East Coast Grid Spatial Study

Summary Report
April 2021

Prepared for:

Project Partners:

Foreword

To achieve net zero as a country, we will need to utilise the marine area in a way that both creates new opportunities for businesses to invest and does so in a way that is sensitive to the importance of its rich ecosystems and biodiversity.

The Government is committed to 40 GW of offshore wind by 2030. Further, the Committee on Climate Change estimates that we could need 100GW or more of offshore wind by 2050 as we step away from fossil energy for good. Whatever the exact numbers, delivery will need a step change in approach in a range of areas, not least in the way we connect this capacity to the grid, facilitating delivery of the power to where it's needed through ensuring connections are more coordinated and planned.

There are clear cost advantages of doing so. Numerous studies over the last decade have identified significant potential capital expenditure savings of a more coordinated approach as opposed to continuing with radial links; the most recent of these was National Grid Electricity System Operator's Offshore Coordination Phase 1 report published in late 2020 which estimated in total £9bn in savings by 2050. There are also clear societal and environmental advantages, such as reduced onshore infrastructure requirements meaning lesser impacts on local coastal communities and a smaller overall footprint for the infrastructure.

There are also pressing spatial considerations that need to be taken into account. In its role of manager of seabed leasing around England, Wales and Northern Ireland, The Crown Estate has the advantage of seeing demand for seabed space from a diverse range of sectors in addition to offshore wind – aggregates, carbon storage reservoirs and telecoms cables to name three – and needs to take into consideration the needs of other sea users, such as commercial fisheries, in considering leasing activity. The Marine Management Organisation has a similarly broad perspective on future uses of the marine area, through its role as the marine planning authority for England and as a marine regulator. The development of the English Marine Plans has to account for social, environmental and economic uses of an increasingly busy marine area across all sectors.

As such, a key question we now face as a nation is how can we design a joined-up system to optimise the sustainable use of the seabed to realise its net zero potential, in a way that also delivers other aspirations for the sea, including protection of the environment and tangible economic benefits? In considering that question, a key element is grid connection which includes implications onshore as well as in the marine area.

This independent study – one of the pilot projects delivered under the Offshore Wind Evidence and Change programme (OWEC) – on the spatial context of developing grid connection solutions along the east coast of England starts to answer this question. The Crown Estate, National Grid Electricity System Operator, National Grid Electricity Transmission and the Marine Management Organisation have come together to commission this study with the aims of: (i) developing a deeper understanding of potential terrestrial and marine constraints that future offshore wind farms connecting into the east coast of England are likely to face as and when grid connection solutions are developed under the prevailing radial connection model; (ii) assessing the risks and issues to deployment of offshore wind projects that these constraints could introduce; and (iii) considering if adopting a more coordinated or integrated approach to offshore transmission in this region could mitigate these risks and issues.

The origin of this project was a desire to introduce an evidence base around the spatial context of developing offshore transmission infrastructure, which has historically been anchored around economic and technical considerations. We believe this will become increasingly important as offshore wind deployment accelerates over the coming decades, with the marine area becoming increasingly busy and in need of more explicit forward planning and strategic decision-making with a focus on coexistence. The east coast of England was chosen as the initial area for review due to the expected growth of offshore wind in the region over the coming years given the excellent wind resource in the area. It was also chosen as there are significant other infrastructure projects seeking to connect in the region (e.g. interconnectors) adding to the pressure and disruption for communities and the environment. Further studies may be necessary in other regions in the future.

We hope this desktop study will provide a useful contribution into the current Offshore Transmission Network Review, OWEC and other programmes, bringing into the foreground the importance of spatial considerations for offshore transmission development. Whilst the report sets out some considerations and recommendations, it is not comprehensive and should not be seen as providing definitive conclusions. We will continue to work with industry, Government, broader stakeholders and departments as we share the findings of this work and explore how, together, we can deliver coordinated outcomes for the benefit of the nation.

Will Apps,
Head of Energy Development,
The Crown Estate

Trudi Wakelin,
Director of Marine Planning, Licensing & Blue Belt, **Marine Management Organisation**

Julian Leslie,
Head of Networks,
National Grid Electricity System Operator

Hedd Roberts,
Head of Customer Solutions,
National Grid Electricity Transmission

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1. Introduction

1.1 Overview of the Study

AECOM was commissioned by The Crown Estate (TCE), in partnership with National Grid Electricity Transmission (NGET), National Grid Electricity System Operator (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 offshore wind farms could connect to the electricity transmission system along the east coast of England in the future.

The study has been commissioned within the context of the current wider policy review[1] being undertaken by the Department for Business, Energy & Industrial Strategy (BEIS) and Office of Gas and Electricity Markets (Ofgem) into how grid connections for offshore wind farms are delivered.

The collaborative approach to the study brings together a number of the key organisations that have a strategic interest and role to play in the connection of future offshore wind capacity. At a time when the approach to grid connections is being reviewed with an increased emphasis on coordinated solutions, the spatial context of future offshore wind grid connections is an important consideration which needs to sit alongside economic, social, technology and broader environmental considerations.

1.2 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.

1.3 Approach to the Study

The approach to the study was designed around the aims described above. It comprised the following key activities which are described in subsequent sections of this report.

- Undertaking a strategic-scale constraints mapping exercise within the east coast region in order to identify terrestrial and marine spatial constraints with the potential to affect the deployment of offshore wind grid connection infrastructure (*Aim (i)*).
- Undertaking a sub-regional level assessment of terrestrial and marine spatial constraints to understand the extent to which they pose risks to, or create issues for, the deployment of offshore wind grid connection infrastructure, particularly radial connections (*Aim (ii)*)
- Developing and assessing a hypothetical offshore wind development scenario and grid connection scenarios in order to evaluate the strengths and weaknesses of radial and alternative coordinated approaches to offshore wind grid connection infrastructure (*Aim (iii)*).
- During the study a programme of stakeholder engagement was held which included relevant local authorities, environmental groups, offshore wind developers and other seabed users. The objective of this was primarily to raise awareness of the study and discuss the approach so that feedback, including around key terrestrial and marine spatial constraints of concern, was addressed.

[1] The Offshore Transmission Network Review: https://www.gov.uk/government/publications/offshore-transmission-network-review

1.4 This Report

This report provides a summary of the work undertaken and the key findings which have emerged from it. Detailed spatial characterisation work and scenario assessment underpins the summary findings presented in this report. The structure of the report is described in Table 1below.

Section	Description of Contents
Section 2. Study Area Characterisation	This section describes the results of a strategic-scale constraints mapping exercise within the east coast region highlighting spatial constraints which have been identified.
Section 3. Offshore Wind & Grid Connection Scenarios	This section describes hypothetical offshore wind and grid connection scenarios which were used to assess the strengths and weaknesses of alternative approaches to future grid connections.
Section 4. Key Study Findings	This section describes the key findings from the study area characterisation and scenario-based analysis and highlights key constraints and opportunities.
Section 5. Conclusions & Recommendations	This section sets out the conclusions of the study putting them into a strategic context with a focus on future approaches to offshore wind grid connections. It also sets out recommendations to take forward.

Table 1. Summary Report Structure and Contents

2. Study Area Characterisation

2.1 General Approach

The study area characterisation was informed by a combination of constraints mapping and desk-based analysis to identify key terrestrial and marine spatial constraints and consideration of which of these factors could influence the development of offshore wind farm grid connection infrastructure in the future.

2.2 The Study Area

The study area is illustrated in Figure 1. It allowed 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 the counties of Lincolnshire, Norfolk, Suffolk and Essex. It has been split into four sub-regions which follow county boundaries extended out to inshore waters within the 12nm limit for the purposes of characterising the study area. It has been developed in taking into account the following factors:

- 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[2];
- 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.

2.3 Terrestrial and Marine Spatial Considerations

Table 2 below describes the range of terrestrial and marine constraints and considerations which were identified as part of the study area characterisation. The subsequent sections provide a summary of key spatial constraints and considerations for each sub-region within the study area. Reference should also be made to the constraints plans contained in **Appendix A**. This summary report focuses on those key spatial constraints which exert the greatest influence over future offshore wind grid connections and so may not make reference to all of the types of constraints referred to in the table.

Themes	Example Terrestrial Spatial Constraints and Considerations	Example Marine Spatial Constraints and Considerations
Biological Environment	This includes designated sites or areas including Special Protection Areas (SPAs), Special Areas of Conservation (SACs) and Sites of Special Scientific Interest (SSSIs)	This includes designated sites or areas including Special Protection 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.

[2] 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
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 2. Summary of Spatial Constraints Considered

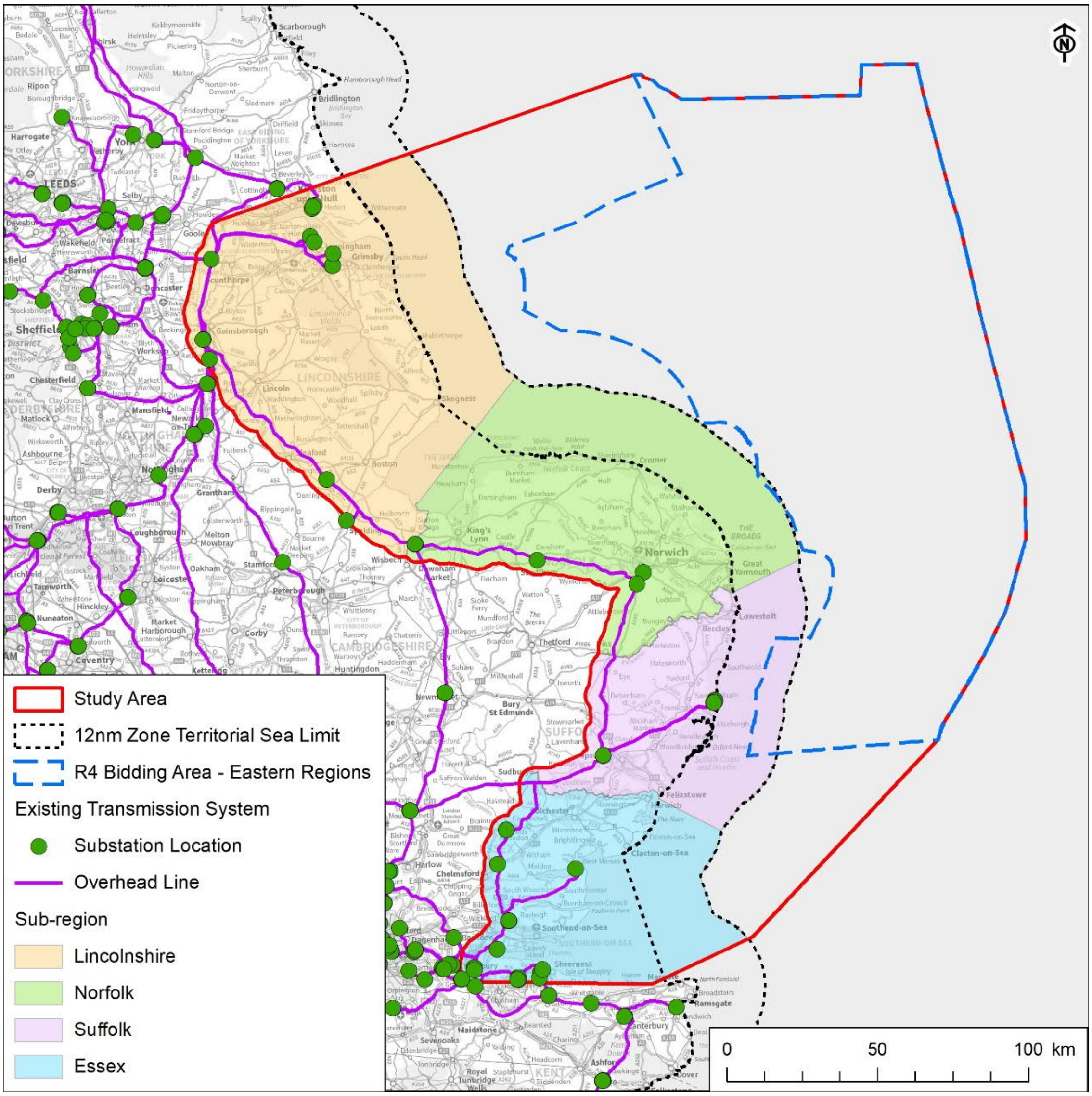

Figure 1. East Coast Study Area

2.4 Lincolnshire Sub-region

The Lincolnshire sub-region extends from the Humber Estuary to The Wash. To the north of the sub-region, the electricity transmission system extends to the coast in the Humber area. However, moving south the system is some way inland and the nearest potential grid connection points are Cottam and Bicker Fen, up to 70 km away. Offshore wind developments connecting in this sub-region could require significant onshore cable routes.

As the sub-region for the study extends some way inland, population density is lower compared to other parts of the wider study area. There are larger settlements to the north associated with the industrial areas around the Humber but further south and inland settlements tend to be smaller and more spread out. Those located in coastal areas, particularly to the south, are generally associated with tourism. Moving inland, land use is predominantly agricultural.

Environmental designations are present within inshore and offshore waters as well as onshore. The coastal areas to the far north and south of the sub-region include the Holderness Inshore MCZ and Humber Estuary SAC, SPA, Ramsar, and SSSI which extends south along the coast to Theddlethorpe as well as Inner Dowsing, Race Bank and North Ridge SAC and The Wash and North Norfolk SAC. Moving inland, environmental designations are generally smaller in scale and scattered across the sub-region. However, the Lincolnshire Wolds AONB occupies a significant area and could be a consideration with regard to offshore wind farms connecting to Cottam or Bicker Fen or the expansions of the transmission system into the coastal areas.

2.5 Norfolk Sub-region

The coastline of the Norfolk sub-region extends from The Wash to Lowestoft. The transmission system is within approximately 30-35 km of the coastline, with potential grid connection points at Necton and Norwich Main Substations. A number of existing or planned offshore wind farms connect to the transmission system at these locations including Hornsea 3, Dudgeon and Sheringham Shoal (including extensions) and Boreas and Vanguard.

The coastline and associated hinterland is 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. Norwich Main Substation is to the south of the city meaning offshore wind farm grid connections from the north Norfolk coast must route around the city.

The majority of the coastline and inshore areas are subject to environmental designations. This includes ecological designations including The Wash and North Norfolk SAC, Cromer Shoals MCZ and the Southern North Sea SAC as well as landscape designations including the Norfolk Coast AONB and Norfolk Broads National Park. The designations along the coastline do not necessarily prevent cable routes through them but reinforce the sensitivity of the sub-region. Moving inland, there are a range of designated sites present which range in size from smaller sites which are relatively avoidable, to larger sites, such as the Broads SAC, which would be a more significant spatial constraint.

2.6 Suffolk Sub-region

The Suffolk sub-region extends from Lowestoft to Felixstowe with approximately 65 km of coastline. To the north of the sub-region, the transmission system is generally located some 35 km inland. However, the nearest existing potential grid connection point is at Norwich Main Substation within the Norfolk sub-region. Further south, the transmission system extends out to the coastline where it connects to the existing Sizewell Nuclear Power Station. A number of existing and planned offshore wind farms and interconnectors connect to the transmission system in this area which constrain future opportunities. At the far south of the study area where it meets the Essex sub-region, there is an additional grid connection point at Bramford Substation.

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.

Offshore, much of the sub-region is subject to ecological designations, with the Southern North Sea SAC present across much of the study area, Orford Inshore MCZ off the coast at Aldeburgh and the northern edge of the Thames Estuary SPA. The immediate coastal area is subject to ecological and landscape designations for much of its length. The former includes a number of SPAs, SACs and SSSIs while the latter is the Suffolk Coast and Heathlands AONB. The AONB extends some way inland towards the transmission system as it is routed south west from Sizewell to Bramford.

2.7 Essex Sub-region

The Essex sub-region extends from Felixstowe to the Isle of Sheppey so incorporates the mouth of the River Thames. The existing transmission system extends to the coast at several locations including Bradwell, and several locations around the Isle of Grain and Tilbury to the south. The main transmission line travels southwest from Ipswich, past Colchester towards Tilbury, passing within 20km of the coast at several locations.

The coastal environment is less densely populated or developed. The main settlements are Colchester, in the north, and 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, to Sheerness and Eastchurch on the Isle of Sheppey.

The inshore and offshore waters in this part of the study area are comparatively more constrained. A combination of other offshore wind farms, interconnectors and shipping and navigations channels as well as ecological designations are all present for much of the area. Estuaries, saltmarshes and mudflats dominate large parts of the coastline and coincide with environmental designations including Essex Estuaries SAC; Stour and Orwell Estuaries SPA; Foulness SSSI, Hamford Water SPA; Colne Estuary Ramsar site and SPA; Blackwater Estuary Ramsar and SPA; Crouch and Roach Estuaries SPA; and Colne Estuaries MCZ, Dengie Ramsar site and SPA; Foulness Ramsar site and SPA; Benfleet & Southend Marshes Ramsar and SPA. Offshore, the Southern North Sea SAC, Margate and Long Sands SAC and Outer Thames Estuary SPA cover much of the sub-region to 12nm.

3. Offshore Wind & Grid Connection Scenarios

3.1 General Approach

In order to evaluate the strengths and weaknesses of radial and alternative coordinated approaches to future offshore wind farm grid connections, hypothetical scenarios were developed. These comprised fixed locations of potential offshore wind farm sites within the study area and considered alternative approaches to connecting them to the transmission system. It is important to note that these hypothetical locations were developed for assessment purposes only and are not a prediction or recommendation as to where future offshore wind development will or should take place.

3.2 Offshore Wind Development Scenario

A hypothetical offshore wind development scenario was established taking into consideration the UK Government's target of 40 gigawatts (GW) of installed offshore wind capacity by 2030, offshore wind farms currently in development and the parameters of The Crown Estate's Round 4 leasing process[3]. This scenario assumes that all known offshore wind projects within the study area will continue to develop as planned and therefore will connect to the transmission system using radial connections.

The purpose of the offshore wind development scenario was to establish a credible spatial scenario representative of how much and where offshore wind development might occur in the future. To this end, the study assumed a further 3.5 GW of additional[4] offshore wind capacity could be installed in the study area. In order to more effectively test radial and coordinated approaches, the scenario was comprised of seven 500 megawatt (MW) conceptual offshore wind farm projects as shown in Figure 2.

3.3 Grid Connection Scenarios

In developing the grid connection scenarios, consideration was given to the routeing and siting of the key components of a typical grid connection for an offshore wind project including potential landfall locations, grid connection points, underground and subsea cable routes as well as overhead line routes.

Landfalls

The coastline within the study area was reviewed to identify potential landfall areas for the purposes of developing and assessing hypothetical grid connection scenarios. This took into account the constraints mapping prepared as part of the study area characterisation. Key considerations during the review of potential landfalls included inshore constraints such as marine designated sites, physical factors including topography, landform and coastal erosion rates as well as proximity to coastal settlements and onwards routeing to potential grid connection points on the transmission system.

Grid Connection Points

In order to define the grid connection scenarios, the study considered existing and planned grid connection points and highlighted where extensions to the transmission system may provide benefits. The potential grid connection points comprised:

- Existing Grid Connection Points – These are existing substations or points on existing transmission system, for example an existing overhead line where a grid connection point could be located.

[3] In terms of the maximum individual project size (1.5GW) and in terms of the maximum capacity in any one area (3.5GW).
[4] This is additional to the known offshore wind projects in the study area.

- Future Grid Connection Points – These are based on known network reinforcements, such as new substations or overhead line extensions, which are under development or have been given a 'proceed' signal in the most Network Options Appraisal (NOA) 2019/20[5].
- Potential Network Extensions – These are potential grid connection points based on the hypothetical extension of the network to coastal or inshore 'hubs' or 'nodes'. These hypothetical extensions would require reinforcement and the development of new infrastructure such as overhead lines.

Grid Connection Scenarios

Four alternative grid connection scenarios were identified and are described in the sections below. An overview of the scenarios is provided in Figure 3 with larger scale plans in **Appendix B**.

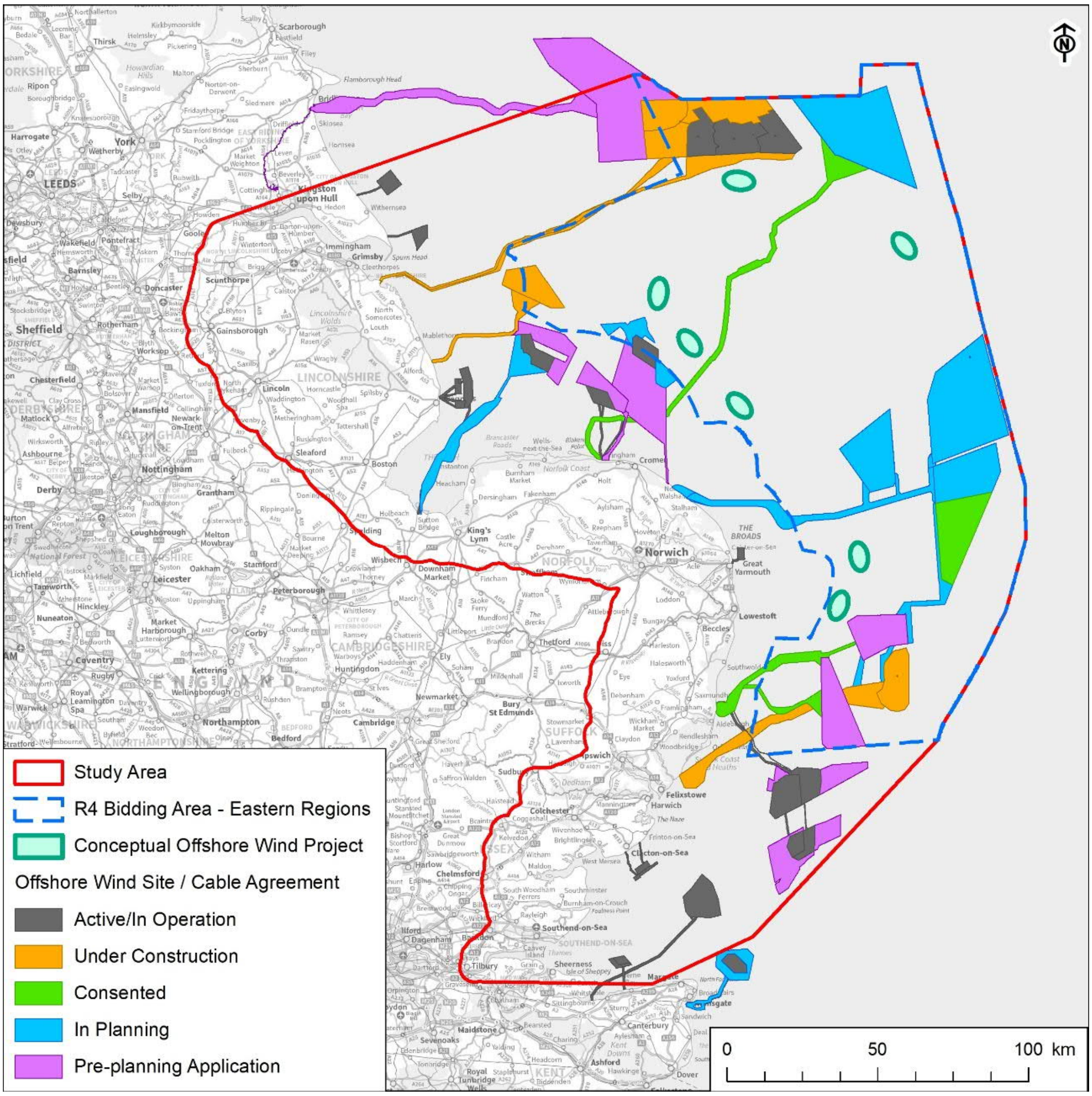

Figure 2. Hypothetical Offshore Wind Farm Scenario

[5] The analysis for this study was undertaken before the outcomes of NOA 2020/21 were published.

3.4 Grid Connection Scenario A – Radial Connection

In this scenario the radial approach to grid connection infrastructure applies. Each wind farm utilises its own radial connection to a grid connection point on the existing transmission system. In spatial terms this scenario requires the greatest amount of new infrastructure and as a result has the potential for greater spatial conflicts or impacts. This is because each offshore wind farm develops its own connection including seven subsea cable routes, seven landfalls and seven onshore cable routes to potential grid connection points.

3.5 Grid Connection Scenario B – Offshore Coordination

In this scenario it assumed that offshore 'hubs' or 'nodes' are established outside of the 12nm limit. Multiple offshore wind farms can connect to a single hub' in the same way that multiple generators onshore might connect to a single substation. The offshore 'hubs' are then connected to a grid connection point on the transmission system via a single export cable route. The benefit of this approach is that it reduces the amount of infrastructure required onshore, for example by reducing the number of landfalls or onshore cable routes required. However, it relies on offshore wind farms being in sufficient proximity to utilise a 'hub'.

3.6 Grid Scenario C – Onshore Coordination

In this scenario it is assumed that the existing onshore transmission system is extended to establish 'hubs' or 'nodes' in coastal or inshore areas within the 12nm limit. Offshore wind farms continue to utilise radial connections but because the grid connection point is located at the coast, it avoids the need for additional onshore cable routes onshore from offshore windfarms. The underlying premise of this scenario is to build infrastructure out to the coast once in order to avoid, for example, three offshore wind farms requiring three onshore cable routes. The benefit of this approach is that reduces the amount of infrastructure offshore wind developers require onshore; these benefits will be more apparent in areas where potential grid connections points are some way inland.

3.7 Grid Scenario D – Blended Coordination

This scenario assumes a blended approach to the development of grid connection infrastructure onshore and offshore. It reduces the overall amount of infrastructure which is required by utilising offshore 'hubs' to connect multiple offshore wind farms and then connecting to an expanded onshore transmission system in a coastal location via a single export cable route. In this scenario the extension of the transmission system reduces the length of onshore cable route required. Given the potential requirement for new overhead lines to a coastal location, the spatial benefits of this approach are most apparent when multiple offshore wind farms are connected to two or more offshore 'hubs' which are then connected at an expanded grid connection point.

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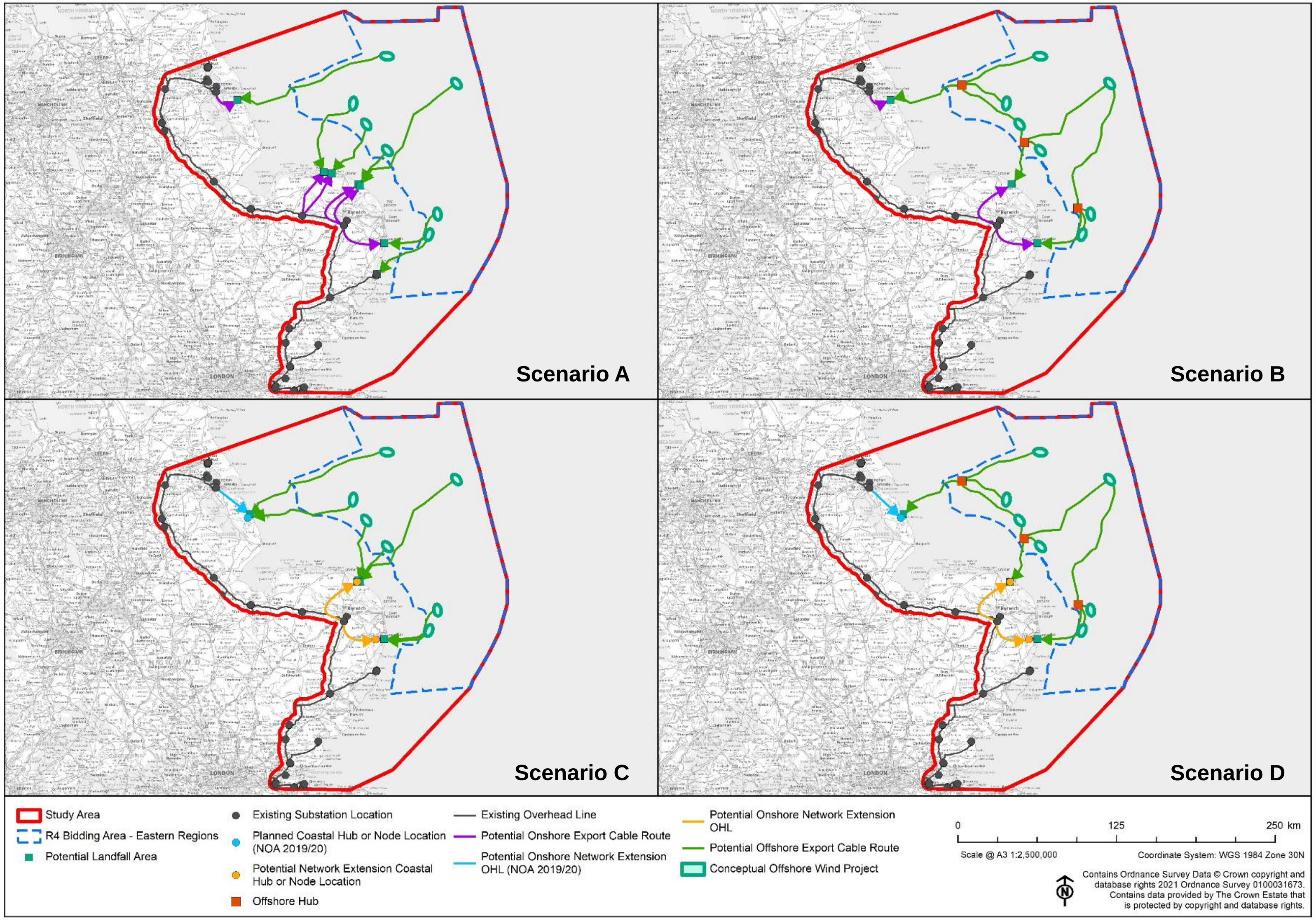


Figure 3. Overview of Grid Connection Scenarios

3.8 Grid Connection Scenarios - Comparison

Table 3 below provides a high-level overview of the main characteristics of each scenario in order to demonstrate how infrastructure requirements can increase or decrease according to which approach is taken to radial or coordinated grid connections. An important point to note is that for all coordinated scenarios considered, the overall infrastructure which is required may be reduced, however, the individual components may be larger. For example, coordinated export cable routes may be comprised of more individual cables requiring a larger installation corridor than would be required for standard radial export cable routes. Similarly, substation or converter stations may be larger for coordinated connections.

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 offshore '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 3. Grid Connection Scenario Characteristics

Key points to note from the comparison of the grid connection scenarios above include:

- In all of the coordinated scenarios, the total infrastructure footprint is smaller than the radial scenario.
- In the coordinated scenarios, the reduction in the infrastructure footprint relates to the reduction in onshore and inshore (12nm) cable routes.
- In the coordinated scenarios the infrastructure footprint in the offshore area (12 to 200 nm) increases because additional cables are required to connect to offshore 'hubs' or 'nodes'.
- In the onshore coordinated scenario, the footprint is smaller overall because it does not include subsea cable routes forming a network and connecting multiple offshore wind farms to 'hubs' or 'nodes'.

4. Key Study Findings

4.1 Introduction

This section describes the key findings from the characterisation of the study area and assessment of alternative grid connection scenarios. As this report is a summary it is focused on the main themes resulting from the assessment so does not focus on particular locations or constraints.

4.2 Study Area Characterisation

The study area characterisation identified a wide range of spatial constraints which could influence offshore wind farm grid connections within each of the sub-regions. While the type and nature of constraints varies by sub-region there are two common aspects of grid connection requirements where spatial constraints are likely to be most significant and pose a greater risk:

- Landfall locations, in particular the constraints such as designated sites, coastal settlements and existing or planned offshore wind farms which are present in coastal and inshore areas where cables come ashore.
- Grid connection points, in particular the proximity of these to the coastline and the scale and distribution of spatial constraints such as environmental designations or settlements between the coastline and potential grid connection.

Landfall Locations

The coastal nearshore and inshore areas are typically the most spatially constrained parts of the study area. As described in section 2, large parts of the coastline and adjacent inshore areas within each of the sub-regions are subject to environmental designations and/or are well developed with coastal settlements spread along the coast.

While these spatial constraints do not prevent the development of offshore wind grid connections under either radial or coordinated approaches, they do highlight the need to consider future grid connections in the context of long-term targets for offshore wind capacity. In the short term it may be possible to continue promoting radial connections but the number of landfalls available for future offshore wind projects will reduce and cumulative impacts could become a significant risk. A coordinated approach to grid connections in which multiple offshore wind farms connect to an offshore 'hub' and utilise a single export cable route and landfall will be more sustainable in the long term and would maximise the value of landfalls.

Proximity to the Transmission System

The proximity of potential grid connection points to the coastline was identified as a key spatial consideration. While some potential grid connection points are located at or close to the coast, for example at the Humber Estuary in Lincolnshire or at Sizewell in Suffolk, opportunities for future grid connections may be more limited due to spatial constraints or other planned offshore wind and interconnector developments. Elsewhere within the study area the transmission system is located some way inland, for example in north Norfolk and south Lincolnshire the nearest potential grid connect points are between 30 and 50 km inland.

Long distances do not prevent the development of offshore wind grid connection but the further inland connection points are located, the more spatial constraints will present a risk (in particular settlements and land use), As the analysis in section 3 demonstrates, opportunities to expand the transmission into coastal areas and establish coastal or inshore 'hubs' could prevent the need for multiple long distance onshore cable routes. However, the extension of the transmission system may require new overhead lines to be constructed to coastal areas, which may result in permanent landscape and visual impacts compared to mainly temporary impacts from underground cables. This would need to be carefully planned to maximise potential spatial benefits and reduce long term impacts associated with overhead lines.

Sub-regional Sensitivities

At sub-regional level, the study area characterisation highlights that some locations are more spatially constrained than others. For regions such as Norfolk and Suffolk, which are spatially constrained due to a combination of environmental designations, coastal settlements and existing and planned offshore wind developments, the early deployment of coordinated grid connections is likely to be beneficial and will support more installed wind capacity in the long-term. However, other regions such as Lincolnshire may be less sensitive to further radial connections in the short to medium term because there are fewer spatial constraints or there are opportunities to address those which are present in the design of future grid connections. Notwithstanding this sub-regional sensitivity, in the long term a coordinated approach will be more beneficial as it could connect larger amounts of offshore wind with less infrastructure.

4.3 Offshore Wind Development & Grid Connection Scenarios

The grid connection scenarios were assessed using a Strengths, Weaknesses, Opportunities and Threats (SWOT) framework, a summary of which can be found in **Appendix C**. This included consideration of number of aspects which are not considered directly relevant to the spatial constraints which are the focus of this study, but nevertheless provide valuable context to the wider evaluation. The following sections set out key findings emerging from this assessment.

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 relatively close to one another to provide meaningful benefits. 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 would appear to be more limited.

While not the focus of the study, when offshore wind development happens, the temporal proximity of offshore wind farms is another 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 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 modular 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[6] which describes a modularised approach which builds up aligning to offshore wind capacity.

Onshore Coordination

The study area characterisation highlighted the proximity of potential grid connection points as a key spatial constraint, this is consistent with the findings of the scenario assessments which highlight the potential reduction in infrastructure requirements if the transmission system could be extended. While changes to the transmission system can be expected in response to offshore wind growth, these may be smaller incremental changes or larger scale reinforcements. The latter does provide spatial benefits

[6] https://www.nationalgrideso.com/future-energy/projects/offshore-coordination-project

particularly when it occurs in parallel with offshore coordination and results in the extension of the network into coastal areas.

As noted in previous sections, the premise of 'building out once' to connect offshore wind farms instead of multiple offshore wind farms building in multiple times' can reduce spatial constraints and impacts as well as impacts over time. However, extension of the transmission system may require new overhead lines to be constructed to coastal areas, resulting in different types of impact to those which result from multiple underground cables.

Offshore Coordination

There are two important points emerging from analysis of this scenario. Firstly, 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'.

Secondly, the size of infrastructure which is required as part of coordinated grid connections. As described in section 3, 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.

These issues do not diminish the benefits of offshore coordination however. Rather they highlight 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. This is particularly the case at landfall and onshore (where coastal settlements could be impacted) as well as offshore where infrastructure requirements may also differ.

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 are 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 support coordinated grid connection solutions.

5. Conclusions & Recommendations

5.1 Conclusions

The study has identified the key terrestrial and marine constraints within the east coast region in order to:

(i) Establish an understanding of the study area's spatial context in particular key spatial constraints including settlement, environmental designations and other land or sea users,

(ii) Evaluate the risks which these constraints present to future offshore wind deployment under radial and coordinated models, and

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

The east coast study area is substantial extending from the Humber Estuary in the north to Thames Estuary in the south. As a result, the type, nature, scale and distribution of constraints varies quite significantly. However, in more general terms, the key constraints which influence the approach to offshore wind grid connections tend to relate to the following:

- The inshore area: 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 a number of cable routes and the potential for future grid connections routes.
- The coastal area: Similar to the inshore area, large parts of the coastline and adjacent onshore 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.
- Grid Connection Points: The proximity of the transmission system to coastal areas is one of the key factors which influences the design of offshore wind grid connections. While some grid connection points are located in coastal areas, much of the existing transmission network is located some way inland requiring long onshore cable routes. While existing coastal locations are preferable, opportunities at locations such as the Humber or Sizewell may be more limited due to existing or planned projects. Extending the transmission system to coastal areas could provide benefits in reducing the number of longer onshore cable routes.

While certain risks and issues will be site or route specific, they do not necessarily rule out the use of radial connections. In broad terms, the type of infrastructure which is required for a coordinated connection is similar to that for a radial connection. The main risk relates to the long-term sustainability of utilising radial connections, particularly in the context of offshore wind targets. There are 'pinch points' such as landfalls where spatial constraints will ultimately limit the availability of suitable landfalls. In the long term, a coordinated approach to grid connections is more sustainable and will maximise the offshore wind capacity connected to the transmission system via less infrastructure.

However, radial connections should not be entirely discounted. This approach has supported the development of more than 10GW of offshore wind to date and is likely to still have a role to play, particularly as the technologies required for coordinated solutions are in their infancy. What the sub-regional study area characterisation has highlighted is that some parts of the east coast region are more spatially constrained than others, and therefore potentially more sensitive to radial connections in the shorter term. This is particularly the case in those parts of the east coast which have experienced greater levels of offshore wind development to date. Ideally the decision between the choice of radial or coordinated connections should consider the regional sensitivity in the context of long-term offshore wind targets.

The alternative grid connection scenarios considered as part of this study have demonstrated some of the benefits of coordinated approaches. The 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, for example on coastal settlements. However, coordinated grid connections will also require additional infrastructure such as offshore ‘hubs’ or ‘nodes’ as well as additional subsea cable routes from offshore wind farms to them. In addition, the individual components which make up a coordinated grid connection will typically be larger than those for a radial connection, for example a cable route may be comprised of more cables so has a larger footprint. The key point is ensuring that, as and when coordinated grid connections are developed, stakeholders understand the difference in the scale of infrastructure that could be proposed.

5.2 Recommendations

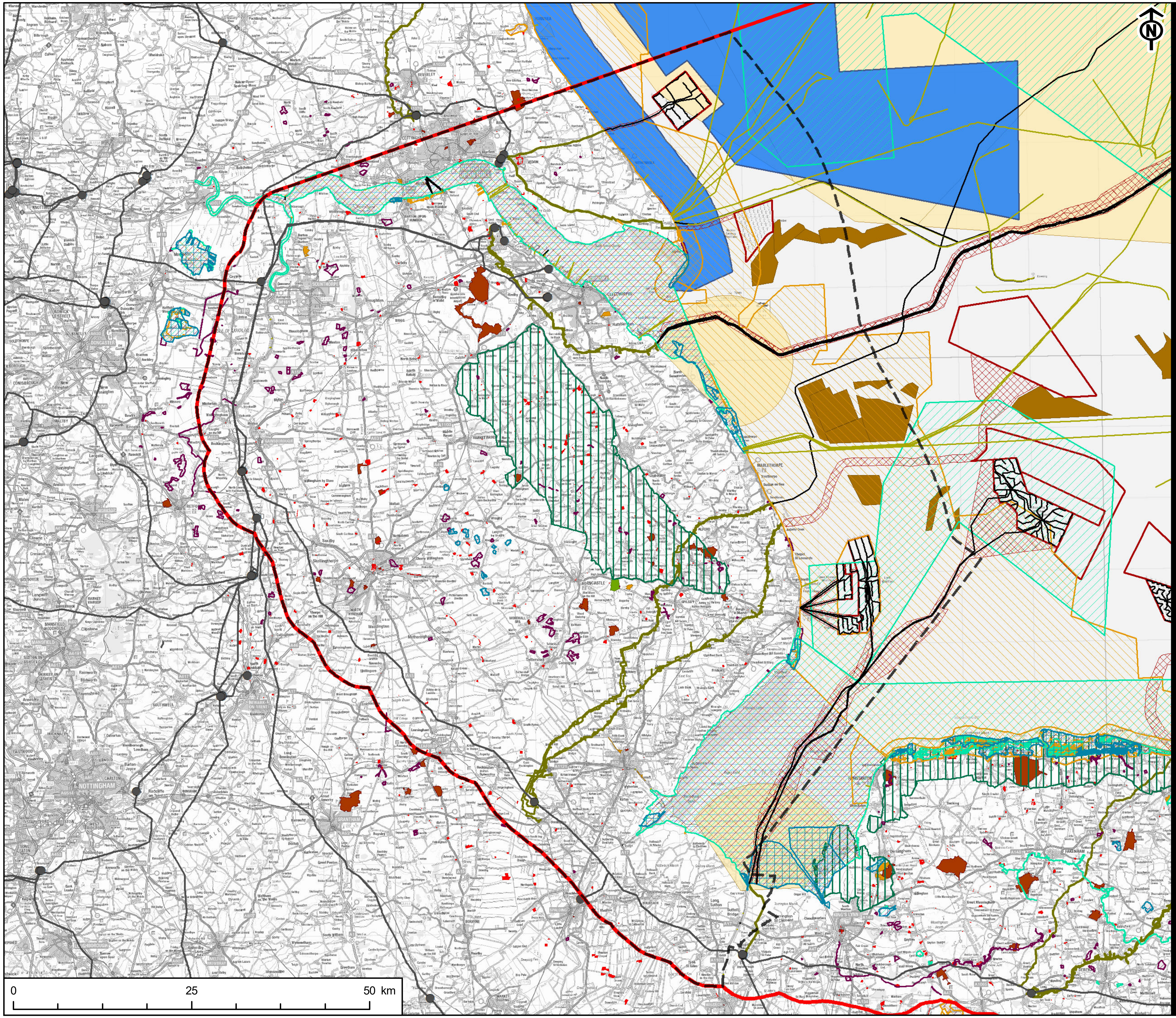
Table 4 sets out a number recommendations and potential areas of further work resulting from this study. These are interlinked around areas where further work and consideration of processes, roles and responsibilities may help to support and establish framework for the development of coordinated approaches to future offshore wind grid connections.

Theme	Recommendation
Strategic planning	There are range of spatial and network planning processes which could be utilised to provide a spatial framework to encourage and drive coordination. This includes marine planning, local plans and network planning. These existing processes could be utilised in their own right or alternatively similar studies to this could be undertaken focused on other regions around the UK. It may be beneficial to consider longer-term regional spatial plans for offshore wind and associated grid connection and transmission infrastructure. These would have the benefit of providing clarity to a wide range of stakeholders from government to local communities.
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.
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. 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 leasing. The objective should be to support long term planning of coordinated grid connection infrastructure beyond leasing rounds.
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 in order to balance short and long term objectives. The investment required for development of coordinated grid connection and transmission infrastructure is

Theme	Recommendation
	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 and operate such assets.
Roles and responsibilities	Given the number of actors in the process, it would be appropriate to gain a common understanding of the roles and responsibilities of each to ensure that they are working collaboratively and are empowered to support coordinated approaches.
Pilot project(s)	Consideration should be given to identifying potential ‘anchor’ projects, i.e. offshore wind farm developments which might provide the opportunity to pilot a coordinated grid connection model. This could provide opportunities to test emerging technologies using a modularised approach to building an integrated offshore network and also stress test the effectiveness of any new or amended policy regimes.

Table 4. Study Recommendations

Appendix A Study Area Characterisation Plans



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

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

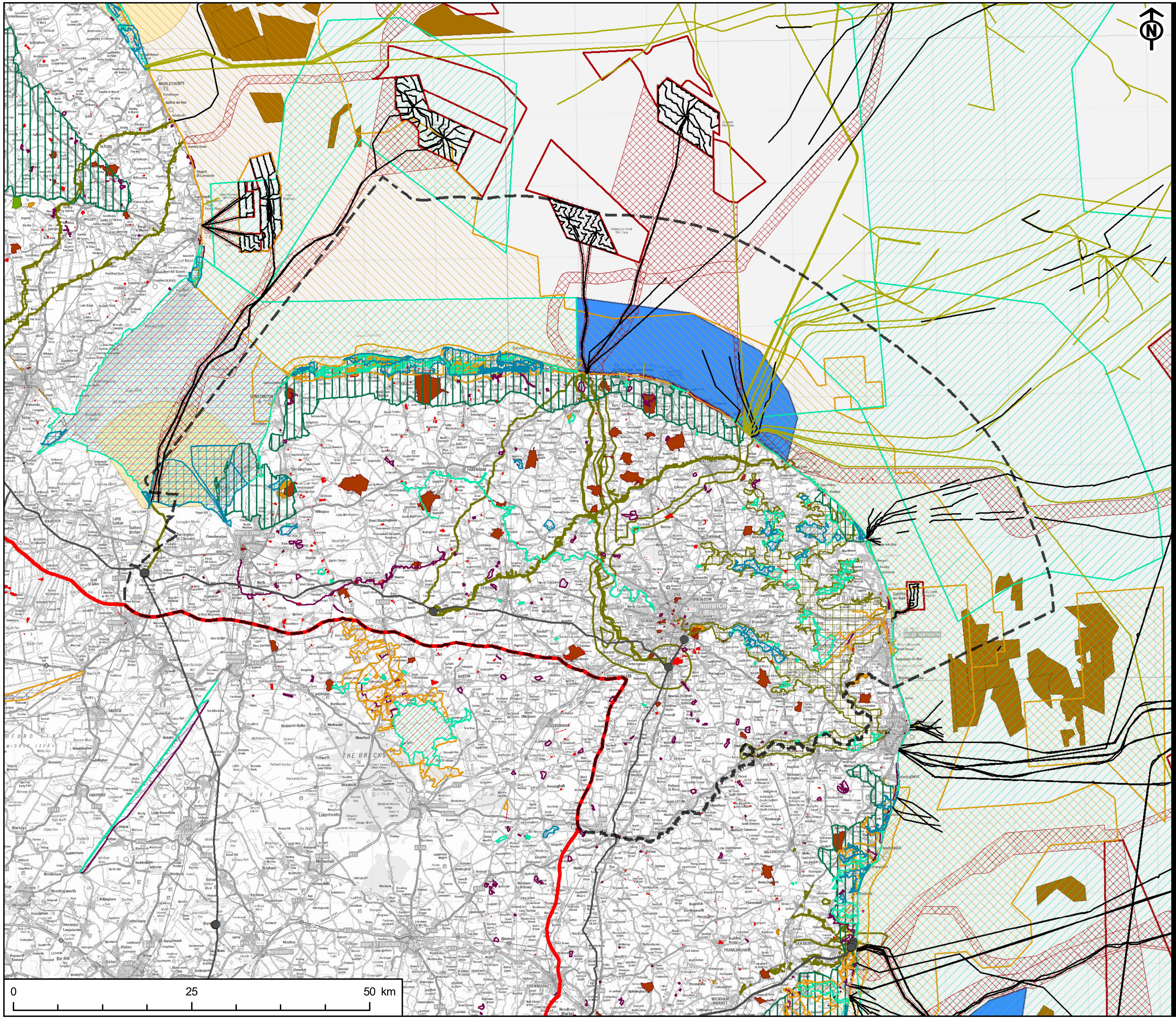
TITLE
APPENDIX A
STUDY AREA CHARACTERISATION
LINCOLNSHIRE SUB-REGION

REFERENCE
ECGS_210318_SR_A_v1

SHEET NUMBER
1 of 4

DATE
18/03/2021

Coordinate System: WGS 1984 Zone 30N



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

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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

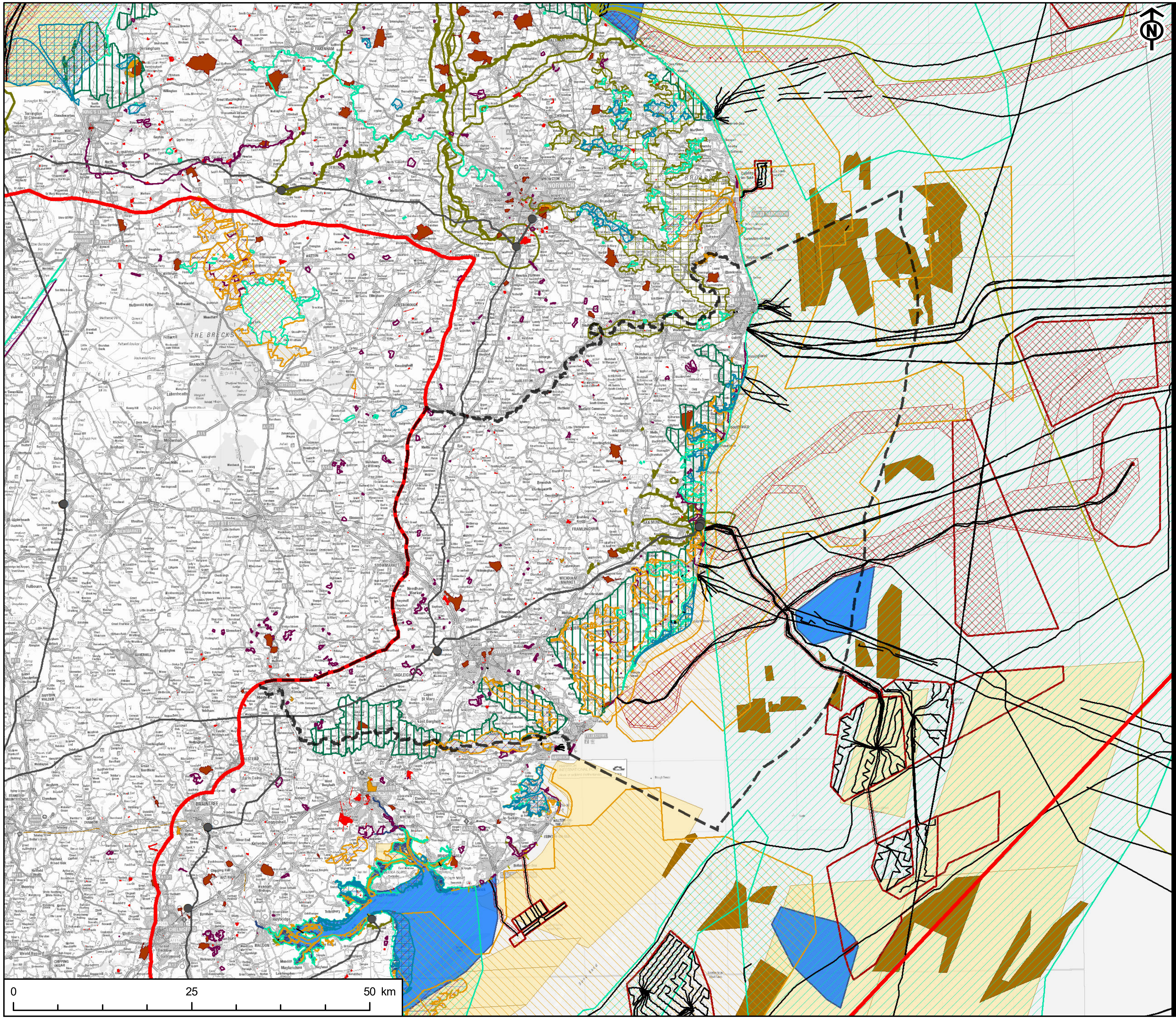
TITLE
APPENDIX A
STUDY AREA CHARACTERISATION
NORFOLK SUB-REGION

REFERENCE
ECGS_210318_SR_A_v1

SHEET NUMBER
2 of 4

DATE
18/03/2021

Coordinate System: WGS 1984 Zone 30N



Scale @ A3 1:500,000

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

AECOM

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
APPENDIX A
STUDY AREA CHARACTERISATION
SUFFOLK SUB-REGION

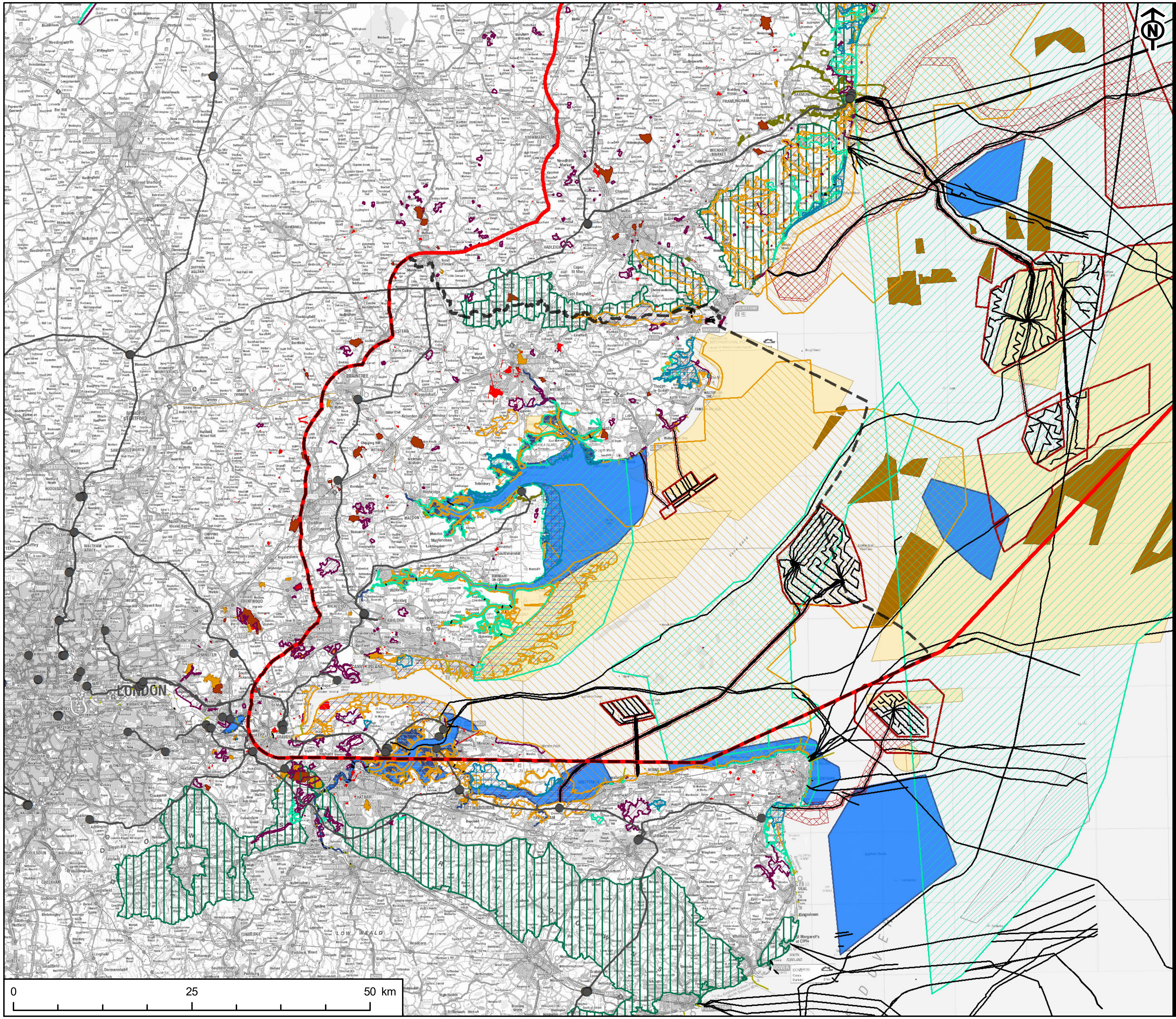
REFERENCE
ECGS_210318_SR_A_v1

SHEET NUMBER 3 of 4

DATE 18/03/2021

Coordinate System: WGS 1984 Zone 30N

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



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PROJECT
EAST COAST GRID STUDY

CLIENT
THE CROWN ESTATE

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
APPENDIX A
STUDY AREA CHARACTERISATION
ESSEX SUB-REGION

REFERENCE
ECGS_210318_SR_A_v1

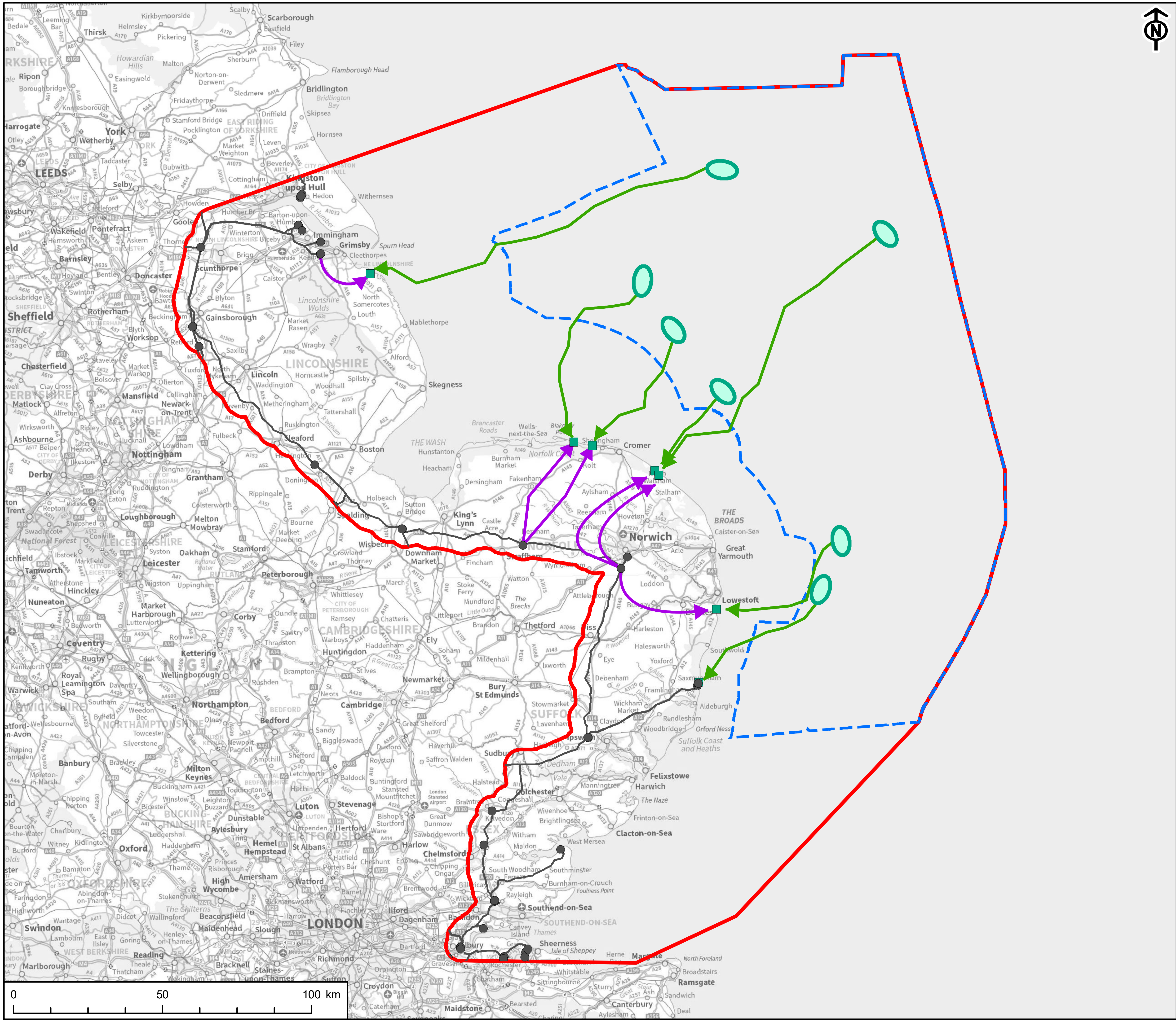
SHEET NUMBER
4 of 4

DATE
18/03/2021

Coordinate System: WGS 1984 Zone 30N

Appendix B Grid Connection Scenario Plans

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



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Coordinate System: WGS 1984 Zone 30N

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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

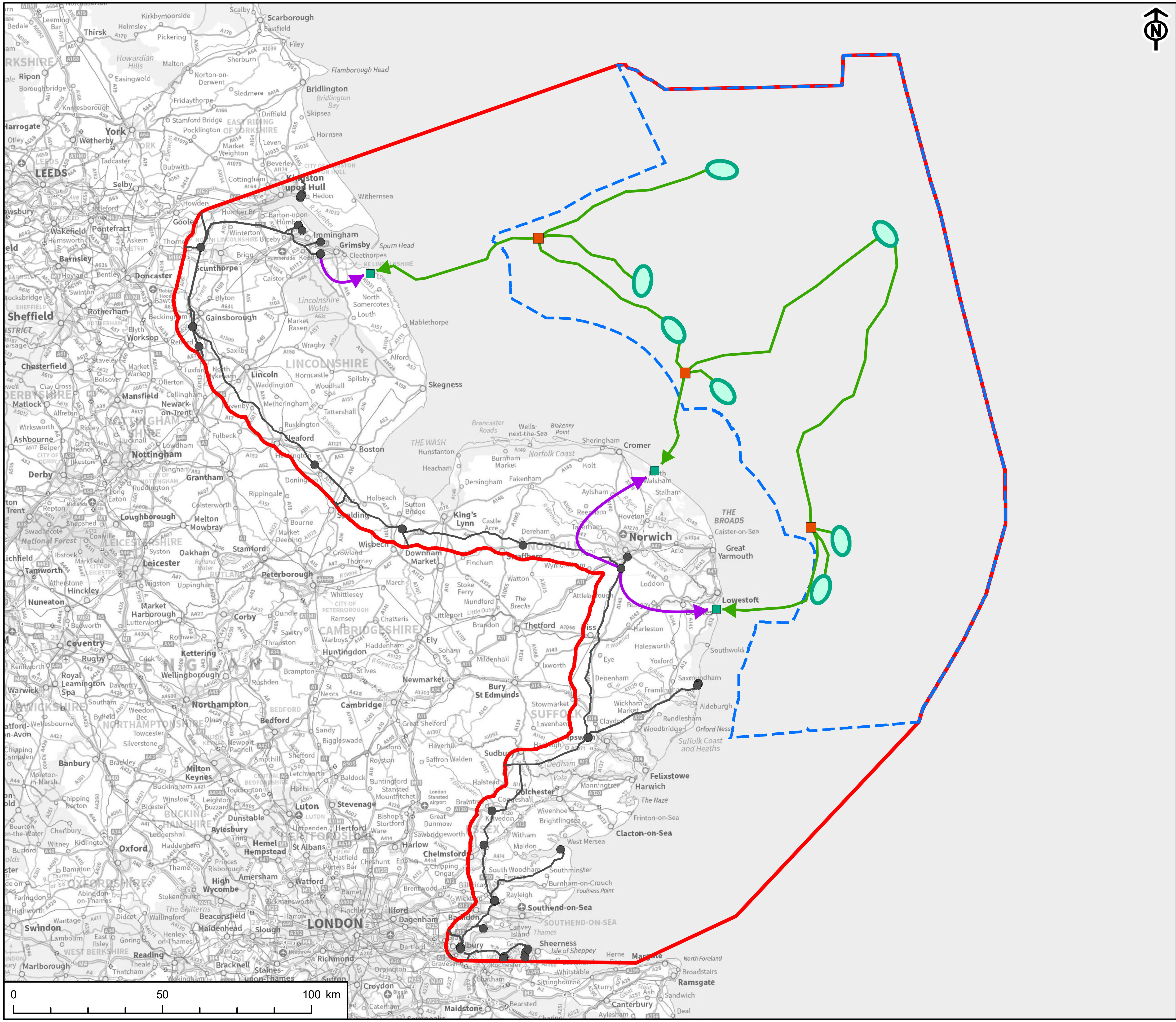
TITLE
APPENDIX B
GRID CONNECTION SCENARIO A
OVERVIEW

REFERENCE
ECGS_210413_SR_B_v2

SHEET NUMBER
1 of 1

DATE
13/04/2021

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
- Offshore Hub
- Existing Overhead Line
- Potential Onshore Export Cable Route
- Potential Offshore Export Cable Route
- Conceptual Offshore Wind Project

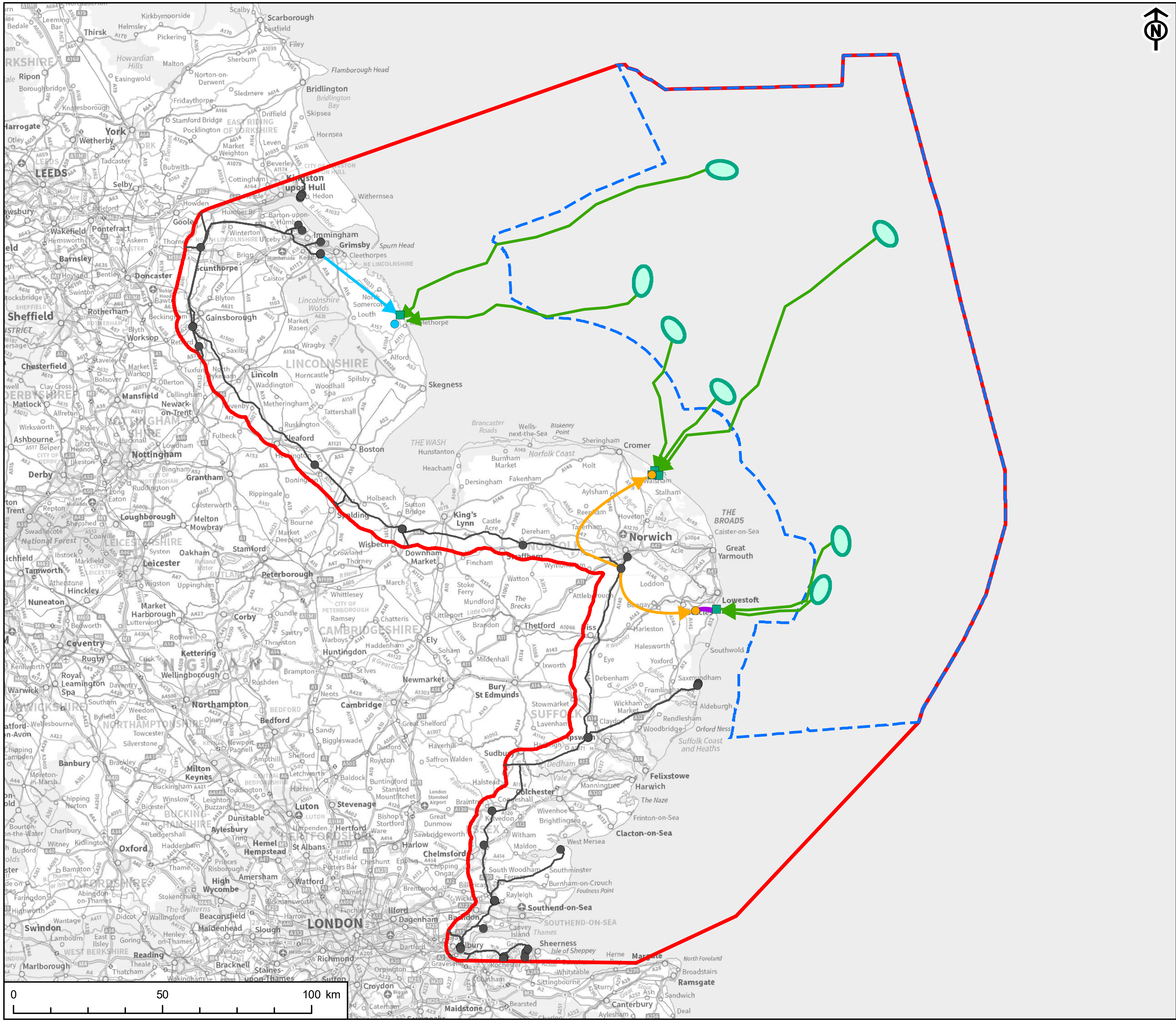
TITLE
APPENDIX B
GRID CONNECTION SCENARIO B
OVERVIEW

REFERENCE
ECGS_210413_SR_B_v2

SHEET NUMBER: 1 of 1

DATE: 13/04/2021

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



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Coordinate System: WGS 1984 Zone 30N

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PROJECT
EAST COAST GRID STUDY

CLIENT
THE CROWN ESTATE

KEY
- Study Area
- R4 Bidding Area - Eastern Regions
- Potential Landfall Area
- 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

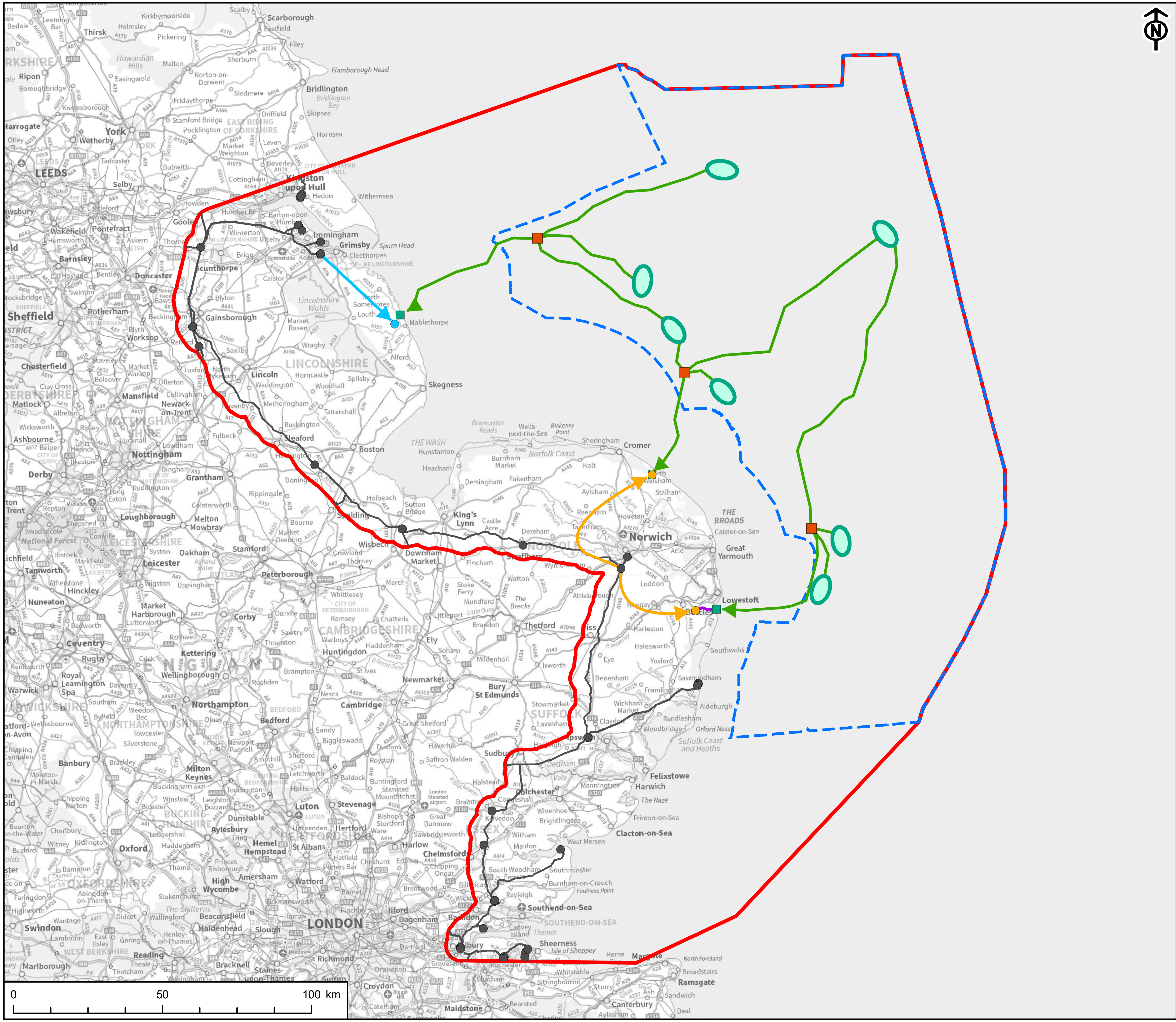
TITLE
APPENDIX B
GRID CONNECTION SCENARIO C
OVERVIEW

REFERENCE
ECGS_210413_SR_B_v2

SHEET NUMBER
1 of 1

DATE
13/04/2021

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



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PROJECT
EAST COAST GRID STUDY

CLIENT
THE CROWN ESTATE

KEY
- Study Area
- R4 Bidding Area - Eastern Regions
- Potential Landfall Area
- Existing Substation Location
- Planned Coastal Hub or Node Location (NOA 2019/20)
- Potential Network Extension Coastal Hub or Node Location
- Offshore Hub
- 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 B
GRID CONNECTION SCENARIO D
OVERVIEW

REFERENCE
ECGS_210413_SR_B_v2

SHEET NUMBER
1 of 1

DATE
13/04/2021

Appendix C SWOT Analysis

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.

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