 4 of 4

DATE 18/03/2021

4. Spatial Assessment

4.1 Approach to Spatial Assessment

For each of the sub-regions within the Study Area consideration has been given to the potential significance of the spatial constraints present and how these could influence or prevent the routeing and siting of grid connection infrastructure required as part of future offshore wind projects. Given the strategic scale of the study this has been a high-level Red, Amber, Green (RAG) analysis integrating consideration of spatial constraints in both the marine and terrestrial environments with typical route and site selection considerations for typical components of grid connection infrastructure which could be used for radial or coordinated approaches.

RAG assessments are a commonly used tool informing route and site selection for a variety of grid connection and/or electricity transmission infrastructure projects. This assessment considers the existing level of constraint within each sub-region (including known / planned projects) for the following typical offshore wind grid connection components:

- Subsea cable routes
- Offshore collector 'hubs' or 'nodes'
- Coastal/inshore collector 'hubs' or 'nodes'
- Landfalls
- Terrestrial cable routes and substations/converter stations, and
- Grid Connection Points.

The criteria used to describe the RAG classifications for this report are outlined below.

Red	High level of potential constraint, with risk to project consent or programme high and possibly unacceptable. Mitigation may be difficult to achieve and/or may also require non-standard approaches.
Amber	Moderate level of potential constraint and risk to project consent or programme may be manageable to achieve to acceptable levels. Mitigation is possible using industry standard methods.
Green	Low level of potential constraint and risk which is unlikely to delay offshore wind connection infrastructure. If required, mitigation is likely to be limited and easy to achieve.

4.2 Subsea Cable Routes

<table>
<tr><th>Lincolnshire</th><th>Norfolk</th><th>Suffolk</th><th>Essex</th></tr>
<tr>
<td>At the north of the region is the Humber Estuary and increased marine traffic and dredging activities.

There are several existing cable corridors in this area, including the export cables for the Hornsea 1 and 2 OWFs.

Through the centre of the region, between 6 and 12 nm limits, are an aggregate area, sequential landings of gas pipelines, Viking Link interconnector, and the Triton Knoll OWF and Inner Dowsing OWF export cables.

The Inner Dowsing, Race Bank and North Ridge SAC extends inshore to the south to the Wash.

There are potential corridors available between areas of constraint with no significant constraints within 6nm of shore in terms of bathymetry, existing infrastructure or marine habitat constraints.</td>
<td>Environmental designations extend across the region including the Wash and North Norfolk Coast SAC, Cromer Shoal Chalk Beds MCZ and the Haisborough, Hammond and Winterton SAC.

Offshore from the north Norfolk coast there are multiple marine cables and wider linear infrastructure, including:
• Sheringham Shoal, Dudgeon, Dudgeon and Sheringham Shoal extensions and Hornsea 3 OWF.
• Multiple pipelines landing at Bacton.
• Similarly, offshore from the east Norfolk Coast are export cables for:
• Boreas, Vanguard and Scroby Sands OWFs

Potential landfall areas are mainly on the north Norfolk coast, where there is high density of coastal infrastructure.

The current level of constraint suggests that the routeing of new infrastructure will be challenging now, and that difficulty is likely to increase over time as more infrastructure is added.</td>
<td>At the north of the region there are various aggregate areas east of Lowestoft and a series of telecoms cables to the south, but limited environmental designations.

There is considerable existing or planned infrastructure off the Suffolk Coast around Sizewell, including infrastructure for:
• East Anglia One, One North and 2, Galloper and Greater Gabbard OWF;
• Interconnector and telecommunications cables.

Further south the East Anglia Three OWF export cable cuts Study Area making landfall north of Felixstowe.

Ecological constraints to the south include the Orford Inshore MCZ.

Whilst there are opportunities to route further marine cables through the sub-region, existing infrastructure is concentrated around a limited number of preferred landfalls.</td>
<td>The Essex coast includes a number of constraints including:
• Margate and Long Sands SAC and Essex Estuaries SAC and MCZ;
• Anchorage areas adjacent to Harwich harbour;
• Military practice areas between Harwich and Foulness Island;
• Explosives disposal areas;
• Gunfleet Sands and London Array OWFs.

Existing cables making landfall in Essex are limited, reflecting the extent and spatial distribution of constraints.

New subsea cable infrastructure will have limited spatial capacity.

Any works will require active agreement with multiple third parties</td>
</tr>
<tr><td>Low level of constraint</td><td>Moderate level of constraint</td><td>Moderate level of constraint</td><td>High level of constraint</td></tr>
</table>

Table 4-1 Subsea Cable Routes – RAG Assessment

4.3 Offshore collector 'hubs' or 'nodes'

Lincolnshire	Norfolk	Suffolk	Essex
Spatial restrictions are not extensive throughout the marine environment, and opportunities to site offshore collector hubs exist. The Southern North Sea SAC extends through the marine environment offshore - designated for marine mammals. The spatial distribution of other constraints such as aggregate areas and Round 4 (R4) bidding areas allows for relatively unconstrained routes to and from potential collector hub locations.	Physical constraints that limit collector hub installation are limited to R4 bid areas to the west and east in this region, as well as aggregate areas immediately off the east Norfolk coast. Designations include Inner Dowsing, Race Bank and North Ridge; North Norfolk Sandbanks and Saturn Reef; and Haisborough, Hammond and Winterton SACs. The Southern North Sea SAC also covers most of the eastern offshore environment. Opportunities are present through large areas of the sub-region to site, and route to and from, a collector hub.	The north of the region is largely unconstrained from physical constraints. R4 bidding areas are present from approximately 30km offshore. Towards the south, off the coast of Aldeburgh and south to the Essex border, constraints become more numerous, including: • Explosive disposal grounds; • Military practice areas; • Navigation routes out of Harwich harbour; • Orford Inshore MCZ; • The Southern North Sea SAC.	The sub-region has numerous dredge disposal areas, aggregate areas, navigation channels and anchorage points. Military practice areas are also present. The Essex Estuaries and Margate and the Long Sands SACs, which are designated for benthic habitats also cover large extends through the southern area of the region. Limited areas may be potentially suitable to locate a collector hub, however significant challenges exist for routeing cables to these locations will restrict that suitability.
Low level of constraint	**Low level of constraint**	**Low level of constraint**	**High level of constraint**

Table 4-2 Offshore Collector ‘Hubs’ or ‘Nodes’ – RAG Assessment

4.4 Coastal/inshore collector 'hubs' or 'nodes'

Lincolnshire	Norfolk	Suffolk	Essex
Opportunities exist to develop a coastal node in Lincolnshire, as the sub-region is broadly un-designated. The coastline is populated with holiday parks and coastal settlements, with limited larger infrastructure. The extension of the existing transmission network to South Lincolnshire may result in a new coastal node suitable for further connections. However, the suitability of any further nodes beyond this new connection point would be dependent on generation capacity off the Lincolnshire coast.	Opportunities exist to extend the existing infrastructure towards the coastline, thus limiting potential requirement for, and the extent of, future onshore cables. A new coastal node would require consideration of its siting in the context of the North Norfolk Coast AONB and The Broads National Park designations, as well as the potential cumulative impacts on the adjacent coastal communities. The development of a single overhead line (OHL) corridor as opposed to multiple further cable corridors adjacent to existing routes avoiding or reducing constraints for cables routeing	Opportunities for coastal nodes within Suffolk are likely to be limited as a result of the Suffolk Coast and Heaths AONB and Suffolk Coast Heritage Coast which extends the length of the county and includes the area up to 7km inshore. The area between Beccles and Lowestoft at the north of the sub-region is located in an area between The Broads National Park and the AONB/ Heritage Coast and may be suitable for coastal node location. There may be opportunities within the sub-region for the reduction of multiple onshore cable corridors.	Opportunities for coastal nodes through Essex are challenging, due to extensive coastal designations and built up areas. Less constrained areas that might be suitable landfalls occur in the north of the sub-region between Harwich and Clacton-on-Sea, however an extension of the OHL network in this area would need to be routed between the Suffolk Coast and Heaths AONB and Colchester.
Moderate level of constraint	**High level of constraint**	**Moderate level of constraint**	**High level of constraint**

Table 4-3 Coastal/Inshore* Collector 'Hubs' or 'Nodes' – RAG Assessment

* Onshore and within inshore waters / 12 nm

4.5 Landfalls

Lincolnshire	Norfolk	Suffolk	Essex
The Lincolnshire coast is typically comprised of broad sandy beaches with limited cliffs, defined by the Humber Estuary to the north and the Wash to the south. The coastline includes various designated areas, however, between the areas of designation however the coastline is largely suitable for landfall - excluding the settlement areas of Mablethorpe and Skegness. Also, within the designated areas there are the landfalls for Hornsea 1 and 2, as well as the Racebank and Lincs OWF, demonstrating some opportunity to land. With increased infrastructure pressure in future such landfall opportunities may become more limited. Nearshore constraints are few, but include: • Pipelines at Mablethorpe; • Export cables for OWFs; • Viking Link interconnector.	The Norfolk coastline is designated throughout most of its extent. The sub-region includes opportunities for landfall locations where impacts to these designated areas could be minimised. However several existing OWF export cables, interconnectors and pipelines make landfall in similar locations, with many less constrained areas taken. Remaining landfall opportunities are more technically / challenging. Therefore whilst there may be landfall opportunities in this sub-region these are limited in spatial extent, and their use may become more challenging as additional connections are installed.	The Suffolk coastline is significantly designated, including marine and terrestrial biological designations, as well as the Suffolk Coast and Heath AONB. Breaks in terrestrial designations are limited to areas of settlement, which themselves limit landfall opportunities. The area around Sizewell may present opportunities for landfall, as the existing transmission network is built out to the coast there. However, there are a number of existing and proposed connections there that would constrain further connections, potentially requiring use of unfavourable areas terrestrially to reach the connection point. Beyond Sizewell, presence of designations and the distance to the existing transmission network constrain other landfall opportunities. There is a narrow section of coast at South Lowestoft which may offer some opportunity for landfall, but would require onward routeing between a National Park and AONB, which may limit the usefulness of the opportunity.	Much of the Essex coast is designated and physically restricted, with multiple large estuaries, which are themselves designated. Avoidance of designated areas for landfall is difficult, with limited opportunities. Between Harwich and Clacton-on-Sea there are potential opportunities for landfall between settlements, with limited nearshore constraints. In this sub-region it is noted that there are also constraints further inland which might affect onward routes to connection.
Low level of constraint	**Moderate level of constraint**	**Moderate level of constraint**	**Moderate level of constraint**

Table 4-4 Landfalls – RAG Assessment

4.6 Terrestrial Cable Routes and Substations/Converter Stations

Lincolnshire	Norfolk	Suffolk	Essex
The distribution of terrestrial constraints through Lincolnshire offers some opportunity for onshore cable routeing. The Lincolnshire Wolds AONB presents a potential constraint to connections the existing network from points between Keadby and Bicker Fen, although it is noted that Viking Link routes through part of this designation. Potential for cumulative impacts on the AONB may influence the number of future crossings. Routeing further north, to connection points on the south Humber bank, is likely to be more favourable in that it avoids the AONB. However it is also noted that in-combination impacts following the Hornsea 1 and 2 cable corridor may limit the number of other cable routes available. At northern connection points the industrialised nature of the area and limited designations limits potential constraint, potentially facilitating grid connection, substation amendments or a converter station. The potential extension of the existing network to South Lincolnshire, would improve opportunities for terrestrial routeing from landfalls in central or southern Lincolnshire.	The Norfolk region between the coast and the existing transmission network is includes only two potential connection points. Opportunities to route to these locations is constrained by the presence of existing connections including Dudgeon, Hornsea 3, Boreas, Vanguard, and Sheringham Shoal OWFs, and the potential Dudgeon and Sheringham Shoal extension. Future corridors may face greater constraint, with more favourable opportunities already exploited by current projects. The connection point at Norwich Main is located in a populated area with potential restrictions to possible extensions to this site to accommodate further connections, or to support additional infrastructure for the existing network. A connection point at Nekton is more rural in nature, offering relatively unconstrained space adjacent to the existing site for extended or additional infrastructure. Opportunities exist to extend the current network to the coast. However, the extensive North Norfolk Coast AONB and The Broads National Park, along with a higher density of population may restrict	Within Suffolk, the heavily designated coastline limits opportunities for routeing, although other terrestrial constraints that might restrict cable routeing are more limited. Potential opportunities exist to reach a landfall at south Lowestoft, however, key designations can potentially be avoided (Suffolk Coast and Heaths AONB and The Broads National Park). However the potential for a cable corridor here is limited, and development beyond a first cable may become more challenging for future projects. Opportunities exist for landfall near Sizewell, and a connection point is available close to the coast. However, access to that connection may be constrained by other projects. Industrial development around Sizewell offers some opportunities to site additional connection infrastructure however cumulative impacts on coastal communities may also be a significant constraint. There are opportunities to extend the existing network to the coast due to limited terrestrial designations and a relatively sparse population. The proximity to which the extension can get to the coast will be	Existing connection points, and opportunities for future connection are typically located on the fringe of urban areas adjacent to major infrastructure and larger commercial or light industrial units such as Braintree, Bulls Lodge, and Bramford. Opportunities for additional connection infrastructure is therefore feasible, although there are limited opportunities to extend the existing network to coastal locations through Essex. As described, in the north of the sub-area the Dedham Vale AONB limits routeing opportunities, and in the south whilst there are no landscape designations the landscape is very rural and flat presenting challenges to introducing infrastructure.

Lincolnshire	Norfolk	Suffolk	Essex
	options to route an OHL or site a connection point.	constrained by the Suffolk Coast and Heaths AONB which extends up to 6km in land.	
Moderate level of constraint	**Moderate level of constraint**	**Moderate level of constraint**	**Moderate level of constraint**

Table 4-5 Terrestrial Cable Routes and Substations/Converter Stations – RAG Assessment

4.7 Grid Connection Points

Lincolnshire	Norfolk	Suffolk	Essex
There is a cluster of existing substations at the north of the sub-region at Grimsby, South Humber Bank, Humber Refinery and Killingholme, which present opportunities for future connections. These opportunities are relatively close to potential landfall locations. The potential reinforcement of the network in the region (as highlighted in NOA 2019/20) to extend the network to South Lincolnshire supports the potential opportunities for future connections in this region.	Limited existing connection points are available within Norfolk, with existing substations limited to Necton and Norfolk Main. Two connections points already connect three OWFs and will connect future extensions to two of the OFWs (Dudgeon and Sheringham Shoal).	Within the Suffolk sub-region current substation locations are limited to Sizewell and Bramford, at the south of the region. Future reinforcements are located at, or adjacent to Sizewell (Sizewell C and Friston substations). Future connections to the existing transmission network in the north of the region require connecting to Norwich Main, or connection in to the OHL network. Multiple connections exist at Norwich Main which is in a well-developed area. Connecting to an existing OHL is generally less preferred as this may require additional infrastructure, however, this approach may allow further connection opportunities.	The existing transmission network in the Essex sub-region is located approximately 30km inshore of the coastline, but does have multiple connection points. Connection points are currently typically in developed areas, so reaching these locations may be challenging. This includes extension out to the Bradwell power station. The Dedham Vale AONB extends from the coast, around Colchester and adjacent to the existing OHL network restricting northern connection options. Constraints associated with connecting to the existing transmission system demonstrated by the decision of OWFs located off the Essex coast to predominantly make landfall in Kent.
Low level of constraint	**Moderate level of constraint**	**Moderate level of constraint**	**Moderate level of constraint**

Table 4-6 Grid Connection Points – RAG Assessment

4.8 Summary of RAG Analysis

Table 4-7 summarises the main findings of the RAG analysis undertaken, and some subregions are more spatially constrained than others. For example, Essex and to a lesser extent Norfolk and Suffolk, are spatially constrained due to a combination of environmental designations, coastal settlements and existing and planned offshore wind developments. There the early deployment of coordinated grid connections is likely to be beneficial and will support more installed wind capacity in the long-term. However, Lincolnshire to the north may be less sensitive to radial connections in the short to medium term because there are fewer spatial constraints or opportunities exist to address those which are present through design and planning of future grid connections.

The levels of constraint encountered also vary between the various components of transmission infrastructure, with landfalls, terrestrial cable routes and grid connection points assessed as potentially the most highly constrained grid infrastructure components in the Study Area, across most subregions except Lincolnshire. Terrestrial cable routes and substation / converter stations are moderately constrained across all subregions, indicating a key component where coordinated solutions which reduce overall constraints would be particularly advantageous.

Component	Lincolnshire	Norfolk	Suffolk	Essex
Subsea Cables	Low	Moderate	Moderate	High
Offshore Collector ‘Hubs’ or ‘Nodes’	Low	Low	Low	High
Coastal inshore collector 'hubs' or 'nodes'	Low	High	Low	High
Landfalls	Low	Moderate	Moderate	Moderate
Terrestrial Cable Routes and Substations/Converter Stations	Moderate	Moderate	Moderate	Moderate
Grid Connection Points	Low	Moderate	Moderate	Moderate

Table 4-7 Summary of RAG Assessment

5. Offshore Wind and Grid Connection Scenarios

5.1 Overview

To analyse the potential of both radial and coordinated approaches to offshore wind grid connection within the Study Areas a series of hypothetical scenarios have been developed. These scenarios draw upon offshore wind generation targets to 2030, aspirations during Round 4, and offshore wind projects currently in development or planning.

The scenarios are not intended to illustrate how or where development should occur but are intended to be representative of the infrastructure potentially required and where it may be located, considering the constraints described in Section 4.

To develop the hypothetical scenarios consideration has been given to:

- The locations within the Study Area where offshore wind generation may occur, referred to as "Conceptual Offshore Wind Projects".
- The locations) within the Study Area where offshore wind export cables may make landfall, referred to as "Potential Landfalls".
- The locations within the Study Area where offshore wind generation may connect to the transmissions system, referred to as "Potential Connection Points".
- Potential route corridors between these locations where subsea or underground cables could be installed as well as potential overhead lines where opportunities to extend the network exist, and
- The opportunities available for coordinated approaches, and indicative locations of any associated additional infrastructure (such as coastal/nearshore or offshore collector hubs).

5.2 Offshore Wind Development Scenario

5.2.1 Overview

The identification of a series of Conceptual Offshore Wind Projects which would require to be connected to the transmission system has been informed by the following:

- Existing and planned offshore wind generation (i.e. Round 3 and Extensions) totalling 10 GW.
- A national target for total generation for offshore wind generation by 2030 of 40 GW.
- A target for future offshore wind generation (i.e. Round 4 and Extensions) totalling 3.5 GW.

5.2.2 Existing and Planned Offshore Wind

Existing Round 3 projects and extensions are a key part of the baseline for the study, and these are assumed to proceed in line with information in the public domain as summarised in **Table 5-1** below.

Project	Capacity	Grid Connection Point	Date[9]
Hornsea 3 (Phase 1)	2GW	Norwich Main	2025
Hornsea 3 (Phase 2)	1GW	Norwich Main	2028
Vanguard	1.8GW	Necton	2024
Boreas	1.8GW	Necton	2027
East Anglia 1 North	0.86GW	Friston	2027
East Anglia 2	0.86GW	Friston	2026

[9] https://www.nationalgrideso.com/connections/registers-reports-and-guidance - connection dates reviewed 24.11.2020

Project	Capacity	Grid Connection Point	Date[9]
Dudgeon/Sheringham EXT.	0.720GW	Norwich Main	2025
Galloper EXT.	0.348GW	South Suffolk / North Essex*	2029
Race Bank EXT	0.565	South Lincolnshire*	2030

Table 5-1 Existing and Planned Offshore Wind within the Study Area

* Grid Connection Points unknown, anticipated areas identified in consultation with Project Partners.

To evaluate both radial and coordinated approaches to connecting offshore wind, a series of assumptions about future potential offshore wind generation deployment have been developed. The process that has been followed to is summarised below.

5.2.3 Conceptual Offshore Wind Projects

A series of seven 0.5 GW Conceptual Offshore Wind Projects were identified within the Study Area, as shown by Figure 5-1 below, with more detailed figures provided within **Appendix B** and **Appendix D**.

Some limited consideration was given to constraints in identifying these locations, however, they are not meant to be representative of where future offshore wind development may be located. The focus of this study is on radial and coordinated approaches to the connection to grid of future offshore wind, rather than the precise location of those offshore wind projects.

Consideration of the grid connection scenarios all use the same conceptual offshore wind projects, with the connection scenarios focussed on the inshore 12 nautical mile zone, including landfalls, and then on to grid connection point.

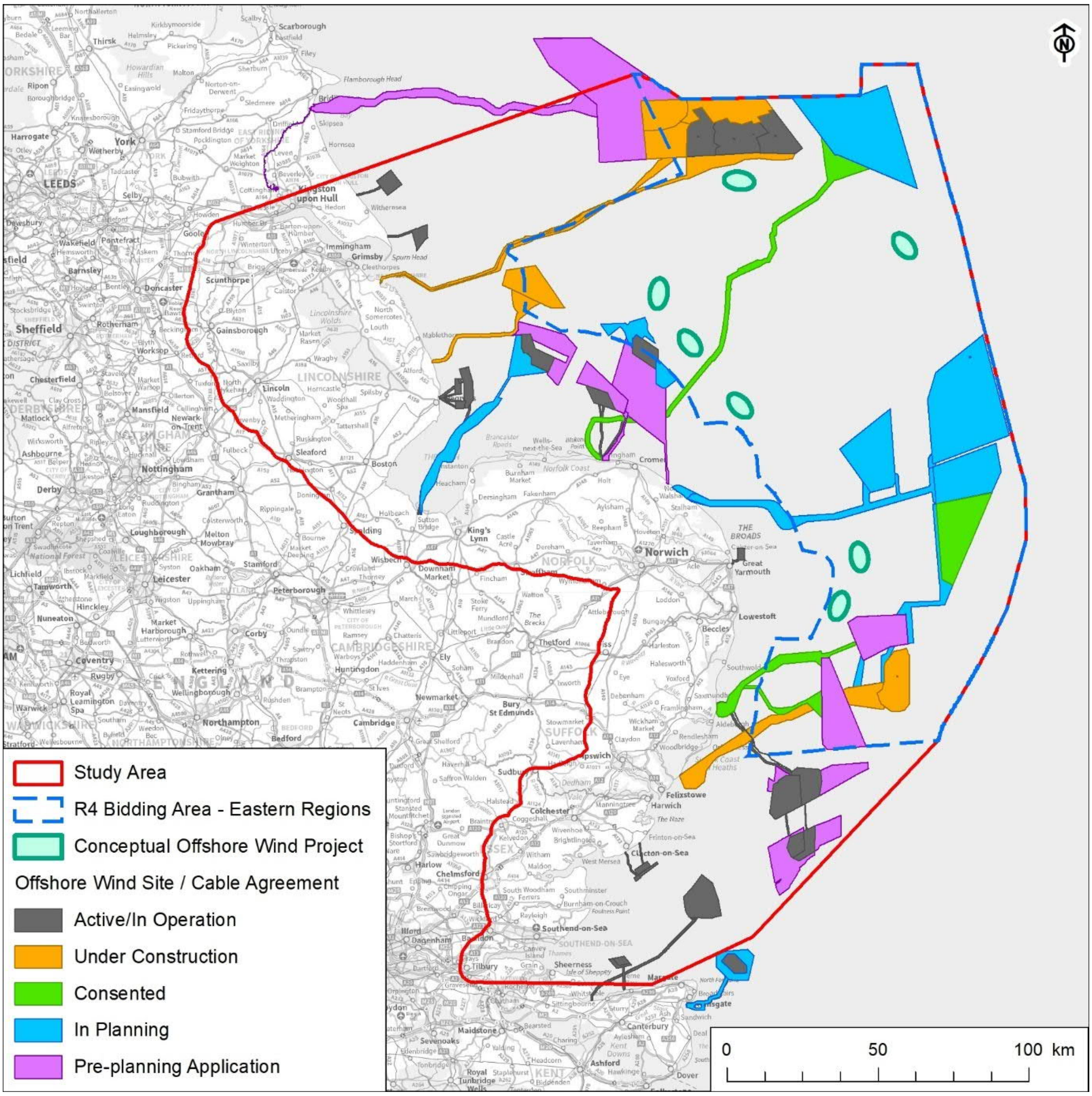


Figure 5-1 Hypothetical offshore wind farm scenario

5.3 Potential Landfalls

5.3.1 Identification of potential landfalls

The coastline within the Study Area has been reviewed to identify potential landfall areas for the purposes of developing grid connection scenarios to be assessed. Given the scale of the Study Area, the review is not exhaustive and other landfall opportunities will likely exist, however, for the purposes of the scenario analysis a number of potential landfall areas have been identified.

Key considerations during the review of potential landfalls were related to physical, environmental, socioeconomic and physical/infrastructure constraints. These parameters, which have themselves been informed by a baseline review of each region, set out areas of preference or areas that would be best avoided when landing a cable. These included:

- Physical environment
  - Nearshore and intertidal substrate – it is generally preferable to install cables in sand and softer substrates to allow cable burial and protection.
  - Topography and coastal landform – it is generally preferable to land cables at beaches and/or gentle slopes instead of rocky coastlines and/or cliffs for ease of construction.

  - Coastal erosion – it is generally preferable to avoid areas which are at higher risk of erosion as shown in shoreline management plans to reduce the risk of cable exposure.
- Environmental and socio-economic constraints
  - Settlement and tourist attractions – it is generally preferable to avoid highly populated areas such as settlements, holiday parks or other coastal tourist attractions to reduce disturbance to people who live, work or holiday in these areas.
  - Environmentally designated areas – it is generally preferable to avoid designated areas, noting that the sensitivity of the site to cable installation activities will vary depending on the designated features of the site for example birds or habitats.
- Existing infrastructure and nearshore sea use
  - Consideration of landfalls for existing offshore wind farms (including those under development)
  - Consideration of other infrastructure including sea defences, outfalls and other cables or pipelines.
  - Consideration of other nearshore and coastal activities including tourism and recreation.

The broad areas of the coastline determined to be potentially suitable for landfall locations are shown in **Figure 5-2**.

The landfall areas that have been considered as part of the grid connection scenarios have considered their proximity to the Conceptual Offshore Wind Projects, and proximity to Potential Grid Connection Points. It is assumed that the most direct, shortest connections between these points would be utilised.

5.3.2 Lincolnshire sub-region

The Lincolnshire coast stretches for approximately 55km from the Humber Estuary to the Wash. It is predominantly comprised of long sandy beaches and relatively short cliff faces.

Large environmental designations are present to the north at the Humber Estuary and to the south at the Wash, however there are some large sections where no designations are present.

There are sections of the coastline at risk of erosion including some areas currently being actively managed.

Coastal development is mixed; at the north of the region close to the Humber comprising a mix of settlement and industry while further south close to the Wash comprising settlement, holiday parks and tourist attractions.

Three potential landfall areas have been identified within Lincolnshire: North Cotes, Theddlethorpe and Anderby. Further details on the key constraints considered under each potential landfall location is provided within **Appendix C**.

5.3.3 Norfolk sub-region

The Norfolk coastline is more developed than that in Lincolnshire, and the coastal landform includes areas of greater cliff height which are less suitable for developing landfalls. Environmental designations are present along the entire north Norfolk coastline from the Wash in the west to Great Yarmouth in the east. This includes the Wash and North Norfolk Coast SAC, North Norfolk Coast SAC, the Cromer Shoal Chalk Beds MCZ and Haisborough, Hammond and Winterton SAC as well as the Southern North Sea SAC which are present in the nearshore area. Large sections of the coastline are well developed with established settlements present that extend along the coastline. In combination the above factors limit the extent of the coastline which provides opportunities for landfalls.

Two landfall areas have been identified within Norfolk: Weybourne and Bacton. Further details on the key constraints considered under each potential landfall location is provided within **Appendix C**.

5.3.4 Suffolk sub-region

As with Norfolk, the Suffolk coastline stretching from Lowestoft to Felixstowe comprises several designated sites, however, with the exception of the Southern North Sea SAC, Outer Thames Estuary SPA and the Orford Inshore MCZ these are typically located on onshore in coastal locations. This includes Benacre to Easton Bavents Lagoons, Minsmere to Walberswick Heaths & Marshes, Orfordness-Shingle Street and Alde-Ore & Butley Estuaries SACs. The Suffolk Coast and Heaths AONB extends along a very substantial length of the Suffolk coastline and while in isolation this should not constrain landfall options it does influence routeing and siting of onshore infrastructure. Some sections of the coastline are well developed with large and moderate sized settlements present as well as Sizewell Nuclear Power Station.

Three landfall areas have been identified within Suffolk: Lowestoft, Sizewell and Bawdsey. Further details on the key constraints considered under each potential landfall location is provided within **Appendix C**.

5.3.5 Essex sub-region

Within the Study Area the Essex coastline stretches for approximately 25km from Harwich to Clacton-on-Sea. This section of the coastline is one of the most well developed and densely populated within the East Coast Region which limits landfall options. Within the coastal and nearshore areas there are a small number of designated sites including Hamford Water SAC, Hamford Water, Naze, and Hollandhaven Marshes SSSIs and Hamford Water SPA. In combination these constraints limit landfall opportunities.

Two landfall areas have been identified within Essex: Harwich South and Clacton on Sea. Further details on the key constraints considered under each potential landfall location are provided within **Appendix C**.

5.4 Potential Grid Connection Points

To aid in the establishment of the parameters for this Study, in conjunction with NGET and NGESO, the following Potential Grid Connection Points have been identified:

- Existing Connection Points – These connection points include any existing infrastructure on the transmission system network, including substations and overhead lines (OHL). It is assumed that no connection would be made beyond the closest point or section of the network to the coastline.
- Future Connection Points – These connection points are based on known network reinforcements, such as new substations or OHL extensions, which are under development or have been given a ‘proceed’ signal in the most recent National Grid Electricity System Operators (ESO) Network Options Appraisal (NOA) 2019/20.
- Potential Network Extensions – These connection points have been suggested for the purposes of the Study only in order to consider what benefits might be realised from extending the network to the coast and establishing coastal ‘hubs’ or ‘nodes’. These extensions would require reinforcement and the development of new electrical infrastructure, including potentially overhead routes or underground cables, from an existing substation to a coastal location.

The location of potential Grid Connection Points is provided in **Figure 5-2** and discussed in **Appendix C**. A summary of considerations surrounding Existing Connection Points, Future Connection Points and Potential Network Extensions for each region is provided in **Table 5-2** below.

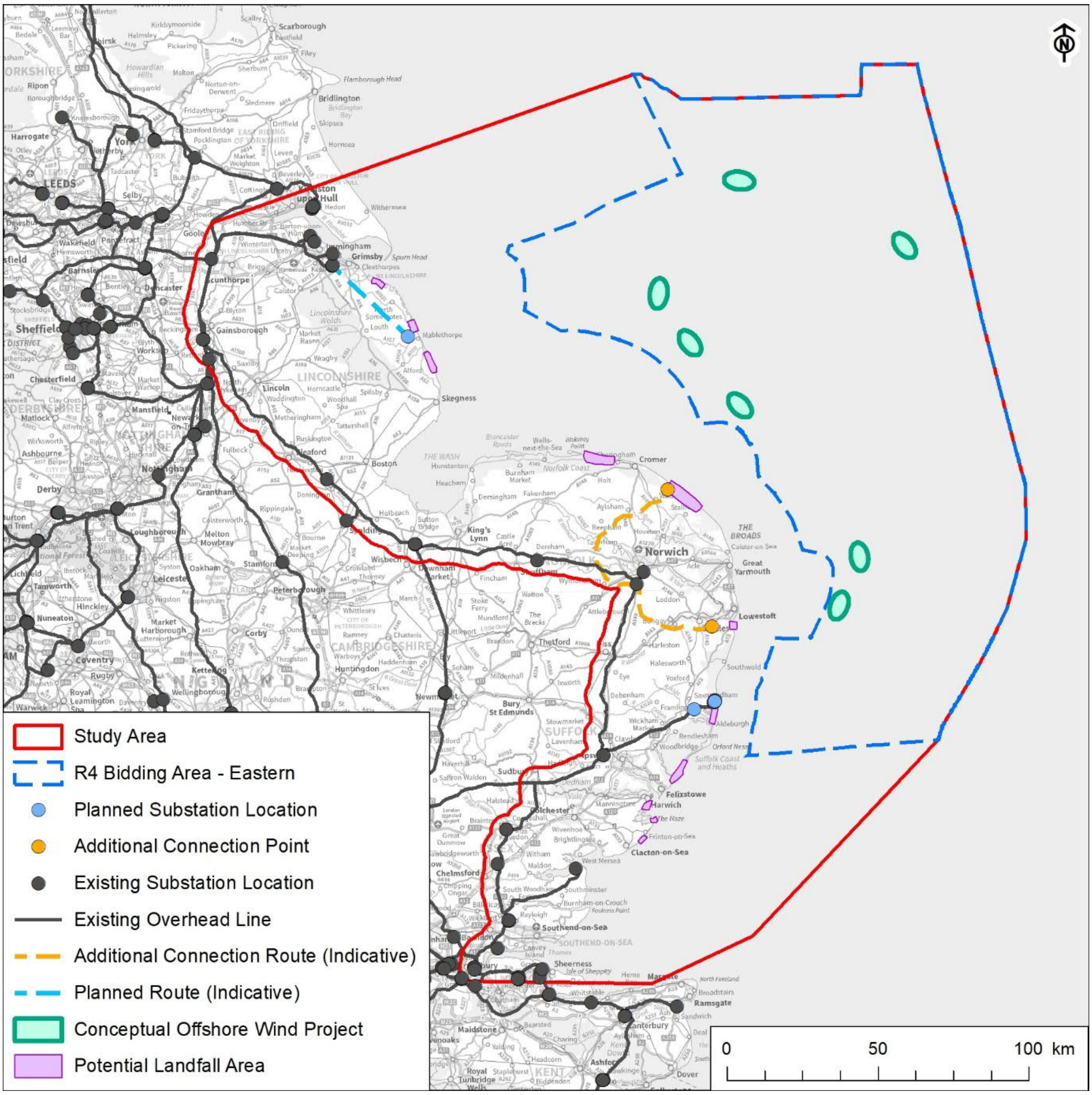


Figure 5-2 Potential landfall and grid connection locations

	Lincolnshire	Norfolk	Suffolk	Essex
Existing Connections Points	The existing substations present within this sub-region include: • Grimsby West, • South Humber Bank, • Humber Refinery, • Killingholme, • West Burton, • Cottam, • Bicker Fen, and • Spalding North. Within Lincolnshire the proximity of the transmission system to the coast varies. At the north of the Study Area in the Humber the network extends out to the industrial developments at Humber Estuary and includes substations at Grimsby West, South Humber Bank, Humber Refinery and Killingholme. Moving further south into Lincolnshire the network is located much further inland (50-65km) and includes substations at West Burton, Cottam, Bicker Fen and then Spalding North.	The existing substations present within this sub-region include: • Walpole, • Necton, and • Norwich Main. In Norfolk the OHL from Spalding North connects Walpole, Necton and Norwich substations, from west to east. Walpole is located approximately 11km south of the coast, however at this location (The Wash) there are no suitable landfalls. Necton and Norwich Main are approximately 35km from the Potential Landfalls on the north Norfolk coast.	The existing substations present within this sub-region include: • Sizewell, and • Bramford. The existing network in Suffolk includes the OHL which runs north-south approximately 35km from the coast between Norwich Main and Bramford; and the connection out to Sizewell substation immediately adjacent to the coast at the nuclear power station site.	The existing substations present within this sub-region include: • Braintree, • Bulls Lodge, • Bradwell, • Rayleigh, • Coryton South, and • Tilbury. In Essex the transmission network tees off the OHL from Bramford and south through the other substations (Bulls Lodge, Rayleigh, Coryton South and Tilbury), with an extension out east to the substation at Bradwell.
Future Connection Points	A new 400kV double circuit from South Humber to South Lincolnshire was given a 'proceed' signal in NOA 2019/20. This would extend the network much further south and closer to the coast within Lincolnshire. Such an extension would provide an	No network reinforcements outlined in NOA 2019/20 relevant to the Study have been identified within the Norfolk sub-region.	Within the Suffolk sub-region there are two future connection points included within the Study: • Friston Substation – substation is proposed to connect East Anglia ONE North and East Anglia TWO	No network reinforcements outlined in NOA 2019/20 relevant to the Study have been identified within the Essex sub-region.

	Lincolnshire	Norfolk	Suffolk	Essex
	alternative connection point for future offshore wind projects. NOA does not indicate the route of the reinforcement of where it would terminate but for the purposes of the study it has been assumed the network would extend south to a new substation in the vicinity of Mablethorpe.		Offshore Wind Farms as well as future interconnectors. • Sizewell C Substation – proposed as part of network reinforcement to connect the new nuclear power station.	
Potential Network Extensions	Taking into account the existing and future connection points no further network extension in the Lincolnshire sub-region was considered.	It is recognised that as several Conceptual Offshore Wind Projects have been identified off the Norfolk coast, as well as multiple existing and proposed connections to the transmission network at Necton and Norwich Main, there may be benefits from the development of a Norfolk coastal node. A coastal node has been identified at Bacton, on the north Norfolk coast. This assumes that a new OHL would be constructed from existing substations at Necton or Norwich Main to the coastal node.	In addition to existing and future connection points it was considered that there may be benefits from the development of a Suffolk coastal node. A coastal node has been identified at South Lowestoft, on the north Suffolk coast. This assumes that a new OHL would be constructed from the existing substation at Norwich Main to the coastal node.	Considering the scope of the scenarios, no network extensions have been identified in the Essex sub-region.

Table 5-2 Potential Grid Connection Points

5.5 Grid Connection Scenarios

For the purposes of evaluating radial and coordinated approaches to offshore wind grid connections within the Study Area four main 'Grid Connection Scenarios' have been identified:

- Scenario (A) Radial Connection Approach.
- Scenario (B) Offshore Coordinated Approach.
- Scenario (C) Onshore Coordinated Approach.
- Scenario (D) Blended Offshore/Onshore Coordinated Approach.

In addition, two anticipatory or exploratory scenarios have also been considered, which allow consideration of approaches to connection and OWF development at an intense sub-regional level (Scenario E) and then at Study Area level over an extended time period beyond 2030.

- Scenario (E) Sub-Regional Coordinated Approach.
- Scenario (F) Beyond 2030 Lookahead.

Scenarios A to F are summarised in **Table 5-3** below and the main scenarios (A to D) are illustrated in **Figure 6-1** later in this report. Full sized figures are provided within **Appendix D** for scenarios A to F.

Scenario	Description / Assumptions
A	**Radial Connection Approach (Business as Usual)** • 3.5GW of offshore wind deployed within the Study Area by 2030; if all projects in the development pipeline are constructed. • All offshore wind development will connect to the transmission system at existing/planned substations on a radial or point to point basis. • Grid connection points identified which take account offshore wind development in the scenario, landfall and overland route to connection.
B	**Offshore Coordinated Approach (Offshore Hubs or Nodes)** • 3.5GW deployed as for Scenario A - Radial Connection Approach above. • Offshore wind development will connect to offshore nodes or hubs from which they will connect to existing/planned substations on the transmission system. • Grid connection points have been identified taking into account location of offshore wind developments and offshore nodes or hubs.
C	**Onshore Coordinated Approach (Coastal/Inshore Hubs or Nodes)** • 3.5GW deployed as for Scenario A - Radial Connection Approach above. • All offshore wind development will connect to the transmission system at existing/planned/indicative coastal hubs or nodes on a radial or point to point basis. • Transmission system is extended out to the coast (unless otherwise already present) to establish grid connection points (e.g. coastal/inshore hubs or nodes).
D	**Blended Coordinated Approach (Offshore and Coastal/Inshore Hubs or Nodes)** • 3.5GW deployed (as for Scenario A - Radial Connection Approach above). • Offshore wind development will connect to a combination of regional offshore or coastal hubs or nodes. • Grid connection take account of location of offshore wind developments, regional offshore nodes or hubs and extension of the transmission system to the coast.

Scenario	Description / Assumptions
E	**Sub-Regional Coordinated Approach (Offshore and Coastal Hubs or Nodes)** • 3.5GW deployed (as for Scenario A - Radial Connection Approach), however, deployment is within a smaller representative area of the Study Area (in this scenario, Generation Zone Four). • 4.5GW of existing projects in the development pipeline go ahead as planned. • Additional offshore wind development is split across four individual projects which are more closely located. • Building upon Scenario D, offshore wind development will connect to a combination of regional offshore or coastal hubs or nodes. Similarly, grid connections will take account of location of offshore wind developments, regional offshore nodes or hubs and extension of the transmission system to the coast.
F	**Beyond 2030 Lookahead Coordinated Approach** • 7GW of offshore wind development (3.5GW of new development to 2030 as described in Scenario D, plus an assumed further 3.5GW of post 2030 development to 2035) is deployed within the Study Area. The 4.5GW development of existing 'in pipeline' goes ahead as planned. • Additional offshore wind is split across 13 individual projects dispersed throughout the Study Area. • Building upon Scenario D, offshore wind development will connect to a combination of regional offshore or coastal hubs or nodes. Similarly, grid connections will take account of location of offshore wind developments, regional offshore nodes or hubs and extension of the transmission system to the coast. • Where export cable networks and offshore hubs need to be extended to 'gather' this generation, this is done with consideration of Round 4 constraints.

Table 5-3 Grid Connection Scenarios

6. Grid Connection Scenario Analysis

6.1 Overview

Having established a range of conceptual offshore wind projects as well as potential connection points to the electricity grid, a series of scenarios for hypothetical development have been developed, as summarised above.

For the purposes of the study, each of these scenarios have been analysed considering the constraints and opportunities, risks and mitigation, advantages and disadvantages resulting from different approaches to connecting future offshore wind development.

Building upon the key themes considered as part of the review of baseline conditions, the focus of the analysis has been on the key environmental, socio-economic and physical/infrastructure constraints and differentiators which might result in delays to or prevent future offshore wind projects in the Study Area.

A variety of data from a range of different sources was been gathered and incorporated into a Geospatial Information System (GIS) for the project; this has served as the main repository for constraints data throughout the project and has formed the basis of the analysis activity.

6.2 Approach to Analysis

A detailed “project” level analysis has been undertaken and is provided within **Appendix C and D.**

Figure 6-1, below shows an overview of the main connection scenarios considered in this section of this report, with more detail provided in **Appendix D.**

Appraisal of the scenarios has been undertaken against the constraint topic areas: Biological Environment; Physical Environment; Landscape and Seascape; Historic Environment; Settlement and Population; and Land and Sea Use.

For each topic, a holistic approach is taken to the presentation of constraints whereby only the most significant potential risks to deployment are presented based on the hypothetical projects established within each scenario. For example, based on recent precedent surrounding the development of cable and offshore wind projects, best practice, design development and mitigation has been able to address the majority of cable works within a SPA. Conversely, landfalls or routes which have the potential to impact habitat features within a SAC or MCZ, for instance, have presented greater challenges to consent, although in many cases suitable approaches have been agreed.

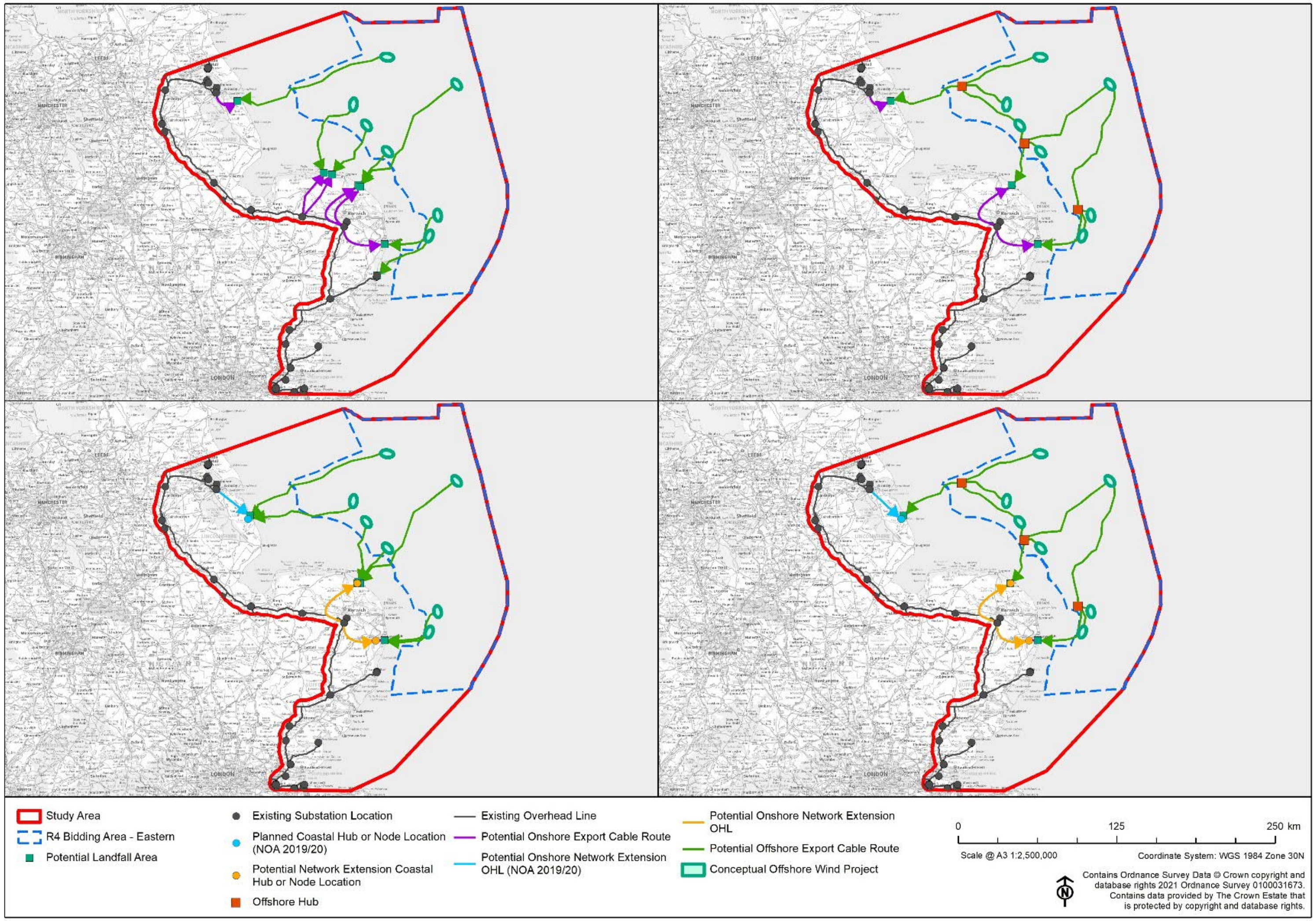


Figure 6-1 Overview of Grid Connection Scenarios

6.3 Scenario (A) Radial Connection Assessment

6.3.1 Summary of Scenario Analysis and Conclusions

Multiple individual project specific offshore cable routes each requiring separate landfalls. At two of the landfall locations considered, cables from multiple conceptual projects land, an outcome that is realistic in a location where suitable landfall sites are limited. This scarcity of landfalls magnifies the effect of potential constraints where available space is limited, presenting cumulative and in-combination challenges, particularly when planned infrastructure development is also considered.

From landfall to transmission network, the capacity for up to seven separate onshore cable corridors is limited, with each connection point to the network also supporting at least one existing or proposed export cable connection. It is assumed that for each of the 'new' connections a less preferred alignment will need to be taken by the cable corridor, in turn resulting in greater length and greater interaction with constraints, such as disturbance to sensitive areas. Sensitive areas include the communities around the connection point and common landfall locations.

A substantial volume of infrastructure would be required to develop individual OWF projects in a radial manner. When considering the entirety of the scenario, there is a large cumulative impact, which is then magnified when the future potential pipeline offshore wind is also considered.

There are opportunities presented by a radial approach, not least the flexibility it affords for development to fill requirements and opportunities outside of a prescriptive environment. However, in locations where significant offshore wind or other coastal infrastructure is already in place, then independent development will generally have an additive impact, with significant cumulative impacts making further development more challenging at any one time.

It is clear that radial development could deliver increased capacity in the short term in many locations, but is less sustainable in the long term, and may constrain the potential for further development to follow, disproportionately constraining the ability to add more offshore wind capacity over time. In the Study Area, Norfolk, and Suffolk in particular show the impact of a radial approach over time, with unconstrained landfalls and cable routes limited.

6.4 Scenario (B) Offshore Coordination Assessment

Scenario B is a coordinated approach to the deployment of offshore wind, deploying 'offshore hubs' to connect multiple conceptual offshore wind projects. This approach reduces the number of landfalls required (three in total, for seven conceptual offshore wind projects), and the overall length of onshore cable. Whilst some challenges do remain due to proximity of potential constraints, the extent of potential interfaces with protected areas, including the need for cable protection and mitigation through habitat-designated sites is reduced, particularly when considered over time and the potential cumulative impacts. This is also true for the potential impacts to coastal communities, where a shared landfall and onshore cable route reduces the extent of infrastructure required and the number of corridors needed.

The reduction in coastal and onshore infrastructure would largely limit the constraints associated with the radial approach, including cumulative impacts to coastal communities and communities adjacent to the connection points.

A key consideration of this Scenario is the sequencing and responsibility for the shared transmission assets. The collector hubs and transmission assets to the connection points are critical for all conceptual offshore wind farm projects; the design, consent and deployment of which are likely to be taken on by the first project developed with uncertainty over the programming, capacity and feasibility of future projects. There is a further potential constraint around the technology of the shared transmission asset and whether this is something that can accommodate or be reinforced to facilitate the greater rating capacity over time with further connections.

Offshore hubs will enable multiple projects to transmit to shore via one shared landfall.

Proximity of offshore wind projects is necessary for it to be feasible and efficient to share transmission infrastructure. Hence proximity is key to successful deployment of coordinated network infrastructure, particularly in the short term.

In the longer-term development of more strategic offshore and onshore connection across regions may facilitate connection of geographically dispersed projects. The ability to support more generation capacity through a reduced landfall and cable corridor footprint overall is advantageous, in that it pushes further away, temporally, the point at which generation capacity is constrained to an extent that no more can be added.

6.5 Scenario (C) Onshore Coordination Assessment

Scenario C considers the extension of the existing transmission network toward the coastline to form coastal nodes; these may be either located on land close to a landfall or within the nearshore area of the 12nm zone.

In this scenario, the same conceptual offshore wind projects have been selected as within the radial scenario however, their export cable routes are directed toward coastal nodes at Theddlethorpe, Bacton and South Lowestoft. Up to seven individual landfalls are required however they do have an extent of 'alignment' insomuch as export cables are focused to three landfalls close to the coastal nodes.

The key advantage to this scenario is the reduction in the overall onshore cable infrastructure required for deployment through increased levels of onshore coordination. This scenario limits the extent of infrastructure across widespread coastal communities; however, the effort is focused on three specific areas where cable corridors and disruption from installation activities will likely be more prevalent.

It is recognised that coastal hubs located within the inshore 12nm zone could potentially improve the performance of this scenario further, however owing to local constraints at each landfall, such as landscape and seascape an onshore coastal node was predicted as being more favourable.

The extension of the existing transmission network is a key consideration of this Scenario, particularly in regard to the sequencing and availability of these connection points for the siting and design development of offshore wind projects. The development of an OHL is difficult and are typically not seen favourably to populations adjacent to the route. Using the proposed extension from South Humber to South Lincolnshire as identified in NOA2019/20 as an example this approximately 35km route will be developed by 2031. The routes to the coastal nodes at Bacton and South Lowestoft are 55km and 35km respectively. For future OWF projects connecting to currently unidentified network extensions it is therefore likely that these would need to be progressed in parallel to the siting, routeing and consenting programme for the connection components.

The development of onshore coastal nodes may require the development of grid infrastructure to those nodes as part of strategic reinforcement.

Onshore coastal nodes will require multiple landfalls in a close geographic area, limiting availability of suitable sites. However, near shore coastal hubs are likely to face significant concern from local communities in response to increased landscape impacts.

Proximity of offshore wind projects is necessary for it to be feasible and efficient to share transmission infrastructure. Hence proximity is key to successful deployment of coordinated network infrastructure, particularly in the short term.

In the longer term development of more strategic offshore and onshore connection across regions may facilitate connection of geographically dispersed projects.

The ability to support more generation capacity through a reduced onshore footprint overall is advantageous, in that it pushes further away, temporally, the point at which generation capacity is constrained to an extent that no more can be added.

6.6 Scenario (D) Blended Offshore/Onshore Coordination Assessment

Scenario D adopts a coordinated approach from both an extension of the existing transmission network to coastal nodes, and also the installation of collector hubs and shared marine transmission infrastructure. This essentially combines coordination from Scenario B and Scenario C.

In this scenario, the same seven conceptual offshore wind projects have been selected as under the radial scenario. However, in Scenario D, there are a reduced number of offshore cable routes which is achieved through the establishment of 'offshore hubs' connecting multiple conceptual offshore wind projects. This approach also reduced the number of landfalls required (three in total under this scenario) located at Theddlethorpe, Bacton and South Lowestoft.

Onshore, the extent of cable infrastructure is significantly reduced, and therefore risks associated with long and less preferred cable corridors are avoided. The extension of the existing transmission network however requires new OHLs to be developed out towards the coastline in Norfolk and Suffolk which includes various landscape designations.

As with the constraints to coordination in Scenarios B and C, the primary risks associated with the coordination in Scenario D relates to the sequencing of the planning and consenting of the shared transmission assets in the marine environment; whilst designing to connect to a point on the transmission network that may not be approved/ have a defined location. There is therefore considerable uncertainty to the design parameters of each of the components that allow for future coordination with other projects, but that are not over-sized that unnecessarily increase the impacts to the environment and coastal communities.

A blended approach to the development of infrastructure onshore and offshore, such as this scenario, may reflect the majority of real life scenarios going forward, as approaches connection respond to local constraints.

Proximity of offshore wind projects is necessary for it to be feasible and efficient to share transmission infrastructure. Hence proximity is key to successful deployment of coordinated offshore network infrastructure, particularly in the short term.

In the longer term development of more strategic offshore and onshore connection across regions may facilitate connection of geographically dispersed projects.

The ability to support more generation capacity for fewer landfalls and a smaller footprint overall is advantageous, in that it pushes further away, temporally, the point at which generation capacity is constrained to an extent that no more can be added.

6.7 Scenario (E) Sub-Regional Coordination Assessment

Scenario E is a variation of Scenario D reviewing the benefits of a coordinated approach where conceptual offshore wind generation projects are located within relative spatial proximity. In this scenario, an offshore hub is used to connect up to four conceptual offshore wind projects of 0.5GW to 1.5GW in size off the north Norfolk coast.

From an offshore hub, there is a single offshore export cable route which 'gathers' the entire 3.5GW sub-regional generation and brings it to shore via a single landfall. This approach further reduces the extent of offshore transmission infrastructure due to generation proximity – this includes export cable lengths and collector hubs; as well as the number of landfalls required. This allows for a reduction in cumulative impacts to coastal communities and sensitive receptors, in comparison to the need for multiple cable routes.

Overall, the scenario demonstrates the importance of proximity in driving optimised coordinated solutions.

As Scenario D indicated, whilst onshore and offshore coordination can drive improvements and reduce the potential for interfaces with designated areas, there are some limitations, for example, that dispersed offshore wind can require substantial infrastructure to achieve connectivity.

When explored, this scenario shows:

- Project-to-project coordination may be more straightforward if there is proximity between projects;
- Project requirements are less likely to drive routeing away from the connection point to align with a collection hub in a different region;
- Sequencing of development is important to ensure infrastructure is in place in a timely manner and to provide certainty to developers and Transmission Operator that the network extension will support all planned future connections.

Spatial proximity of major projects is a major driver for increased coordination at a regional level, while conversely separation of development projects has the opposite effect.

Deployment of coordination infrastructure with thought to enabling increasing capacity over time or is capable of upgrading over time to allow the same, will be a key requirement to encourage this outcome.

6.8 Scenario (F) Beyond 2030 Lookahead Assessment

Scenario F is a variation of Scenario D, which increases the total hypothetical volume of deployment within the Study Area; this includes the original 3.5GW from Scenario D, an additional 1.5GW within the Round 4 Eastern Region and a further 2GW within the Study Area but outside of the Round 4 Eastern Region. In this scenario, a series of three offshore hubs are used to connect up to 13 conceptual offshore wind projects of between 0.5GW and 1GW in size.

In the nearshore environment there are only three export cable routes which ‘gather’ the entire 7GW generation across the Study Area.

Key challenges associated with this scenario, as with the other coordination scenarios, is the sequencing of the development of infrastructure to support connections, both terrestrially in regard to the network extension, and also the collector hubs and shared transmission assets. Further to these challenges is transmission of export capacity via three exports cables and whether technology can facilitate this, as well as the pressures on the transmission network at the coastal nodes and the realistic reinforcements needed to support this export. Under this scenario the resilience of the existing transmission network is a key consideration as well as the resilience of the marine network and the assurance to developers that generation can be exported in the event of a fault somewhere within the network. The potential interface with interconnectors in this scenario has likely benefits.

The development of shared infrastructure provides an opportunity for the addition of further capacity over time, either via new projects or the repowering and possible re-routeing of export for existing projects as their original technologies are swapped out.

To maximise the potential for this outcome the infrastructure must be strategically planned, to allow sufficient capacity to allow for additional transmission, or be designed to facilitate additional infrastructure or upgrading.

6.9 Grid Connection Scenarios - Comparison

The development scenarios considered in this study were reviewed and compared, supported by analysis of the Strengths, Weaknesses, Opportunities and Threats (SWOT) associated with each of the four main development scenarios (A to D) discussed in this report. Details of the SWOT undertaken are provided in **Appendix E**.

Table 6.1 below summarises the key parameters of the 4 main scenarios (A to D) considered in detail in Section 5.4 and within the SWOT (**Appendix E**).

Scenario Aspect	Scenario A Radial	Scenario B Offshore Coordination	Scenario C Onshore Coordination	Scenario D Blended Coordination
No. of offshore Wind Farms	7	7	7	7
No. of offshore hubs	0	3	0	3
No. of inshore cable routes	7	3	7	3
No. of landfalls	7	3	7	3
No. of coastal nodes	0	0	3	3
No. of onshore cables	7	3	1	1
No. of onshore transmission system extensions	0	0	3	3
No of substations	7	3	3	3
No. of Grid Connection Points	4	2	3	3
Onshore footprint (km^2)*	260	123	143	139
Inshore footprint (km^2)*	192	80	169	73
Offshore footprint (km^2)*	298	461	310	461
Total footprint (km^2)*	**750**	**664**	**622**	**673**

* In order to estimate approximate infrastructure footprints, assumptions have been made taking account of the approximate lengths of subsea or underground cable and overhead line routes as well as site footprints for 'hubs' or 'nodes' and onshore substations or converter stations. These are not based on actual designs but are intended to indicative of spatial footprints required.

Table 6-1 Comparison of key parameters for scenarios A to D

6.10 Spatial and Temporal Proximity

A potential barrier to coordinated grid connections is the spatial proximity of offshore wind farms, and when offshore wind development occurs. The hypothetical offshore wind farm scenario was designed with seven offshore wind farms located throughout the east coast region. However, coordinated grid connections require offshore wind farms to be located relatively close to one another to provide meaningful benefits.

6.10.1 Radial Scenario

Radial connection may continue to be suitable in scenarios where there is limited opportunity for coordination due to the spatial separation of projects in initial phases of development. For example, if there were only two larger offshore wind farms, for example one off the north coast of Lincolnshire and another off the east coast of Suffolk, opportunities for a coordinated grid connection may be more limited.

Over time it is anticipated that further development phases will follow in locations close to existing projects. Where multiple radial projects are located sufficiently closely to result in competition for development resources (connection point, landfall and cable route), after the first project achieves consent, competition for those resources make it more challenging for following projects to achieve consent. This constraint of development resources through sequential radial development has potential to reduce the amount of potential installed offshore wind capacity compared with coordinated approaches, adversely affecting achievement of targets of renewable generation over time.

6.10.2 Coordinated Scenarios

Where multiple projects are developed in relative proximity to each other, or such development is planned or anticipated, then coordination offers to potential for multiple projects to make use of the same development resources (connection point, landfall and cable route).

6.10.3 Temporal considerations

While not the focus of the study, when offshore wind development happens, the temporal proximity of offshore wind farms is an important consideration in the development of coordinated grid connections. The hypothetical offshore wind farm scenario assumed all seven offshore wind projects occur within the same period and at the same. In practice leasing rounds and project-specific factors influence when and how quickly offshore wind development happens and could make opportunities for coordinated grid connections less feasible or attractive to developers.

The risk of spatial and temporal proximity acting as a barrier could be mitigated by taking a longer-term view of a coordinated grid combined with a modularised approach to its build-out - that is connecting offshore wind farms to a coordinated grid connection solution as they come forward. This approach is consistent with the findings of NGESO's Offshore Wind Coordination Project, which describes a modularised approach which builds up aligning to offshore wind capacity.

6.11 Connection Scenario Footprint

All the coordinated approaches have a smaller total footprint than the radial scenario, with the onshore coordinated scenario C showing the greatest reduction.

The reduced footprint of the coordinated scenarios is achieved onshore and in the inshore marine area out to 12 nm. Across those two combined areas, coordinated scenarios B and D show the strongest reduction in footprint compared to A, each more than halving (55% and 53% reductions respectively) the infrastructure footprint in those areas, with C showing a reduction of approximately 30%.

In the offshore (beyond 12 nm) environment there was an increase in footprint for all the co-ordinated strategies, reflecting longer cable routes offshore to connect to hubs or shared nodes.

While offshore coordination provides reductions in the amount of infrastructure required in inshore waters as well as onshore, there is an increase in the amount of infrastructure offshore. This includes establishing offshore 'hubs' or 'nodes' as well as additional subsea cable routes from offshore wind farms to these 'hubs' or 'nodes'.

Offshore coordination therefore provides reductions in the amount of infrastructure required in inshore waters as well as onshore, however, there is an increase in the amount of infrastructure offshore. This includes establishing offshore 'hubs' or 'nodes' as well as additional subsea cable routes from offshore wind farms to these 'hubs' or 'nodes'. The footprint of each of the scenarios relates broadly to the level of constraint encountered and there is therefore a clear benefit in reduced footprint from coordination onshore and inshore.

6.12 Scale of Infrastructure

Scenario A requires the greatest amount of supporting infrastructure to achieve, reflecting the need for 7 full sets of transmission and connection infrastructure. The amount of infrastructure and scale of footprint leads to a larger potential for constraint. This is expected to manifest constraints on landfall and onshore cable routes.

Scenarios B and D have the lowest infrastructure requirements inshore of 12nm and onshore, largely because of offshore coordination elements reducing landfall requirements significantly. This reduction is achieved using offshore hubs in the offshore (beyond 12nm) area to consolidate infrastructure from that point to connection.

Scenarios C and D assume an extension of grid to the coast and the establishment of coastal nodes for the connection of multiple projects. However, while scenario D benefits from offshore coordination through use of hubs to reduce the landfall requirements to 3. Scenario C does not benefit from offshore coordination and requires 7 separate landfalls. With landfall availability potentially highly constraining, this gives the fully co-ordinated approach of D a potentially significant advantage over C.

While there is a clear benefit from coordination in terms of the number of infrastructure components required (in other words there is less infrastructure under coordinated scenarios), the individual components which make up a coordinated grid connection will typically be larger than those which make up a radial connection. For example, an export cable route connected to a 'hub' may be comprised of more individual cables requiring a larger installation corridor than would be required for standard radial export cable routes which may lead to greater spatial conflicts with other sea users such aggregate extraction areas or oil and gas infrastructure. Similarly, onshore substation or converter stations may be larger for coordinated connections compared to those for radial connections meaning greater land-take and potential for spatial conflicts or impacts. This localised impact is potentially significant to coastal communities, as discussed further later in this section, and highlights the need to ensure that as and when coordinated grid connections are developed, stakeholders understand the difference in the scale of what could be proposed.

6.13 Technology

The technology associated with radial development of offshore wind projects is known, both in terms of HVAC and HVDC solutions. As a result, the risks associated with use of that technology can be more easily understood and managed. For coordinated approaches there is greater technological uncertainty and risk, especially where infrastructure components are untested or being used in new ways.

6.14 Community

Impacts on coastal communities are expected to mirror the scale of infrastructure development on land, with greatest impacts anticipated in the radial scenario, which is potentially more impactful than all coordinated approaches through the scale of its footprint. The radial approach is also predicted to be most constrained in the long term, in areas where there is a history of earlier infrastructure development which has already utilised areas for development and routeing.

The smaller scale of overall footprint and infrastructure associated with coordinated approaches and the resulting benefits to coastal communities and user groups are achieved using coastal nodes and offshore hubs. It has been assumed in all scenarios assessed that offshore hubs are located more that 12nm offshore, reducing the potential for landscape and visual impacts.

As noted in Section 6.12, the infrastructure associated with coordinated solutions is potentially more substantial than that for any single individual radially connected project. While overall coordinated footprints will be smaller regionally, the impact at specific locations may be substantial, affecting local communities at those locations. This is expected particularly for scenarios using coastal nodes and including extension of grid to the coast. Larger localised impacts will need to be balanced in planning, with wider benefits regionally because of greater efficiency in connection of generating capacity, and minimisation of total footprint and associated impacts regionally. The management of the concerns of affected communities will be highly important.

6.15 Existing Legislative and Policy Regimes

Currently offshore wind farms and radial grid connections are generally consented under the Planning Act (PA) 2008 and the laying of other subsea cables such as interconnectors is consented under the Marine and Coastal Access Act (MCAA) 2009 (where applicable). The type of infrastructure that may be required as part of coordinated grid connections or an integrated offshore network will require a clear route to consent, and the applicability of existing consenting regimes to this infrastructure creates some uncertainty when compared to the clearly defined approach for radial connections. The same would apply for the main policy framework which may be used to support a more coordinated approach to grid connection, as National Policy Statements and Marine Plans have different weightings for decisions made under either the PA or MCAA.

In terms of economic regulation, different regulatory regimes apply to onshore transmission, offshore transmission and interconnectors. Whilst not a consideration of this study explicitly, it seems clear that these regimes, and the underlying definitions of the different types of infrastructure within the Electricity Act 1989 (as amended), would need to be reviewed in order to ensure they facilitate and support coordinated grid connection solutions.

7. Conclusions & Recommendations

7.1 Conclusions

7.1.1 Study Area Characterisation and Spatial Assessment

The degree of potential constraint on offshore wind connection infrastructure varies regionally across the Study Area, with some locations more constrained than others. The strategic review and assessment of the distribution and nature of constraints at a regional and sub-regional level identified both opportunities and constraints for grid connection.

The Study Area is substantial, extending from the Humber Estuary in the north to Thames Estuary in the south and the type, nature, scale, and distribution of constraints varies quite significantly across that geographical area. This study considered constraint on grid connection infrastructure in the inshore marine environment and the coastal terrestrial environment as discussed below.

<u>The inshore area</u>

Across the east coast region, large parts of the inshore area (within 12nm) are subject to environmental designations including sites designated for their seabed habitats and features, marine mammals, and birds. While these designated areas do not necessarily prevent subsea cable routes through the inshore area, they are sensitive to, and could be impacted by, future offshore wind grid connections. This risk is exacerbated in areas which are already crossed by several cable routes and the potential for future grid connections routes.

<u>The coastal area</u>

Like the inshore area, large parts of the coastline and adjacent onshore coastal areas are constrained by a combination of ecological and landscape designations and coastal settlements. One of the key challenges identified in these areas was the identification of potential landfalls for future grid connections whether under a radial or coordinated model. Spatial constraints (such as settlements) combined with existing and planned offshore wind grid connections could limit the availability of suitable landfalls for future grid connections and those opportunities that exist may be expected to be oversubscribed.

<u>Subregional differences</u>

The level of constraint varies across the subregions within the study area, as discussed in Section 4 of this study, with Essex the most constrained of all the subregions, with significant constraint offshore and onshore. Norfolk and Suffolk are less constrained than Essex, with some opportunities for grid connection infrastructure both offshore and onshore, with landfall the most constraining component.

Lincolnshire to the north is considered least constrained in the short to medium term with fewer spatial constraints and potential for landfall and grid connection, particularly in the north. Some constraints exist, but there is more opportunity for avoidance of those constraints which do exist through design and planning.

7.1.2 Grid Connection Scenario Analysis

<u>Grid Connection Points</u>

The proximity of the transmission system to coastal areas is one of the key factors influencing the design of offshore wind grid connection. While some grid connection points are in coastal areas, most of the existing transmission network is further inland requiring longer onshore cable routes. While existing coastal locations are preferable, opportunities at locations such as Sizewell, may already be constrained or become limited over time because of existing or planned future projects. Extending the transmission system to coastal areas would reducing the number of longer onshore cable routes required to achieve connection for new offshore wind farms.

Infrastructure component risks

Levels of constraint across the grid connection scenarios vary between the different transmission infrastructure components, with the key onshore elements, landfalls, onshore cable routes and grid connection points, assessed as the most potentially constrained components within the Study Area. This potential for constraint suggests that these components would particularly benefit from coordinated solutions which would minimise their potential to encounter constraints through reduction of overall footprint.

Radial connection risks

Radial connection risk across the Study Area relates to 'pinch points' such as landfalls where spatial constraints will limit the availability of space for infrastructure. While in the long term, a coordinated approach to grid connections is more sustainable than a radial approach, through use of less space for a given capacity of installed MW, it is clear that radial connection of offshore wind has worked well to date, with a significant pipeline of projects already in planning, and that this approach to future connections should not be entirely discounted.

Subregional characterisation has highlighted that some parts of the Study Area are more spatially constrained than others, with a limited capacity for further connection infrastructure. Radial connections in such locations, while possible in the short time, would limit the potential capacity (MW) connected in the long term. This is particularly the case in those parts of the east coast which have experienced greater levels of offshore wind development to date.

Continuing with radial connection beyond currently planned projects will impede the ability of the UK to maximise installed capacity (MW) of offshore wind and meet carbon reduction targets over coming decades, while also impacting the environment, coastal communities and user groups. There is opportunity to change the UK's approach to connection of offshore wind and maximise connection of installed capacity, while minimising impacts on the environment, coastal communities and socio-economic receptors.

Advantages of coordination

When more than one offshore wind project is planned in the same subregional location, coordinated approaches to offshore wind deployment encounter similar levels of constraint to a single radial connection, but allow for a greater potential installed capacity (MW) over time.

The potential benefits of coordination are most clearly identified in the coastal area (onshore) and in the inshore (<12 nm) marine areas. By contrast there is potential for increased infrastructure offshore (beyond 12 nm) under coordinated solutions (when compared to radial solutions) as multiple projects are connected and 'brought together' in that offshore area.

The benefits of coordinated approaches can be demonstrated using a simple footprint based upon an assumed corridor width encompassing cables and associated infrastructure, with a comparison then made between the footprint of each grid connection scenario. Using this simple method a reduction of between 30 and 55% in the footprint of connection infrastructure onshore and within inshore waters through the adoption of coordinated approaches (see Table 6-1) can be demonstrated. Such a reduction in the overall amount of infrastructure required to connect larger amounts of offshore wind to the transmission system should result in less spatial conflicts and reduce impacts and pressures upon sensitive receptors such as coastal settlements and their communities.

Coordinated grid connection requires new infrastructure such as offshore 'hubs' and coastal 'nodes' as well as additional subsea cable routes from offshore wind farms to those hubs and nodes. As well as the new or additional infrastructure involved, the individual components, which make up coordinated grid connection infrastructure will typically be larger than those required for radial connection. As an example, a coordinate cable route may be comprised of several cables and so have a larger footprint than a radial connection for a single project. The potential for significant localised impacts of major infrastructure must be acknowledged and placed in the context of overall regional reductions in infrastructure footprint, compared to radial alternatives. Key will be ensuring that when coordinated grid connections are developed, stakeholders understand the differences in scale and potential for local and regional impacts.

7.1.3 Risk of separation of projects by geography and time

When multiple offshore wind projects are developed in similar timeframes but sufficiently spatially separate the benefits of coordination are less apparent, and the simplicity of single radial projects may appear to offer advantages in cost and planning, at least in the short term. However, with extensive offshore wind development expected, many initially isolated projects will be joined by newer projects coming forward in the longer term. If radial approaches are followed initially, then those projects following later will face greater constraint than the preceding projects. To avoid this scenario it may be necessary to take longer term strategic coordination approaches (planning, regulatory and leasing systems), utilise modularised technology which enables the gradual build-up of coordinated infrastructure as well as consider the benefits of anticipatory investment in shared infrastructure to facilitate coordination.

7.2 Recommendations

7.2.1 Strategic Planning

There are several spatial and network planning processes which could be utilised to provide a spatial framework to encourage and drive coordination, including marine planning, local plans, and wider network and infrastructure planning. These existing processes should be utilised to facilitate the adoption of coordinated grid connection approaches.

It may be particularly beneficial to consider development of longer-term regional spatial plans for offshore wind and associated grid connection and transmission infrastructure. These would provide a clear planning framework within a wide range of stakeholders including government, offshore wind developers and local communities can develop medium to long term plans for management and investment.

Regional Marine Plans are one example an existing spatial planning mechanism that offers a potential mechanism for the achievement of several policy and management objectives. For example, the current East Marine Plan contains policies supportive of offshore wind development (for example affording a level of protection to current offshore wind installations and leases, and support for applications brought forward from Round 3 zones (WIND2)). It is therefore possible to see how Marine Planning even now offers a mechanism for facilitating and implementing shared transmission infrastructure, as part of a coordinated grid system.

Strategic anticipatory investment at a government or industry wide level may be necessary to support sector transition to a coordinated approach to transmission infrastructure by reducing investment risk for technology development and shared connection infrastructure.

7.2.2 Legislation and policy

Existing planning and marine licensing regimes for the planning, development and consenting of coordinated grid connections and transmission infrastructure should be evaluated to establish a clearly defined route to consenting. Consideration should also be given to reviewing and updating relevant planning and policy, including Marine Plans and National Policy Statements, such that they provide a supportive policy framework for a more coordinated approach where needed.

Shared transmission infrastructure is by its scale significant infrastructure with potential for significant environmental impacts. As part of any review of legislation consideration should be given to incorporating offshore grid connection/network infrastructure into the relevant EIA regulations.

7.2.3 Future Leasing Activity

The approach to leasing of offshore wind and grid connection infrastructure should be reviewed to identify ways to facilitate the development of coordinated grid connections and transmission infrastructure which supports multiple projects. This could include consideration of the role played by hybrid interconnectors, which include infrastructure to allow the connection of offshore farms into the interconnector.

Consideration should be given to the design of future leasing rounds, for example grid connection infrastructure could form part of a separate process in parallel with or following on from offshore wind farm leasing rounds. The objective should be to support long term planning of coordinated grid connection infrastructure beyond leasing rounds.

Alternatively, coordinated grid connection could be strategically planned and managed through development of a nationally planned expansion and reinforcement of grid infrastructure.

7.2.4 Project Planning

At a project level, there is a need to consider what party or parties will be responsible for the development, operation, and maintenance of coordinated grid connection infrastructure.

While the current Offshore Transmission Owner (OFTO) regime works well for radial connections, a new approach is likely to be required for coordinated solutions to balance short to long-term objectives. The investment required for development of coordinated grid connection and transmission infrastructure is likely to be substantial and consideration needs to be given as to the costs and benefits of private and public funding of development, as well as competition for rights to develop, own and operate such assets.

7.2.5 Roles and Responsibilities

Strategic coordination and investment

Strategic coordination and high-level planning for both offshore wind development and transmission infrastructure will be necessary to achieve coordinated connection. This will require alignment and cooperation of several organisations currently active in the planning and management of offshore wind and connection infrastructure.

Given the number of actors in the development of offshore wind development and grid connection, it would be appropriate to gain a common understanding of the roles and responsibilities to map opportunities for collaborative working and are empowering of coordinated approaches to connection.

Investment required for development of shared transmission infrastructure is substantial and consideration needs to be given to investment approaches to encourage coordination, including anticipatory investment.

The Crown Estate

The Crown Estate's role in the leasing of transmission assets should be reviewed, as part of a wider review of planning and management mechanisms suitable to the development and management of shared transmission assets. Alternative regimes for planning, ownership and management of shared transmission assets should be considered.

National Grid

This study shows that extension and reinforcement of the existing transmission system to the coast to support coordinated grid connection will reduce the regional footprint and associated impacts of new offshore wind development, when compared to radial approaches. However, the infrastructure required for coordinated grid connection is large and its local footprint will be substantial, even if the overall regional footprint is relatively low. Early, extensive and meaningful engagement with local residents and user groups should therefore form part of any programme of such works by National Grid.

Coordinated solutions requiring extension or reinforcement of transmission assets to the coast, if undertaken as anticipatory investment would facilitate coordinated connection, especially when combined with planning, policy or legislative drivers with the same objective. The potential for National Grid to undertake anticipatory investment to facilitate shared connection should be explored as an alternative to a transmission asset leasing round.

Marine Management Organisation

The potential for the MMO to direct or influence coordination of shared transmission infrastructure through the Regional Marine Plan system should be reviewed.

7.3 Further Works and Studies

7.3.1 Application of methods followed in this study to other UK regions

The approach to coordination may vary regionally depending upon the nature and distribution of constraints present. Reviews of constraints and connection opportunities for shared transmission infrastructure should therefore be undertaken in other regions of the UK, to identify regional sensitivities and appropriate approaches to coordination.

Undertaken pre-emptively, the identification of regional constraints and opportunities would inform leasing rounds for the next generation of offshore wind sites, or the location of technology demonstration sites. Alternatively, a focus on leasing areas already identified by The Crown Estate, for example Round 4, or technology demonstration areas (for example, floating offshore wind demonstration areas), would identify opportunities for cooperation between new offshore wind farm lease holders.

The potential implications of an increased infrastructure footprint offshore (beyond 12nm) for all coordinated connection strategies reviewed should be carefully considered as part of future regional reviews of constraints and connection options. This includes identification of appropriate high level mitigation strategies where significant potential impacts on offshore features are indicated.

Potential approaches to mitigation and compensatory measures for communities and users affected by shared infrastructure should be explored. This would acknowledge potential high levels of impact on communities and user groups at a very local level due to the scale of shared infrastructure, within the wider context of a lower regional impact.

7.3.2 Opportunity for Pilot Projects

After completion of leasing rounds by the Crown Estate, or as part of a wider strategic planning it may be possible to incentivise successful agreement for lease holders to allow their projects to become ‘anchor’ projects. Such projects would be given the opportunity to pilot a coordinated grid connection model, with project design that allows for a modularised approach to building an integrated offshore network, which allows for future addition of new infrastructure, capacity and / or projects.

7.3.3 Planning and regulatory review

A review of current legislative and planning constraints on the ownership, operation and use of shared transmission assets would allow a route map to achieving coordinated grid connection to be developed and obstacles to such coordination removed.

Appendix A – Technology Assumptions

Technology assumptions for this study are based on currently deployed technologies, or those technologies expected to be available by 2030. This has been informed by the ESO Offshore Coordination Project and its supporting technical reports.

It is assumed that transmission technologies can be scaled up to accommodate the export ratings required to accommodate the projected offshore generation scenarios. Unknown aspects of future technology and the associated constraints are acknowledged as a risk, although detailed assessment of technical risks is beyond the scope of this project.

Beyond the scope of this study, but as highlighted in the ESO Offshore Coordination Project, it is noted that opportunities exist to form an integrated offshore network, potentially including offshore wind connecting directly into interconnectors (between the UK and another energy market) or HVDC subsea reinforcements.

Key components and key terminology related to transmission technology are outlined below.

Component	Outline	Radial or Coordinated
Alternating Current (AC) transmission cables	• AC is an electrical current which periodically reverses its flow and constantly changes magnitude. AC carries the same volume of power in one direction as the other (compared to DC which flows in only one direction). • Electricity is transmitted via subsea AC export cables, as opposed to DC export cables. To date offshore, offshore wind farms have deployed AC transmission technology only, however HVDC connections are under development for three projects in the UK Dogger Bank region of the North Sea[10]. • For AC transmission the export cables are installed in multiples of three and therefore generally require a larger corridor for installation than DC cables. A larger corridor may restrict options and add risk to consenting if looking to route in an area with a number of existing and proposed export cables. • AC transmission is the same technology as the National Electricity Transmission System (NETS) and therefore less additional infrastructure is required to facilitate a connection to the existing network. • Whilst subsea AC transmission cables have minimal losses over short distances, for long-distance transmission (for example, beyond 50km), losses can be far higher; a particular limitation of AC	Radial & Coordinated

[10] Creyke Beck A, Creyke Beck B and Teesside A will use HVDC technology to connect into the UK Grid. This will include HVDC cables, converter systems and HVDC offshore converter platforms.

Component	Outline	Radial or Coordinated
	transmission cables is the volume of reactive power required to energise the circuit. However, this reduction in efficiency through increased losses is less notable for onshore overhead lines when compared to subsea or underground cables.	
Direct Current (DC) transmission cables	• DC is a unidirectional flow of electrical charge whereby current flows in a single constant direction (compared to AC which periodically reverses its flow). • Electricity is transmitted via subsea DC export cables. DC transmission is via multiples of two cables, generally with a smaller installation corridor than AC transmission. • DC technology is generally preferred for longer distance connections due to efficiencies in transmission and is readily deployed for interconnectors and subsea network reinforcements (bootstraps). • As DC transmission varies from the existing NETS technology, additional infrastructure is required to facilitate a connection to the existing network – namely the requirement of a converter station (see below).	Radial & Coordinated
Collector Hub	• A collector hub combines export cables, or circuits, from various offshore wind farms to a single circuit. From the collector hub electricity generated from the multiple project sites can be transmitted to the NETS via shared transmission infrastructure. • A collector hub is generally an offshore platform, similar to those utilised for inter-array cables, and can be for either AC or DC technology. • Collector hubs are key components to the development of a coordinated offshore network (or meshed network as referred to in the Offshore Coordination Project). • An offshore (OFTO) substation also forms part of the offshore collector hub.	Coordinated
Converter Station	• A converter station consists of electrical equipment that converts DC to AC technology – or vice versa. They are required for any DC export transmission assets and are commonly deployed for interconnector projects.	Radial & Coordinated

Component	Outline	Radial or Coordinated
	• Converter stations can be housed within buildings, or may be exposed; they are typically enclosed when located in higher salinity coastal and marine locations to protect against the risks of corrosion. • Converter stations can be terrestrial or marine (on a platform). However, it is typically the case that the greater the distance from the NETS, a greater length AC cable corridor is required (typically wider than DC).	
Connection Point	• The substation where a transmission asset connects to the NETS. • The substation may be existing or proposed. To reduce the extent of additional onshore infrastructure, from either a coordinated or radial approach (assuming multiple connections under approach) the NETS could be developed towards the coast to form a coastal node. • To facilitate an extension of the NETS to the coast a new overhead line would be required which likely has a higher consenting risk profile than underground cables due to the nature of the permanent above ground infrastructure.	Radial & Coordinated

Appendix B – Study Area Characterisation

See separate PDF document with figures detailing distribution of key features and constraints.

Appendix C - Spatial Assessment

C1. Introduction

This appendix has been provided alongside the East Coast Grid Study Final Report ('the full report') to supply additional information in support of the project.

A signposting summary between each area of the appendix and the full report is provided below.

Item in Appendix C	Linkage to the full report
Section C2: Study Area Description A detailed review of baseline constraints has been provided for each of the regions within the wider study area (i.e. Lincolnshire, Norfolk, Suffolk and Essex).	**Section 3: The Study Area** A summary of the study area for the project is provided in the full report.
Section C3: Scenario Development Additional details regarding the development of the conceptual offshore wind development scenarios and the identification of potential landfalls.	**Section 5: Offshore Wind and Grid Scenarios** A description of the context of the wider ongoing offshore wind development baseline within which the Scenarios are considered. Summary of the potential interactions of landfalls and grid connection points with key constraints.
Section A4: Assessment of Scenarios Additional details surrounding the process for assessing scenarios is provided; specifically, this focuses on the process for establishing and assesing the Conceptual Offshore Wind Farms and Potential Landfall locations. The analysis included in this appendix is the "project" level analysis which sits 'behind' the report.	**Section 5: Offshore Wind and Grid Scenarios** A broad summary of the assessment process for the offshore wind scenarios is provided in the full report; this focuses on the approach to analysis and the assessment itself. The analysis presented within the full report is at a strategic level.

This appendix should be read alongside the main report and **Appendix B (Report Figures)**.

C2. Study Area Description

The following sections outline the existing baseline constraints as per the above constraint 'themes' within each of the sub-regions. This section should be read in conjunction with **Figures B3** – **B11** within **Appendix B**.

Sub-Regional Constraints: Lincolnshire

Offshore

Biological Environment

At the north of the sub-region is the Humber Estuary SAC, SPA, Ramsar, and SSSI which extends down the Lincolnshire coastline to Saltfleet, which also overlaps with the Saltfleetby-Theddlethorpe Dunes SAC. This area includes various cited features within the designations, from sand dunes, mudflats and saltmarshes to supporting extensive populations of breeding and wintering birds and non-cited populations of marine mammals (seal).

In the marine environment to the north of the study area is the Holderness Inshore MCZ, the southern half of which overlaps with the study area. The MCZ supports a mosaic of seabed types including rock, sand and mud, in turn supporting a diverse benthic ecology, as well as fish and crustacean species. The portion overlapping the study area is at the southern half of the designated area and supports intertidal and mud, as well as subtidal mixed sediments and coarse sediments. Also, at the northern end of the study area, but further offshore is the Holderness Offshore MCZ, which includes areas both inshore and offshore of 12 nm. The site is designated for its seabed habitats and the range of infauna and epifauna they support, as well as having importance for some spawning fish species.

Throughout the Lincolnshire coastline, and much of the area to the 12nm boundary, is the Greater Wash SPA. This area is designated for several Annex I marine bird populations through both the non-breeding and breeding seasons. The area of the SPA also includes a range of marine habitats, including intertidal mudflats and sandflats, subtidal sandbanks and biogenic reef, including Sabellaria reefs and mussel beds.

At the south of the sub-region, there are multiple statutory nature conservation designations including the Inner Dowsing, Race Bank, and North Ridge SAC which extends from the coast at Skegness beyond the 12nm limit, as well as the Gibraltar Point and the Greater Wash and North Norfolk Coast SACs which cover the Lincolnshire coastline to the south. The site encompasses a range of sandbank types and biogenic reefs.

The presence of internationally and nationally designated habitat areas along the Lincolnshire coastline in the north and south of the sub-region has the potential to restrict siting and routeing of marine infrastructure.

Physical Environment

The nature of the physical environment varies within the region although it is predominantly characterised by lengthy sandy beaches, shifting sands and intertidal muds backed largely by sloping dunes.

The Shoreline Management Plan policy adopted for the majority of the region is Hold The Line with some section of No Active Intervention to the north of the Humber Estuary.

In terms of underlying geology, alluvium and chalk tend to dominate the sub-region. The inshore 12nm zone is predominantly sand and gravel with some muds; to the north of the sub-region, there are also notable volumes of river silt arising from the Humber Estuary. Conditions are largely favourable for potential landfall, with the notable exceptions of cliff structures within some of the region.

In multiple locations around the region, there are coastal reinforcements to protect the coastline against erosion and coastal communities from tidal flooding, predominantly at the higher density population areas to the south (Skegness). This includes long sections of seawall, rock armouring, beach groynes but also major flood defence schemes, such as the notable tidal barrage under construction at Boston.

Historic Environment

There are no Protected Wreck sites or other designated heritage assets in the marine environment within the Lincolnshire region.

Other Sea Use

At the north of the sub-region significant activities and uses are associated with the Humber Estuary including fisheries, port operations (including freight and passenger transport) and operation and maintenance for offshore wind projects.

At Immingham / Grimsby, there is a Major Offshore Wind Farm (OWF) Operations and Maintenance base; the port also serves as a key east coast fishing port supporting both local vessels and large >10m international fishing effort. Fishing effort is varied but includes focused effort on cod, haddock, plaice, mackerel, whiting and sandeel although there is also widespread potting and trapping for crustaceans in the sub-region.

Vessel densities vary across the sub-region but reach peak levels (up to ~50,000 movements per year) within the approaches to the Humber Estuary and inside the Estuary itself; there are multiple traffic separation schemes, and owing to the specific risks of the Humber Estuary, there are numerous hazard markers denoting shifting sand bars and risks to grounding.

To seaward, there are several restricted areas for defence use including the Donna Nook practice area to the north of the sub-region.

Centrally within the sub-region, there are several large licenced aggregate extraction in the region including Humber 1-4, Off Salfleet, Humber Overfalls, Humber Estuary and Inner Dowsing, located off the coast from around Mablethorpe.

There are also multiple oil and gas assets within the sub-region; this includes gas, methanol and chemical lines landfalling at Theddlethorpe as well as gas and methanol lines landfalling at Easington.

At the south of the region the Triton Knoll, Inner Dowsing and Lincs OWFs represent major investment and development of renewable energy in the area, as well as the Viking Link interconnector which makes landfall south of Mablethorpe.

Onshore

Biological Environment

At the north of the Study Area the Humber Estuary is heavily designated (as a SPA, SAC, Ramsar and Site of Special Scientific Interest (SSSI)), which extends along the north Lincolnshire coast to Theddlethorpe and is designated for mudflat and saltmarsh, among others, and their support of various flora and fauna. Between Saltfleetby and Theddlethorpe the sand dunes are also designated as a SAC and SSSI. This stretch of north Lincolnshire coast also includes the National Nature Reserves (NNR) of Donna Nook and Saltfleetby-Theddlethorpe Sand Dunes.

Through the south Lincolnshire coast, around the Wash, is another section of various designations including the Gibraltar Point (SAC, SPA, Ramsar, SSSI and NNR), and The Wash (SAC, SPA, Ramsar, SSSI and NNR) which borders Norfolk.

Away from the coastline there are no other internationally designated areas. To the south of Louth, and to the east and southeast of Lincoln there are frequent pockets of ancient woodland. Those to the east and southeast of Lincoln are also associated with the Bardney Limewoods SSSI and NNR areas, and the Kirkby Moor and Fulsby Wood SSSI. However, these areas are more discrete in scale than the sites at the coast.

Physical Environment

From the coast the landform through Lincolnshire is very flat and includes little incline through much of the region. The land does rise slightly through the Lincolnshire Wolds, however the area is still characterised by flat, open areas. These areas are predominantly good/ moderate agricultural land (Grade 3 Agricultural Land Classification (ALC), in terms of versatility and yield for productivity), comprising alluvium and till deposits.

Due to the area being flat and low-lying, especially around the coast there is a broad area of higher susceptibility to flooding (Flood Zone 3, 1 in 200 annual probability from flooding from the sea). This coastal flood extent extends approximately 7 km inshore from the coast through the eastern region, and over 14 km around Boston at the south. This southern area of the region between Skegness and Boston is characterised by a large number of drains.

Historic Environment

There are numerous Scheduled Monuments within the Lincolnshire Wolds AONB, but are more disparate through the remainder of the region. The others are more spatially disparate, and only a few towards the coastal area (largely inland of Mablethorpe and to the south). There are also several Registered Parks and Gardens, the largest of these is Brocklesby Park (Grade I) located between Immingham and the north of the Lincolnshire Wolds. Others include Well Hall, Revesby Abbey and Scrivelsby Court which are located within or around the Lincolnshire Wolds and are much smaller in scale.

There are multiple Designated Military Remains, reflective of major defensive development during World War II within this region (in part driven by historical war production and manufacturing in Humberside). These are largely coastal, with the greatest concentration of these at Saltfleet.

Landscape and Seascape

Through the centre of Lincolnshire, between the coast and the existing transmission network is the Lincolnshire Wolds Area of Outstanding Natural Beauty. The designated area is approximately 14 km from the coast and extends between Cleethorpes and Welton Marsh. There are no other designated areas, save three country parks at Cleethorpes, Snipe Dales and Hartsholme.

The region (within the Study Area) is largely rural, agricultural land. The landform is generally more rolling through the Lincolnshire Wolds and open and flat to the south of the region. Main settlements are located on the outer fringes along the existing transmission network, from Grimsby and Immingham on the industrialised banks of the Humber Estuary, to Scunthorpe to the west and then south through Gainsborough, Lincoln on to Boston and Spalding. Around the Wolds are smaller settlements such as Louth, Horncastle and Spilsby. A slightly greater string of development is present along the A52 between Skegness and Boston along the northern coast of the Wash at the south of the region.

The coastline through Lincolnshire comprises extensive areas of exposed sandy beaches, which attract large volumes of visitors particularly in the summer. There are also a large number of holiday parks between small coastal settlements including North Somercotes, Mablethorpe, Chapel St Leonards and Skegness. Seaward, there are stretching coastal views within the region but also includes considerable marine activity around the Humber Estuary. The Inner Dowsing and Lincs OWF are also a very prominent feature around the coast at Skegness.

Land Use Constraints

The northern part of the region is heavily industrialised, along the southern bank of the Humber estuary, and along the M180 corridor to Scunthorpe. This also includes the Humberside Airport. The remainder of the region is largely agricultural.

Infrastructure within the region, beyond local roads is also relatively sparse. The gas terminal at Theddlethorpe is notable and connects to a gas site at Hatton which includes a number of other pipeline connections from the Humber, Scunthorpe and down to Peterborough and Wisbech. In the north of region, the export cables for Hornsea 1 and 2 OWFs make landfall at North Cotes and connect at Killingholme via the same corridor. In south Lincolnshire the export cable for Triton Knoll OWF and the underground cable for the Viking Link interconnector (both currently under construction) make landfall south of Mablethorpe, following separate corridors towards Bicker Fen substation.

Sub-Regional Constraints: Norfolk

Offshore

Biological Environment

At the north of the sub region lie the Wash and North Norfolk Coast SAC, the Greater Wash SPA, Ramsar, and SSSI extending south from the Wash. The sites are designated for a range of coastal and saltmarsh habitats as well as physical features such as sandbanks, shallow inlets and bays, intertidal mud and sand flats and reefs. Species include harbour seal and both breeding and non breeding seabird species as well as their foraging habitat.

The North Norfolk Coast SPA extends along the coast 40km from Holme to Weybourne and includes a variety of coastal habitats and populations of breeding and non-breeding bird species. The site is one of the largest areas of undeveloped coastal habitat of its type. It is the fourth most important wetland site for waterfowl in Britain. This section of coast also incorporates the Winterton to Great Yarmouth North Denes SPA; and Horsey Dunes SAC and SSSI.

Offshore and east of Blakeney Point the Cromer Shoal Chalk Beds MCZ is the longest chalk reef feature known in Europe, extending 30km along the coast and 10km offshore. The MCZ is designated for its seaweed dominated chalk reef and related habitat features and associated species.

Offshore the Southern North Sea SAC is designed for harbour porpoise and straddles the 12mile limit, as also does the Hammond and Winterton SAC designated for its sandbank features.

The subregion is heavily designated with multiple constraints which may present a challenge to cable routing and landfall, depending upon the nature of the features potentially impacted.

Physical Environment

The region is varied and includes a combination of lengthy sandy beaches, shifting sands and intertidal lagoons. There are large sections of saltmarsh and extensive examples of mudflat, particularly within the nearshore areas of The Wash. Further south and east long shingle frontages and multiple cliff (chalk-based) features which back this frontage are found.

Large sections of this region fall under the Shoreline Management Plan Policy Hold The Line. However, there are also sections of Managed Realignment (notably from Sheringham to Eccles on Sea) and two sections of No Active Intervention to the east of Burnham Market.

Underlying geology is characterised by alluvium/chalk (generally to the west), till (generally to the east) and glacial sand / gravel (also generally to the east).

Seaward within the 12nm zone, the sub-region is largely sand and gravel with some mud overlying mudstone/sandstone. There are various coastal defence programmes within the region which include hard coastal defence features (rock armouring, seawalls, beach groynes etc.) but also more dynamic approaches which include the Bacton to Walcott "Sand Engine".

Much of the area is likely to be technically challenging for landfall however two potential locations have been included in the review.

Historic Environment

The sub-region includes the North Norfolk Coast Heritage Coast.

There are no Protected Wreck sites within the Norfolk coastline and wider inshore 12nm zone. T

The majority of scheduled monuments in the sub-region are coastal (terrestrial) sites however there are two marine scheduled monuments located within the 12nm inshore zone – 'Xanthe' and 'The Seagull'.

Other Sea Use Constraints

To the far west of the sub-region, the Holbeach Military Practice area fills much on the nearshore area of The Wash.

There are few fishing ports within the sub-region, however, there are sporadic beach-launch fisheries throughout the area including notable activity at Cromer. Inshore fishing activity is largely targeted at species including plaice, sole, herring and mackerel.

Great Yarmouth and Lowestoft are notable in terms of their operation as major support hubs for both the oil and gas and offshore wind industries. Sheringham Shoal OWF is located to the north of Cromer/Sheringham within the 12nm zone; Lynn, Lincs and Inner Dowsing OWFs are located to the east of Skegness.

There are some Oil and Gas assets in the sub-region, most notably at Bacton where there approximately 14 individual gas, gas interconnector and chemical and lines. More widely, there are three wellheads all of which are disused, abandoned and/or decommissioned.

There are variable levels of marine traffic in the area but typically, higher levels are found around main shipping lanes between the 6nm and 12nm inshore zone as well as the sea east of Cromer where high volumes of continental shipping enter UK waters. There are no notable peaks of vessel density owing to the lack of any major port facility within the sub-region.

Onshore

Biological Environment

The Wash designation extends around the north Norfolk coast to Holme next the Sea and is immediately abutted by the North Norfolk Coast designations (SAC, SPA, Ramsar, SSSI and NNR) as far east as Weybourne.

From Weybourne to the east of Mundesley the cliffs of the coast (between areas of development) are designated as SSSIs. Around to the east of the Norfolk, designations are largely orientated around The Broads National Park which covers most of the areas east of Norwich, and includes SACs (The Broads and Winterton-Horsey Dunes), SPAs (Broadland, Great Yarmouth North Denes and Breydon Water), Ramsars (Broadland and Breydon Water) as well as numerous SSSIs and NNRs throughout and at the coast from Waxham to Caistor-on-Sea.

Further inland, Norfolk includes various other designations including the River Wensum SAC and SSSI and River Nar SSSI, which cover much of the length of the length of the county between King's Lynn and Norfolk. Other designations throughout the area include smaller SACs, SSSIs, NNRs and areas of ancient woodland.

Physical Environment

The landform through Norfolk is generally raised from the coastal cliffs and is gentle undulating throughout the region. The tallest summit is at the coast at Sheringham which raises only to ~100 m above ordnance datum (AOD). The Broads at the east of the region is generally flat. These areas are predominantly good/ moderate agricultural land (in regard to versatility and yield for productivity) to the west of the region, and good or excellent to the west.

The low-lying coastal areas in the west (at Kings Lynn), and east (The Broads) include broad areas of higher susceptibility to flooding (Flood Zone 3, 1 in 200 annual probability from flooding from the sea). At The Broads this is dominated by the various associated rivers including R. Thurne, R. Bure, R. Yare and R. Waveney.

Historic Environment

There are a considerable number of Registered Parks and Gardens through the region, although these are predominantly located within the Lincolnshire Wolds AONB. The largest of these are Holkham Hall and Houghton Hall (both Grade I), located at Burnham Market and Harpley, respectively at the west of the region. The other larger parks include:

- Hunstanton Hall Grade II
- Sandringham House II*
- Raynham Park Grade II
- Melton Constable Hall II*
- Felbrigg Hall Grade II*
- Wolterton Hall Grade II*
- Blickling Hall Grade II*
- Langley Park Grade II, and
- Somerleyton Park Grade II*

There is a greater number of Scheduled Monuments, however these are much smaller in scale. Predominantly these are distributed across the western area of the region.

There are also multiple Designated Military Remains, reflective of major defensive development during World War II within this region. These are largely coastal representing defences at potential landing sites, with the greatest concentration of these at Weybourne.

Landscape & Seascape

The Norfolk Coast AONB cover approximately 90 km of coastline between King's Lynn and Bacton, and a further 10 km between Sea Palling and Winterton on Sea. These areas extend inland between 2.5 and 6.5 km. The north Norfolk coast between Holme next the Sea and Weybourne is also designated as a Heritage Coast. The Broads National Park further dominates the region to the east of Norwich, extending between North Walsham and Lowestoft (Suffolk) at the south of the region. There are Country Parks also located within the region including at Holt, Dersingham and Norwich.

The region (within the Study Area) is largely rural, agricultural land. The sand dunes and salt marshes that dominate the north Norfolk coast to the west are generally sparsely populated and settlement areas are smaller. Most of the visitor attractions and holiday homes are located within the vicinity of the larger coastal settlements further east including Sheringham and Cromer. Between Cromer and Caister-on-Sea the coastal settlements dissipate and again become smaller and increasingly sparse. Great Yarmouth dominates the eastern coast.

There are various recreational routes and paths of interest through the region, including the Peddar's Way and Norfolk Coast Path between Hunstanton and Cromer, and the England Coast Path between Cromer and Hopton on Sea. There are also multiple cycle routes associated with the National and Regional Cycle Networks. Seaward, there are distant views of some operational OWFs such as Lynn and Lincs OWF from the northwest coast, Sheringham Shoal from the north coast around Blakeney Point, Weybourne and Sheringham, and Scroby Sands from the east coast at Caistor-on-Sea.

Other Land Use Constraints

The region is largely agricultural, beyond only a few populated areas – namely King's Lynn and Norwich. The region does also include the Cotlishall Airfield (RAF Coltishall) and Norwick International Airport located to the east of the region.

Infrastructure within the region radiates from two broad landfall areas at Weybourne and between Mundesley and Eccles on Sea. At Mundesley is a gas terminal with five pipelines extending across the King's Lynn and south to the west and east of Norwich. This also includes the landfall for the Boreas and Vanguard OWF export cable connecting at Necton, as well as potentially being the site of landfall for the Dudgeon and Sheringham Shoal extension OWF export cable connecting to Norwich Main (project currently in Scoping). The Weybourne landfall currently includes the Dudgeon, Sheringham Shoal, and Hornsea 3 OWF export cables, and may potentially also include the Dudgeon and Sheringham Shoal extension OWF export cable.

Sub-Regional Constraints: Suffolk

Offshore

Biological Environment

Within the Suffolk coastline and wider inshore 12nm zone, there are multiple statutory designations with potential to influence cable / development corridor routing.

The Minsmere-Walberswick SPA lies on the Suffolk coast between Southwold and Sizewell and contains a mosaic of habitat, including extensive areas of freshwater and coastal grazing marsh, coastal reedbeds, saltmarsh, lowland heathland, woodland, intertidal mud and mixed sediment, which support breeding and non breeding bird species.

Further south, the Alde, Ore and Butley Estuaries SAC is the only bar-built estuary in the UK, and is designated for its salt meadows, estuary features and intertidal mudflats and sandflats. To the south again the Orfordness - Shingle Street SAC is designated for its Annex 1 features including coastal lagoons and vegetated shingle spits.

At the southern end of the sub region lie the Deben Estuary SPA; Stour and Orwell Estuaries SPA; and Alde-Ore Estuary SPAs. The Deben Estuary is constrained by seawalls, with extensive saltmarsh and mudflat supporting breeding, wintering and migratory water birds. The Stour and Orwell SPA has saltmarsh, and extensive mudflats, with some vegetated shingle and low cliffs, also supporting breeding, wintering and migratory wildfowl. The Alde Ore Estuary also supports vegetated shingle, mudflats and saltmarsh, as well as being notable for the presence of saline lagoons. These habitats support breeding and wintering water birds in common with other nearby sites.

Offshore, the Southern North Sea SAC, which provides protection for winter and summer harbour porpoise habitat extends for much of the offshore and inshore marine area, from north to south. Offshore of the Ale, Ore and Butley Estuaries and straddling the 12 nm inshore limit lies the Orford Inshore MCZ supports mixed sediment seabed providing habitat that support a range of shark species and foraging seabirds and harbour porpoise.

The northern edge of the Outer Thames Estuary SPA (discussed in detail for the next sub-region) also extends into the southern edge of the Suffolk sub region.

Physical Environment

The Suffolk intertidal foreshore is dominated by sand and gravel in the north of the county, changing to a gravelly substrate for ~23 km encompassing the mouths of the Alde-Ore and Deben Estuaries. The estuaries themselves being mud, are important habitats for birds, hence their SPA designations. There are also some areas of coastal saltmarsh and vegetated shingle in the sub-region.

The Shoreline Management Plan policies for the area are variable with multiple sections of Hold The Line, No Active Intervention, Managed Realignment and two isolated examples of Advance The Line to the north of Southwold.

Underlying geology is characterised by till, mudstone/sandstone, sand and clay within the northern and central areas of the sub-region whilst further south, there is emergence of London Clay. In the inshore 12nm zone, the Study Area is predominantly sand, gravel and mud overlying sandstone / mudstone features. There are also large volumes of river silt / sediment within and adjacent to the main estuaries at Southwold, Aldeburgh and Felixstowe. South of Shingle Street, there are various built coastal defence systems (predominantly consisting of rock armour and beach groynes) and from the southern breakwater of Harwich Harbour, much of Harwich is protected by a series of seawalls, rock armour and beach groynes.

The Suffolk coastline is subject to erosion caused by subsidence and southward longshore sediment movement caused by dominant north-easterly wave action.

Historic Environment

Dunwich Bank is a protected wreck located ~0.5 km off the coast of Dunwich Heath. The wreck constitutes the remains of an armed cargo vessel which foundered in the area in what is thought to be between 1536 and 1600. The main site consists of a small steep-sided wreck mound, surrounded by a scatter of bronze muzzle-loading guns, iron muzzle and breech-loading guns, and various concretions, no more than 650 square metres in extent. Beyond the main site there are several shallow depressions within a seabed which is otherwise flat and appear to indicate the presence of modern debris. No part of the restricted area lies above the high-water mark of ordinary spring tides.

Other Sea Use Constraints

The inshore 12nm zone hosts some fishing effort, primarily undertaken by <10m vessels targeting species such as Sandeel, Plaice, Tope shark, Thornback Ray, Sole, Herring and Mackerel. There is some limited beach-launch fishing effort throughout the sub-region using a range of techniques (potting, trapping and drift netting being some of the most popular).

There are also multiple aggregate extraction areas (i.e. Yarmouth / Yarmouth expansions to the north east) in the northern part of the county, whilst further south, the four ‘Shipwash’ aggregate extraction areas are located, albeit seaward. Whilst there is no local OWF generation currently within the inshore 12nm zone, the East Anglia One North and East Anglia export cable routes are located within this sub-region. Lowestoft, to the north of the sub-region, is a major operational and maintenance hub for

Galloper OWF. The Galloper export cable route itself passes through and landfalls within the sub-region.

Despite the presence of Great Yarmouth, a major Oil and Gas hub to the north of the region in Norfolk, there is only one Oil and Gas asset within the 12nm inshore zone (a wellhead which is disused, abandoned and/or decommissioned).

At Sizewell, cooling water infrastructure for the (legacy) Sizewell A and (operational) Sizewell B Nuclear Power Stations extend into the inshore 12nm zone. Further south, there are notable major port facilities at Felixstowe Dock. The inshore 12nm zone generally has an average volume of marine traffic however further toward the 12nm limit, there are main coastal shipping routes and these are bisected with marine traffic to and from mainland Europe. Vessel densities peak at Lowestoft (~10,243 vessel movements per year) and Harwich Haven / Felixstowe (up to ~34,000 vessel movements per year). The higher volumes of traffic for these southern ports are reflective of major container shipping volumes (~40% of the UK's container freight moves through this area) as well as ro-ro traffic, bulk cargos and cruise shipping. Felixstowe / Harwich Haven is surrounded by multiple traffic separation schemes, restriction areas and much of the inshore 12nm zone east of Felixstowe falls under the Harwich Harbour Area.

Onshore

Biological Environment

Through the Suffolk coast there are a series of coastal lagoons, estuaries and marshes which are internationally designated (SPA, SAC, Ramsar) and stretch through the majority of the coastline save some short sections between. There is a maximum of 6.5 km between internationally designed sites through the Suffolk coast. These biologically designated areas include:

- Bebacre to Easton Bavents Lagoons,
- Minsmere-Wallberswick (and Minsmere-Wallberswick Heaths & Marshes)
- Alde-Ore & Butley Estuary
- Orfordness-Shingle Street
- Staverton Park & The Thicks Wantisden
- Sandlings
- Deben Estuary, and
- Stour and Orwell Estuaries.

Whilst there are some designated areas located further inland between the coast and the existing transmission network, these are smaller in scale and scattered spatially.

Physical Environment

The landform through Suffolk is gentle undulating throughout the region, with sporadic taller summits generally to the south of the region (north of Ipswich). These areas are predominantly good/ moderate agricultural land (in regard to versatility and yield for productivity) to the west of the region, and good or excellent in river valleys. The coastal area of the region (generally between the coast and the A12 corridor) is more forested, with mudflats and marsh at estuary mouths.

Areas at greater risk of flooding (Flood Zone 3, 1 in 200 annual probability from flooding from the sea) are typically highly localised to river valleys and estuaries, however there are a large number of these down the Suffolk coast. These include: Hundred River, Smear marshes, R. Blyth, Westwood marshes, Dunwich River, Minsmere River, R. Alde, R. Ore, Butley River, R. Deben. As well as the R. Waveney across the north of the region, and the R. Orwell at the southern border with Essex.

Historic Environment

There are 11 Registered Parks and Gardens through the region, and only one of these is located within the Suffolk Coast and Heath AONB.

There are relatively few Scheduled Monuments through of the region, and none of which are spatially expansive.

There are also multiple Designated Military Remains, reflective of major defensive development during World War II within this region. These are largely coastal representing defences at potential landing sites, concentrated around Wallberswick, Aldeburgh, and Bawdsey (including Bawdsey Manor).

Landscape & Seascape

The Suffolk Coast & Heaths AONB covers almost the entire coastline of Suffolk – stretching between Kessington just south of Lowestoft to the River Orwell valley (excluding Felixstowe). At its narrowest, the designation is 2 km (at Leiston) to over 10 km further south. The coast between Kessington and Felixstowe is also designated as a Heritage Coast. There are four Country Parks located within the region which are much smaller in scale, however these also include the Kessington Country Park which extends north of the AONB.

The region (within the Study Area) is largely rural, agricultural land spread across a relatively flat plateau that dips towards the sandy heathlands along the coast. The various river valleys, as described above, due to their number also largely define the region.

Population within the region is predominantly around a few larger settlements at the north (Lowestoft) and the south (Felixstowe and Ipswich), with some smaller towns located in between, including Leiston, Saxmundham and Wickham Market.

There are various recreational routes and paths of interest through the region, including the Suffolk Coast Regional Cycle Network between Dunwich and Felixstowe.

There are currently no OWF within the inshore environment that are visible from the coast, however cooling water infrastructure associated with Sizewell A and B is currently visible. Further south in the county, whilst not industrial, Felixstowe Ferry and the Felixstowe Ferry Sailing Club are notable in the area.

Other Land Use Constraints

The region is largely agricultural, beyond only a few populated areas – namely Lowestoft, Ipswich and Felixstowe.

Infrastructure within the region is largely focused around the Sizewell area – which includes the proposed Sizewell C nuclear site, as well as the East Anglia One and Two OWF export cables (connecting to the proposed Leiston substation).

Sub-Regional Constraints: Essex

Offshore

Biological Environment

The Essex coastline is heavily designated with several estuaries designated for their habitats and species (Essex Estuaries SAC; Stour and Orwell Estuaries SPA; Hamford Water SPA; Colne Estuary Ramsar and SPA; Blackwater Estuary Ramsar and SPA; Crouch and Roach Estuaries SPA and Colne Estuaries MCZ).

Coastal designations include Dengie Ramsar and SPA; Foulness Ramsar and SPA; Benfleet and Southend Marshes RAMSAR and SPA.

In the offshore environment the sub region includes part of the Southern North Sea SAC, designated for harbour porpoise, the Margate and Long Sands SAC, designated for its sandbank feature, and the Outer Thames Estuary SPA is designated for its important feeding habitat for a number of seabird species. Of these the sandbank features of the Margate and Long Sands SAC would have greatest potential for constraint upon cable laying works, and the Southern North Sea SAC perhaps the least.

Physical Environment

The Essex intertidal foreshore is largely mud, with some patchy muddy gravel, namely surrounding the Colne Estuary, spanning from West Mersey to Colne Point.

The Shoreline Management Plan policy for the region is mainly Hold The Line but with various pockets of No Active Intervention, Managed Realignment and a number of isolated sections of Managed Realignment to the west of Harwich Haven.

In the north of the sub-region, a stretch of sandy beach ~5.5 km lies between Walton-on-the-Naze and Frinton-on-Sea.

Much of the frontages in the sub-region are backed by extensive coastal defences which stretch along much of the peninsula (comprising a combination of rock revetment, rock armour, beach groyne, re-charge and dressed gabion).

Historic Environment

The maritime wreck, believed to be the “London”, a second rate 'large ship', is located at The Nore, Thames Estuary, off Southend-on-Sea. A second area of wreckage adjacent, known for many years as the King, from a cannon recovered from the vicinity, is most likely part of the London. This is a site of both historical and archaeological interest and is therefore designated as a Protected Wreck Site.

The remains of a wreck thought to be that of a Swedish cargo vessel dating from 1787 to the early nineteenth-century, resides in the South Edinburgh Channel, Outer Thames Estuary, off Margate. Although sand levels over the site fluctuate, hydrographic evidence suggests that there is over 6 metres of sand currently above the site. This site is designated under the Protection of Wrecks Act 1973, for protection from unauthorised interference.

Other Sea Use Constraints

There is some limited fishing effort within the 12nm zone along the Essex coast (primarily understood to be <10m vessels), however this is to some extent limited by marine traffic accessing Harwich Harbour/Hawich Haven and Felixstowe further north.

To the south east of the inshore 12nm zone are Gunfleet Sands I, II and Demo OWFs and Longsand aggregate extraction area. The Neuconnect interconnector route is at the 12nm limit of the inshore zone and further to the south east is the London Array OWF. Walton and Frinton Yacht Club, Titchmarsh Marina and The Naze Marine Holiday Park are notable recreational feature of the locality.

Onshore

Biological Environment

At the south of the Study Area the coastline through Essex is dominated by river estuaries, almost all of which are designated as areas of international importance including: Stour and Orwell, Hamford Water, Colne, Blackwater, Crouch and Roach and the River Thames. Between Clacton-on-Sea and the

Thames estuary are also the Dengie, Foulness and Benfleet and Southend Marshes designated areas (Ramsars and SPAs).

The Essex coastline, with the exception of approximately 15 km of coastline that includes the towns of Frinton-on-Sea and Clacton-on-Sea, is internationally designated, with the area between these two settlements nationally designated as a SSSI (Holland Haven Marshes). The banks of all of these estuaries are also SSSIs (and many are NNRs) which extend the extent of designation inland.

As with Lincolnshire and Suffolk, whilst there are some nationally designated sites further inland (such as Abberton Reservoir and Chalkney Wood, and pockets of ancient woodland along the A12 corridor) these areas are more discrete and spatially separate.

Physical Environment

The landform through the Essex region of the Study Area is heavily dominated by the low-lying coastal areas and large and numerous estuaries – therefore blurring the line between terrestrial and nearshore environments. Throughout there are no prominent elevations. The more coastal areas – within the boundary of the A12 – are generally good/ moderate agricultural land (in regard to versatility and yield for productivity), and good or excellent inland of the A12, and also to the immediate east of Colchester.

Areas at greater risk of flooding (Flood Zone 3, 1 in 200 annual probability from flooding from the sea) are typically highly localised to river valleys and estuaries. At the lower lying areas in the south this includes much of the coastal area (and up to 4 km inland) through Dengie and Foulness Island.

Historic Environment

There are 15 Registered Parks and Gardens through the region, which are predominantly located around the settlements of Chelmsford, Witham and Colchester. There are also two in near shore locations at Brightlingsea and Thorpe-le-Soken (around Clacton on Sea).

There are relatively few and scattered Scheduled Monuments through of the region. The most extensive of these are areas of Iron Age settlement within and around Colchester.

There are also multiple Designated Military Remains, few of which are located around the coast. The greatest density of these are pillboxes adjacent to the A130 south of Chelmsford.

Landscape & Seascape

The Suffolk Coast & Heaths AONB extends over the county boundary to Essex in the north, covering the northern bank of the River Stour as far as Brantham. The Dedham Vale AONB is to the immediate west of this extending across the entire valley of the River Stour between Brantham and Bure. There are two coastal Country Parks at Clacton on Sea and East Mersea (Holland Haven and Cudmore Grove, respectively), as well as six others which are within built up areas.

The coastal landscape is very remote, unpopulated with marshland and estuaries being prominent features. Settlement is largely restricted to medieval hamlets and villages. Historic military landmarks are also characteristic features of the coastal landscape. Further inland the landscape is slightly more populated and dominated by arable agriculture, with Colchester being the largest settlement in the area.

There are various recreational routes and paths of interest through the region, largely associated within the National and Regional Cycle Networks.

Aside from infrastructure and traffic associated with Harwich Harbour/Harwich Haven, there are largely unconstrained views of the coast. Gunfleet Sands I and II OWFs are also prominent in the seascape from Clacton on Sea and Frinton-on-sea. Dependent on conditions, distant views of London Array are also possible from the coast in southern parts of the county.

Other Land Use Constraints

The region is sparsely populated beyond large settlements of Colchester, Chelmsford and Clacton on Sea. Land use is largely agricultural beyond the low-lying marshlands which extend throughout the coastline.

Existing and proposed infrastructure within the region is also limited. Bradwell B is proposed adjacent to the existing site north of Bradwell on Sea. There is also the landfall of the export cable of the Gunfleet Sands OWF which land immediately north of Clacton on Sea.

C4. Scenario Development

Hypothetical Offshore Wind Farm Development

The potential for the number and location of future offshore wind developments underneath the Round 4 3.5GW cap[11] within these Offshore Wind Generation Zones was considered

In developing the Conceptual Offshore Wind Farms, a range of capacities were considered. This included:

A small number of sites with a large generation capacity (2.5GW);

A moderate number of sites with varying generation capacities (0.5GW-2.5GW); and

A large number of smaller generation capacity (0.5GW).

A large number of small (0.5GW) projects has been used as the basis for the analysis because…. This may be less realistic noting that more recent offshore wind developments have larger generation capacities (between 1-2GW). However, it was considered that considering a larger number of project would provide an opportunity to more effectively analyse radial and coordinated approaches to connecting offshore wind across the Study Area when compared to a smaller number of larger projects. There are fewer opportunities for a coordinated approach with fewer, more geographically dispersed sites (i.e. it is likely to be unrealistic to have coordination between sites with large separation distances).

Basic assumptions were set in order to define the size of a Hypothetical Offshore Wind Project; this included (conservative) spacing of 1km between devices and 1.4km between rows of devices. A series of seven 0.5GW Projects were identified within the Study Area, as shown by **Figure B12** provided within **Appendix B**. Some limited consideration was given to constraints in identifying these locations, however, they are not representative of where future offshore wind development may be located. The focus of this study is on of radial and coordinated approaches within the inshore 12 nautical mile zone, including landfalls, and then on to onshore connection point

Potential Landfalls Locations

Following the review of physical characteristics of the coastline through the Study Area, in line with environmental and socio-economic constraints and existing infrastrure a number of borad landfall arreas were identified. These areas are outlined below.

Lincolnshire

- **North Cotes** – on the north Lincolnshire coast at the mouth of the Humber Estuary. This landfall area overlaps with the Humber Estuary designations (SPA/SAC) as well as the Greater Wash SPA. At the northern end of the Lincolnshire coastline there is no scope to avoid nearshore routes through/landfalls within these designations. Subject to the exact location a cable route crossing of the designated sites could be up to 6km long. Based on Nationally Significant Infrastructure Project (NSIP) case precedent and the current suite of mitigation typical for OWF projects, it is predicted that impacts from cable installation may typically be temporary. It is predicted that they could potentially be mitigated through a combination of detailed micro-routeing in response to survey results as well as the timing and method of installation. This landfall area is also in a similar location to the existing Hornsea 1 and 2 OWF export cables and is the closest likely option to the existing transmission network in the Lincolnshire region (there is

[11] https://www.thecrownestate.co.uk/en-gb/what-we-do/on-the-seabed/offshore-wind-leasing-round-4/

a cluster of potential connection points at Grimsby West, South Humber Bank, Humber Refinery, and Killingholme).

- **Theddlethorpe** – located immediately north of Mablethorpe. This landfall area overlaps with the southern-most extent of the Humber Estuary designations as well as the Theddlethorpe-Saltfleetby Dunes SAC, however, at this location the designations occupy a much narrower section of the foreshore providing opportunity to avoid them through the use of Horizontal Directional Drilling (HDD). The Greater Wash SPA is also present in the nearshore and cannot be avoided. This may pose a constraint on timing or method of installation but is not considered to be a spatial constraint. There is limited settlement/development in this section of the coastline. Whilst further from the existing transmission network, opportunities exist to connect to Grimsby West 30km to the north, Bicker Fen 65km to the south west or, subject to the future expansion of the network in South Lincolnshire, to a connection point in the Mablethorpe area (see Potential Grid Connection Points below).
- **Anderby** – between the settlements of Mablethorpe and Chapel St Leonard. This landfall is north of the Inner Dowsing, Race Bank and North Ridge SAC. The Greater Wash SPA is also located adjacent to the coastline. There is limited settlement/development in this section of the coastline. The Viking Link Interconnector and Triton Knoll Offshore Wind Farm both have landfalls within this section of coastline but there is sufficient space for future projects to also make landfall here. As above potential connections to the existing transmission network are located to the north at Grimsby West or inland at Bicker Fen, or, subject to the future expansion of the network in South Lincolnshire, to a connection point in the Mablethorpe area (see Potential Grid Connection Points below).

Norfolk

- **Weybourne** – on the north Norfolk coast. The landfall area extends west to east from Cley on Sea to Sheringham. It is adjacent to, and would require nearshore subsea cable routes to cross, the North Norfolk Coast SAC and Cromer Shoal Chalk Beds MCZ for approximately 10km as well as require onshore cable routes to cross the Norfolk Coast AONB. The suitability of this section of the coastline for landfalls is highlighted by the number of existing or proposed landfalls along this stretch. This includes the landfalls for Hornsea 3, Sheringham Shoal, Dudgeon OWFs and potentially also the Sheringham Shoal and Dudgeon OWF extensions. These are located in the central and eastern part of the landfall area identified. Constraints are present to the western and eastern extents of the landfall area (saltmarshes to the west and the north Norfolk railway line to the east). These would not preclude landfall sites but would be more complex in engineering terms than those already present.
- **Bacton** – on the north eastern coast of Norfolk. Coastal landform becomes taller with larger cliff faces here than in the north and northwest of the Norfolk region. The landfall area is located adjacent to the eastern extents of the Cromer Shoal Chalk Beds MCZ while the Southern North Sea SAC is also present. There are a significant number of pipelines which make landfall to the west of the area connecting into the Bacton Gas Terminal, this includes pipelines which are routed parallel to the coastline and would require to be crossed by nearshore cable routes and therefore would require additional protection measures in shallow waters. The Vanguard OWF (approved) and Boreas OWF (pending decision) also make landfall in this area.

Suffolk

- **Lowestoft** – between Lowestoft and the Suffolk Coast and Heaths AONB occupying a relatively narrow area of the coast. The landfall area largely avoids environmental designations and settlements, however, subject to detailed siting would require a crossing of a narrow section of the Pakefield to Easton Bavents SSSI. Moving inland from the landfall, the AONB and The Broads National Park would influence routeing and siting of onshore infrastructure.

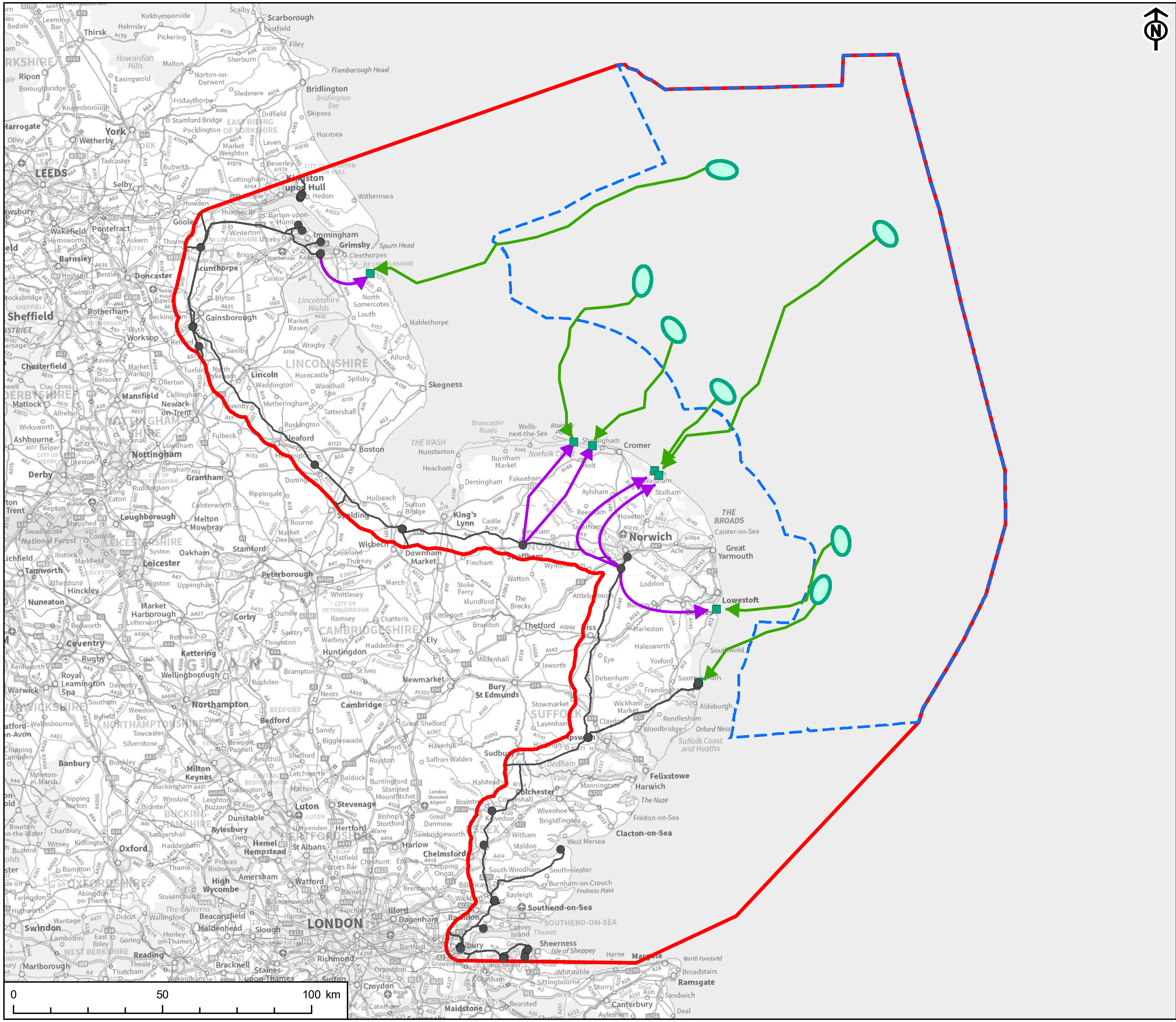
- **Sizewell** – from north of Sizewell to Aldeburgh. At this section of the coastline there are landfalls for a number of existing and proposed offshore wind farms (including East Anglia One and Two, Greater Gabbard and Galloper OWFs). In addition, interconnectors (Nautilus and EuroLink) have agreements to connect to the proposed Friston Substation located less than 10km from the coast. The proximity of the transmission system to the coast combined the coastal landform in this area provides suitable landfall opportunities. However, in the longer term in combination with settlement, other large-scale development such as Sizewell C Nuclear Power Station and environmental constraints, landfall opportunities may become more limited or require more complex engineering solutions.
- **Bawdsey** – at the south of the region. The landfall area is within the Suffolk Coast and Heaths AONB but is less constrained by designations compared to other sections of the coastline. For the majority of its length the coastline is formed by narrow sand/shingle beaches adjacent to agricultural land. Relative to other sections of the Suffolk coastline, the landfall is largely unpopulated. A key consideration with this landfall area is it proximity to the transmission system. The 400kV OHL between Sizewell and Bramford is approximately 15km north west, however, moving inland larger settlements such as Ipswich are present.

Essex

- **Harwich South** – located immediately south of Harwich. This landfall is at an area of low-lying coast, with limited population. This area is located to the north of the Hamford Water designated site (SAC, SPA, Ramsar, SSSI and NNR). The proximity to Harwich Harbour to the landfall area introduces the risk of disturbance to shipping traffic.
- **Clacton-on-Sea** –located between Clacton-on-Sea and Frinton-on-Sea. The Holland Haven Marshes SSSI occupies the undeveloped area between the two settlements and would likely mean that any landfall requires to be installed by HDD. The landfall for Gunfleet Sands OFW is also located in this area but this could be avoided in siting additional landfalls in this area.

Appendix D Grid Connection Scenario Plans

Project Management Initials: DR Designer: LC Checked: FF Approved: DR



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Coordinate System: WGS 1984 Zone 30N

AECOM

PROJECT
EAST COAST GRID STUDY

CLIENT
THE CROWN ESTATE

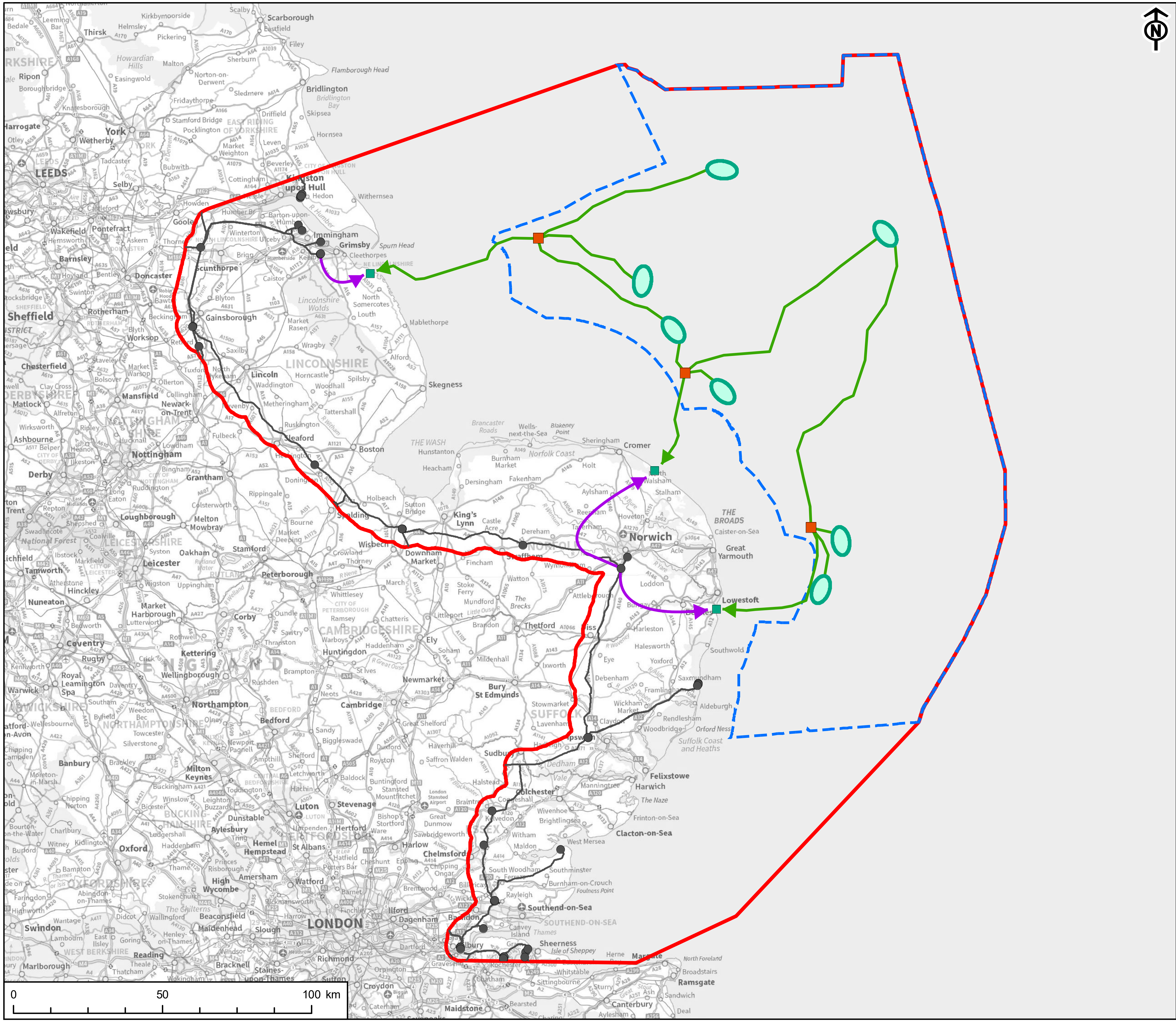
KEY
- Study Area
- R4 Bidding Area - Eastern Regions
- Potential Landfall Area
- Existing Substation Location
- Existing Overhead Line
- Potential Onshore Export Cable Route
- Potential Offshore Export Cable Route
- Conceptual Offshore Wind Project

TITLE
APPENDIX D
GRID CONNECTION SCENARIO A
OVERVIEW

REFERENCE
ECGS_210416_D_v1

SHEET NUMBER	DATE
1 of 1	16/04/2021

Project Management Initials: DR Designer: LC Checked: FF Approved: DR



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AECOM

PROJECT
EAST COAST GRID STUDY

CLIENT
THE CROWN ESTATE

KEY
- Study Area
- R4 Bidding Area - Eastern Regions
- Potential Landfall Area
- Existing Substation Location
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- Existing Overhead Line
- Potential Onshore Export Cable Route
- Potential Offshore Export Cable Route
- Conceptual Offshore Wind Project

TITLE
APPENDIX D
GRID CONNECTION SCENARIO B
OVERVIEW

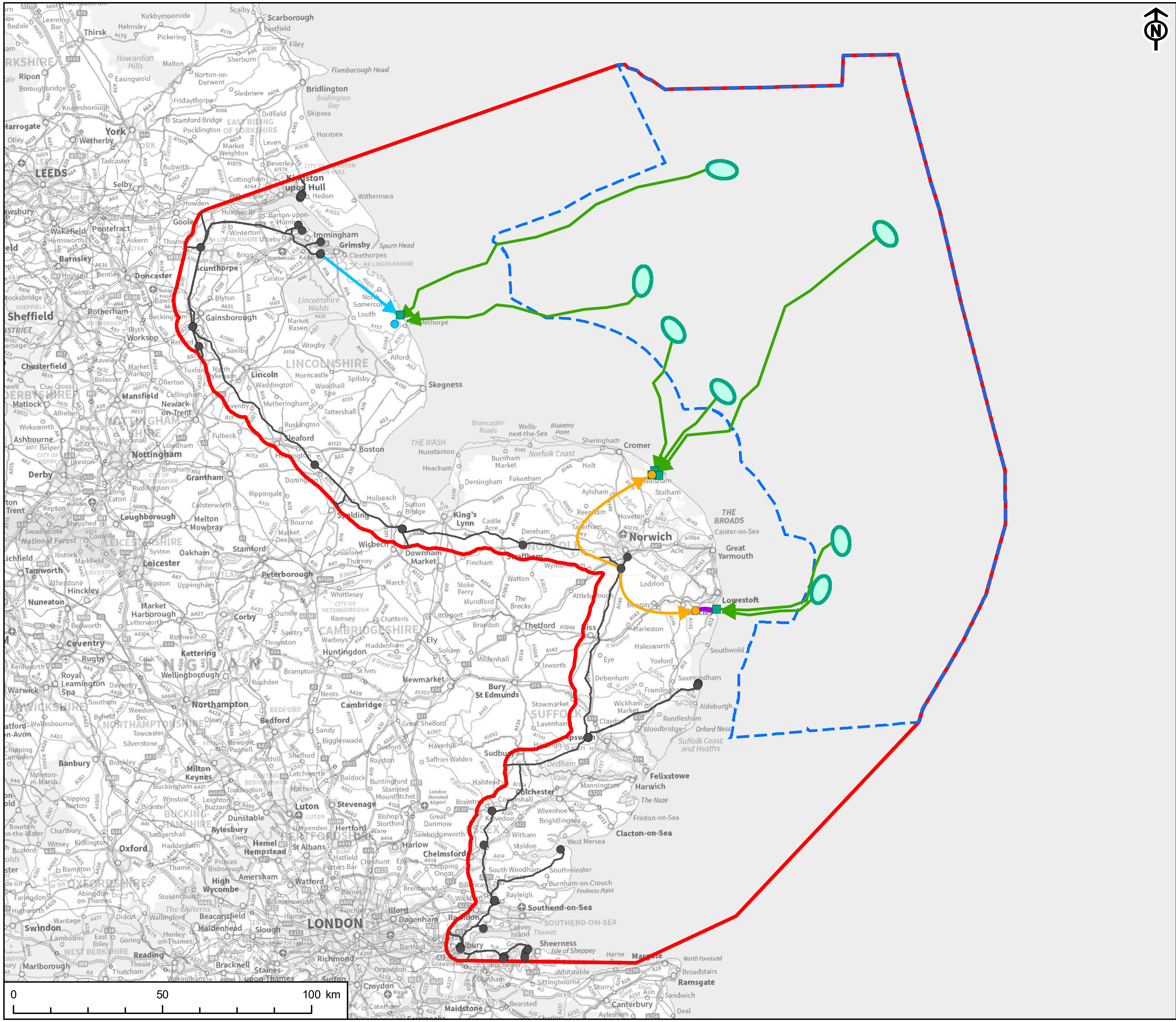
REFERENCE
ECGS_210416_D_v1

SHEET NUMBER 1 of 1

DATE 16/04/2021

Coordinate System: WGS 1984 Zone 30N

Project Management Initials: DR Designer: LC Checked: FF Approved: DR



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Coordinate System: WGS 1984 Zone 30N

AECOM

PROJECT
EAST COAST GRID STUDY

CLIENT
THE CROWN ESTATE

KEY
- Study Area
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- Existing Substation Location
- Planned Coastal Hub or Node Location (NOA 2019/20)
- Potential Network Extension Coastal Hub or Node Location
- Existing Overhead Line
- Potential Onshore Export Cable Route
- Potential Onshore Network Extension OHL (NOA 2019/20)
- Potential Onshore Network Extension OHL
- Potential Offshore Export Cable Route
- Conceptual Offshore Wind Project

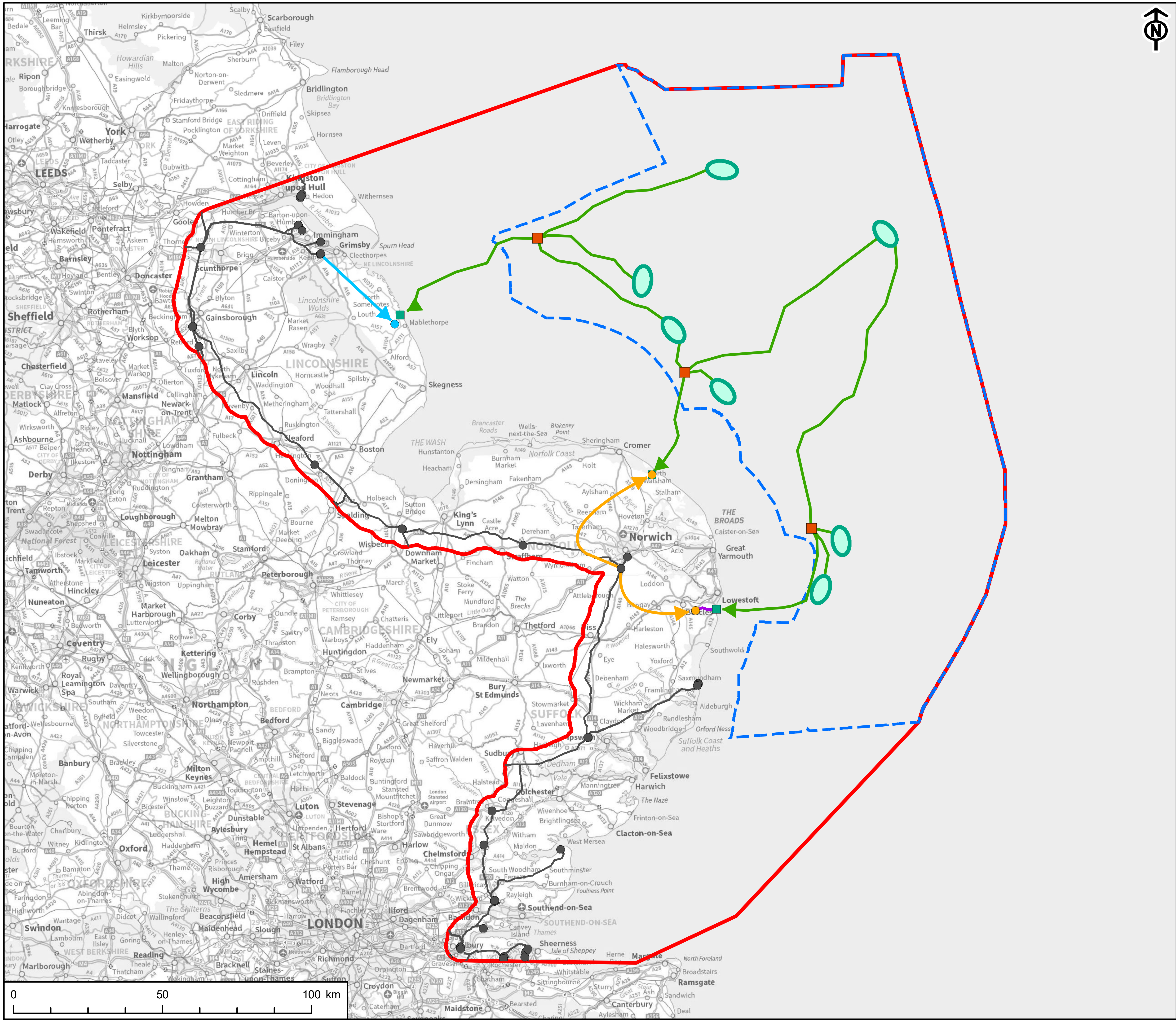
TITLE
APPENDIX D
GRID CONNECTION SCENARIO C
OVERVIEW

REFERENCE
ECGS_210416_D_v1

SHEET NUMBER
1 of 1

DATE
16/04/2021

Project Management Initials: DR Designer: LC Checked: FF Approved: DR



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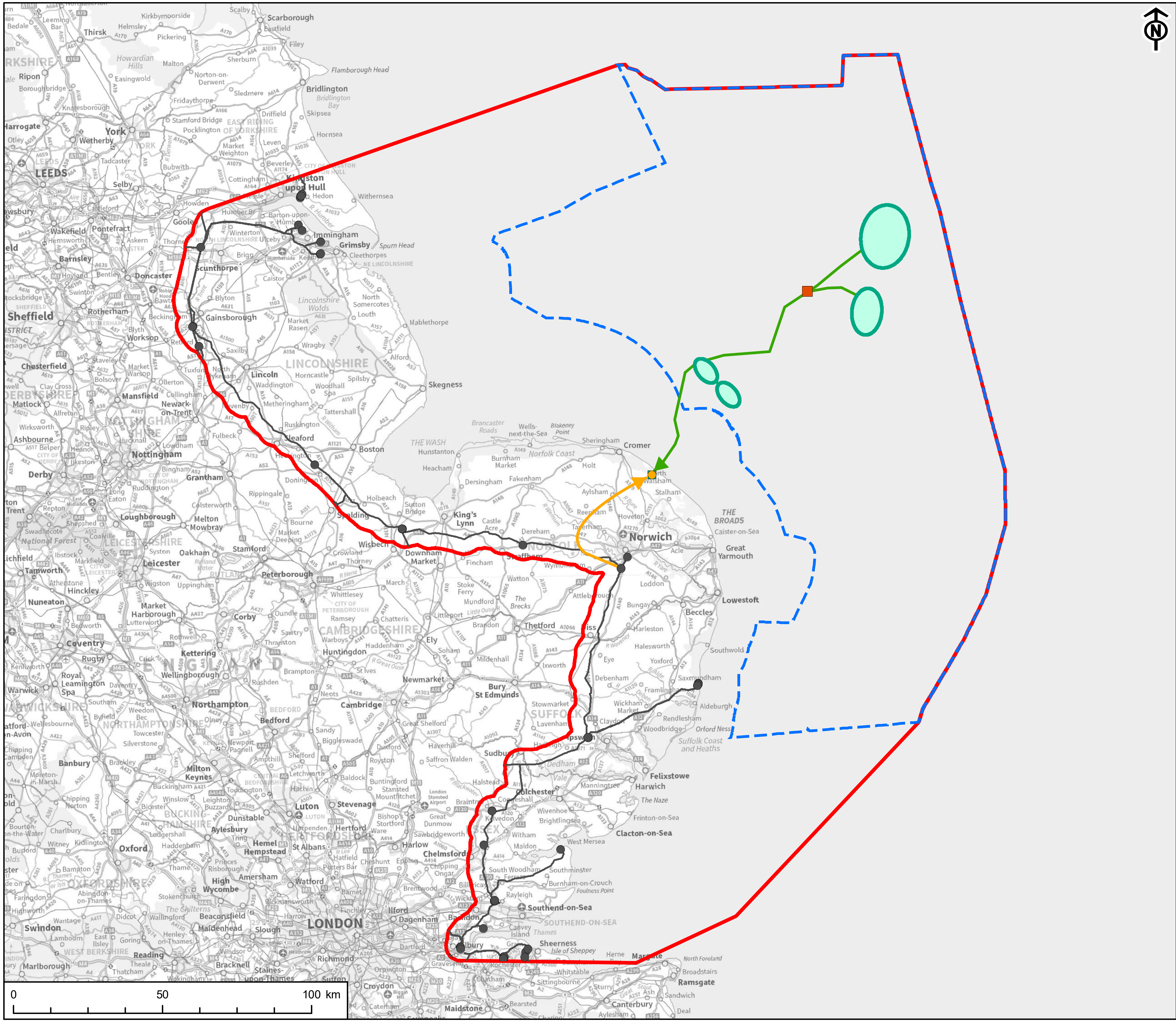

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- Existing Overhead Line
- Potential Onshore Network Extension OHL
- Potential Offshore Export Cable Route
- Conceptual Offshore Wind Project

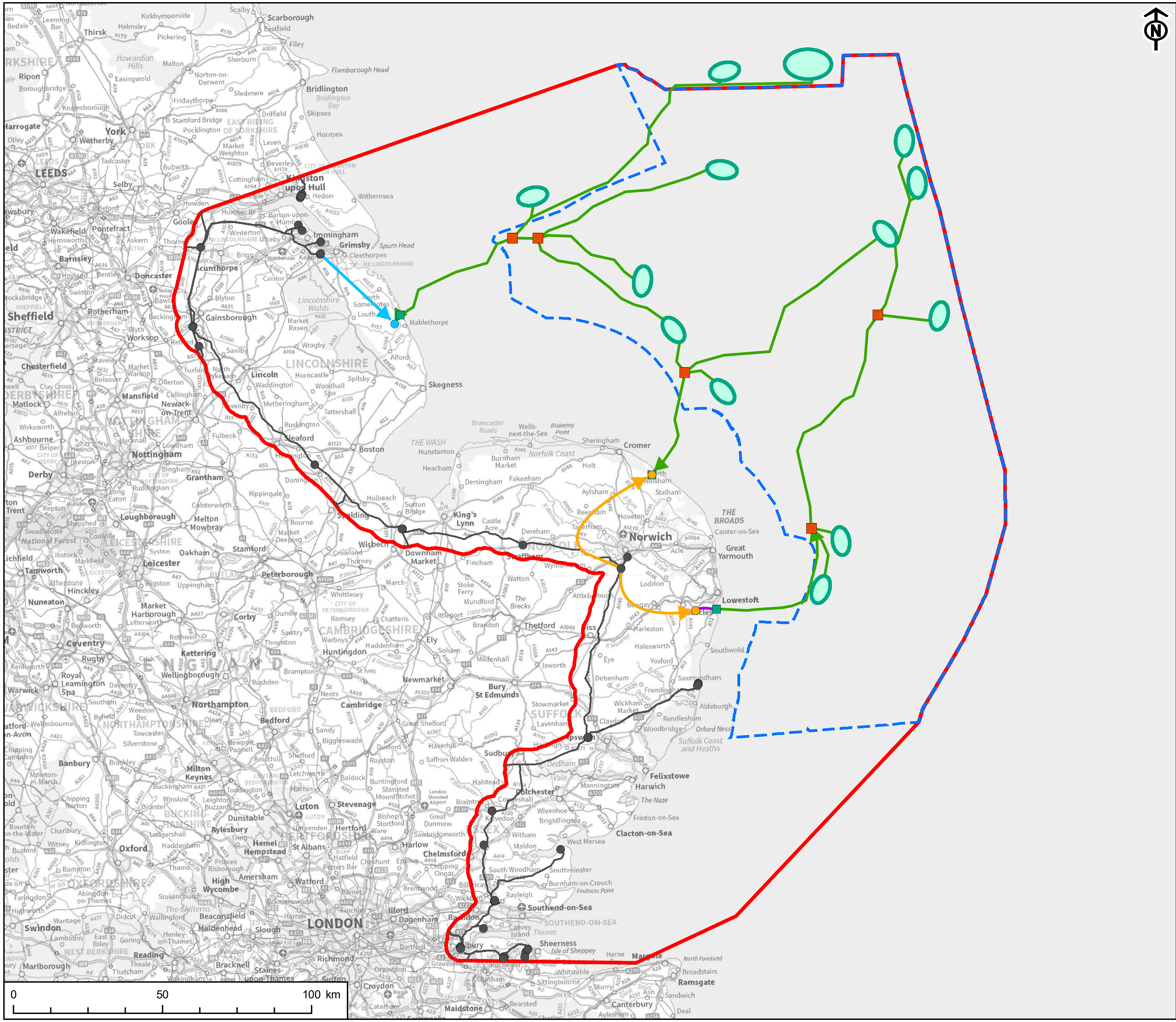
TITLE
APPENDIX D
GRID CONNECTION SCENARIO E
OVERVIEW

REFERENCE
ECGS_210416_D_v1

SHEET NUMBER: 1 of 1

DATE: 16/04/2021

Coordinate System: WGS 1984 Zone 30N



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- Potential Onshore Network Extension OHL
- Potential Offshore Export Cable Route
- Conceptual Offshore Wind Project

TITLE
APPENDIX D
GRID CONNECTION SCENARIO F
OVERVIEW

REFERENCE
ECGS_210416_D_v1

SHEET NUMBER
1 of 1

DATE
16/04/2021

Appendix E SWOT Analysis

Approach to SWOT

SWOT analysis is a simple tool that can be used to analyse the differences between strategies, or in this case, development scenarios or approaches, by considering the Stengths, Weaknesses, Opportunities and Threats (SWOT) associated with the scenario or approach being assessed.

SWOT allows the assessor to take consideration of a proposal both from an 'outside in' and an inside out' standpoint, by appraising the internal or intrinsic attributes of an approach and contrasting this to external influences upon a given scenario as follows:

- Internal attributes, characteristics or features of each scenario are categorised as:
  - Strengths; and
  - Weaknesses.
- External influences which may have potential to affect the success of each scenario are considered to be:
  - Opportunities; and
  - Threats.

Outputs of SWOT

The SWOT outputs for each of the four main scenarios for development to 2030 are presented below.

Scenario	Strengths	Weaknesses	Opportunities	Threats
A. Radial Connections	• Approach to planning and development of radial grid connection is well-known and understood. • Fewer third-party interdependencies such as spatial or temporal proximity as mainly developer-led. • While the total infrastructure footprint may be higher, the individual components required may be smaller, for example fewer cables within a cable route. High redundancy of assets requiring less protection. • Low technology risk or challenge due to known and established equipment.	• Largest footprint with resulting greatest potential to interact with constraints. • Greater competition with other parties for grid connection and landfall. • Increasing spatial engineering challenges due to competition for routeing / siting of grid connection.	• Established legal and regulatory regime allows process to proceed immediately. • Known responsibility for management of assets post consent and regulation under OFTO. • Ability for developer to design grid connection infrastructure specific to need. • Established technology and approach to development means that design understanding among regulators and stakeholders will not pose a risk to programme.	• Piecemeal approach to development with planning uncertainty and cumulative impacts. • Greatest potential to overlap or interact with spatial constraints and comparatively higher potential for impacts on environment overall. • Comparatively greater potential for impact on or disruption to coastal communities. • Level of environmental and community impact leads to greater consenting risk and risk of programme delay.
B. Offshore Coordination	• Coordinated scenario has a smaller physical footprint than radial scenario due to less infrastructure being required. • Less competition with other parties for grid connection and landfall. • Lower spatial engineering challenge with less competition for routeing / siting of grid connection including offshore ‘hubs’ or ‘nodes’. • Offshore ‘hubs’ or ‘nodes’ may have less impact on coastal communities than coastal or nearshore ‘hubs’ or ‘nodes’.	• Approach to planning and development of coordinated grid connection requires development. • Potential third-party interdependencies such as spatial or temporal proximity with other offshore wind or coordinated grid asset developers. • While the total infrastructure footprint may be lower, the individual components required may be larger, for example more cables within a cable route. Lower redundancy of assets and higher value requiring greater asset protection. • Potentially a higher level of cable protection / risk management than for radial connections.	• More coordinated approach to development should increase planning certainty and reduce cumulative impacts. • Lower potential to overlap or interact with spatial constraints and comparatively lower potential for impacts on environment overall. • Comparatively less potential for impact on or disruption to coastal communities due to requirement for less onshore infrastructure. • Level of environmental and community impact should lead to less consenting risk and risk of programme delay.	• Need to develop legal and regulatory regime or adapt existing to enable progress. • Need to establish responsibility relating to development and enduring operation and maintenance of coordinated grid connection infrastructure. • Need to establish a mechanism for developers to influence design and management. • New or emerging technology and approach to development could lead to delays with regulators and stakeholders and pose increased risk to programme (and potentially wider Net Zero targets as a result if not managed appropriately).

Scenario	Strengths	Weaknesses	Opportunities	Threats
		• Higher technology risk or challenge due to new or emerging technology.		
C. Onshore Coordination	• Approach to planning and development of radial grid connection and transmission expansion is well-known and understood. • Coordinated scenario has a smaller physical footprint than a standard radial scenario but each project still requires its own grid connection. Reduction is in mainly in onshore routeing requirements for each offshore wind development. • Fewer third-party interdependencies as mainly developer-led (offshore wind developer and Transmission Owner). • High redundancy of assets requiring less protection. • Low technology risk or challenge due to known and established equipment (unless siting offshore 'hubs' or 'nodes' within 12nm).	• Level of competition with other parties for grid connection and landfall will still exist. • Requires coordinated investment in the transmission network at least in parallel with offshore wind development in order to prevent delays.	• Established legal and regulatory regime allows process to proceed immediately. • Known responsibility for management of assets post consent and regulation under OFTO. • Ability for developer to design grid connection infrastructure specific to need. • Established technology and approach to development means that design understanding among regulators and stakeholders will not pose a risk to programme. • Opportunity to build out to the coast once rather than build in multiple times for multiple offshore wind farms. • Coastal and nearshore 'hubs' or 'nodes' are large infrastructure with potential for impact on or disruption to coastal communities but less impact overall due to less onshore routeing requirements.	• Extension of transmission network to the coast and establishment of coastal or nearshore 'hubs' or 'nodes' could be challenging as a result of landscape/visual impacts and impacts on settlements including coastal communities. • Greater potential for impact and cumulative impact in the nearshore environment as developers seeking connection at the same location so comparatively higher potential for impacts on environment overall. • Level of environmental and community impact leads to consenting risk and risk of programme delay.
D. Blended Coordination	• Coordinated scenario has a smaller physical footprint than radial scenario due to less infrastructure being required. • Less competition with other parties for grid connection and landfall.	• Approach to planning and development of coordinated grid connection requires development. • Potential third-party interdependencies such as spatial or temporal proximity with other	• More coordinated approach to development should increase planning certainty and reduce cumulative impacts. • Lower potential to overlap or interact with spatial constraints and	• Need to develop legal and regulatory regime or adapt existing to enable progress. • Need to establish responsibility relating to development and enduring operation and maintenance of

Scenario	Strengths	Weaknesses	Opportunities	Threats
	• Lower spatial engineering challenge with less competition for routeing / siting of grid connection including offshore 'hubs' or 'nodes'. • Offshore 'hubs' or 'nodes' may have less impact on coastal communities than coastal or nearshore 'hubs' or 'nodes'. • Approach to planning and development of radial grid connection and transmission expansion is well-known and understood.	offshore wind or coordinated grid asset developers. • While the total infrastructure footprint may be lower, the individual components required may be larger, for example more cables within a cable route. Lower redundancy of coordinated grid connection assets and higher value requiring greater asset protection. • Potentially a higher level of cable protection / risk management than for radial connections. • Higher technology risk or challenge due to new or emerging technology used in coordinated grid connection infrastructure.	comparatively lower potential for impacts on environment overall. • Comparatively less potential for impact on or disruption to coastal communities due to requirement for less onshore infrastructure. • Level of environmental and community impact should lead to less consenting risk and risk of programme delay. • Opportunity to build out to the coast once rather than build in multiple times for multiple offshore wind farms. • Coastal and nearshore 'hubs' or 'nodes' are large infrastructure with potential for impact on or disruption to coastal communities but less impact overall due to less onshore routeing requirements.	coordinated grid connection infrastructure. • Need to establish a mechanism for developers to influence design and management. • New or emerging technology and approach to development could lead to delays with regulators and stakeholders and pose increased risk to programme. • Extension of transmission network to the coast and establishment of coastal or nearshore 'hubs' or 'nodes' could be challenging as a result of landscape/visual impacts and impacts on settlements including coastal communities.

Imagine it.
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