Norfolk Vanguard Offshore Wind Farm

Chapter 4

Site Selection and Assessment of Alternatives

Environmental Statement

Volume 1

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For and on behalf of Norfolk Vanguard Limited

Approved by: Ruari Lean and Rebecca Sherwood

Signed: [redacted]

Date: 8th June 2018

For and on behalf of Royal HaskoningDHV

Drafted by: Kerrie Craig, Ruth Henderson, Amy Harrower

Approved by: Alistair Davison

Signed: [redacted]

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Glossary

AHOB	Ancient Humans of Britain
AONB	Area of Outstanding Natural Beauty
CLA	Country Land and Business Association
CAAV	The Central Association of Agricultural Valuers
cSAC	candidate Special Area of Conservation
DCO	Development Consent Order
EAOW	East Anglia Offshore Wind
EIA	Environmental Impact Assessment
ES	Environmental Statement
EU	European Union
GMSL	Global Marine Systems Ltd
HDD	Horizontal Directional Drilling
HE	Historic England
HRA	Habitat Regulations Assessment
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
IMO	International Maritime Organisation
kV	Kilovolt
LVIA	Landscape and Visual Impact Assessment
MCZ	Marine Conservation Zone
MoD	Ministry of Defence
MW	Megawatt
NCC HES	Norfolk County Council's Historic Environment Service
NETS	National Electricity Transmission System
NFU	National Farmers Union
NGET	National Grid Electricity Transmission
NHER	Norfolk Heritage Environment Record
NPS	National Policy Statement
OESEA	Offshore Energy Strategic Environmental Assessment
O&M	Operations & Maintenance
OWF	Offshore Wind Farm
PEI	Preliminary Environmental Information
PEIR	Preliminary Environmental Information Report
PEXA	Practice and Exercise Area
PRoW	Public Right of Way
SAC	Special Area of Conservation
SCI	Site of Conservation Importance
SPA	Special Protection Area
SPR	ScottishPower Renewables
VWPL	Vattenfall Wind Power Ltd
ZAP	Zonal Appraisal and Planning
ZDP	Zonal Development Plan

Terminology

Array cables	Cables which link the wind turbine generators and the offshore electrical platform.
Cable Relay Station	Primarily comprised of an outdoor compound containing reactors (also called inductors, or coils) and switchgear to increase the power transfer capability of the cables under the HVAC technology scenario as considered in the PEIR. This is no longer required for the project as the HVDC technology has been selected.
Constraints Mapping	GIS desk based exercise where a range of environmental data sets within a defined study area are mapped and buffers applied to aid in the process of selecting siting options for onshore electrical infrastructure.
Interconnector cables	Buried offshore cables which link the offshore electrical platforms
Jointing pit	Underground structures constructed at regular intervals along the cable route to join sections of cable and facilitate installation of the cables into the buried ducts.
Landfall	Where the offshore cables come ashore at Happisburgh South.
Landfall compound	Compound at landfall within which Horizontal Directional Drilling (HDD) drilling would take place.
Link boxes	Underground chambers or above ground cabinets next to the cable trench housing low voltage electrical earthing links.
Mobilisation area	Areas approx. 100 x 100m used as access points to the running track for duct installation. Required to store equipment and provide welfare facilities. Located adjacent to the onshore cable route, accessible from local highways network suitable for the delivery of heavy and oversized materials and equipment.
Mobilisation zone	Area within which the mobilisation area will be located.
National Grid new / replacement overhead line tower	New overhead line towers to be installed at the Necton National Grid substation.
National Grid overhead line modifications	The works to be undertaken to complete the necessary modification to the existing 400kV overhead lines.
National Grid substation extension	The permanent footprint of the National Grid substation extension.
National Grid temporary works area	Land adjacent to the Necton National Grid substation which would be temporarily required during construction of the National Grid substation extension.
Necton National Grid substation	The existing 400kV substation at Necton, which will be the grid connection location for Norfolk Vanguard.

Offshore accommodation platform	A fixed structure (if required) providing accommodation for offshore personnel. An accommodation vessel may be used instead.
Offshore cable corridor	The corridor of seabed from the Norfolk Vanguard OWF sites to the landfall site within which the offshore export cables will be located.
Offshore electrical platform	A fixed structure located within the wind farm area, containing electrical equipment to aggregate the power from the wind turbines and convert it into a more suitable form for export to shore.
Offshore export cables	The cables which bring electricity from the offshore electrical platform to the landfall.
Offshore project area	The overall area of Norfolk Vanguard East, Norfolk Vanguard West and the offshore cable corridor.
Onshore project substation temporary construction compound	Land adjacent to the onshore project substation which would be temporarily required during construction of the onshore project substation.
Onshore 400kV cable route	Buried high-voltage cables linking the onshore project substation to the Necton National Grid substation.
Onshore cable corridor	200m wide onshore corridor within which the onshore cable route would be located as submitted for PEIR.
Onshore cable route	The 45m easement which will contain the buried export cables as well as the temporary running track, topsoil storage and excavated material during construction.
Onshore cables	The cables which take the electricity from landfall to the onshore project substation.
Onshore project area	All onshore electrical infrastructure (landfall; onshore cable route, accesses, trenchless crossing technique (e.g. Horizontal Directional Drilling (HDD)) zones and mobilisation areas; onshore project substation and extension to the Necton National Grid substation and overhead line modification).
Onshore project substation	A compound containing electrical equipment to enable connection to the National Grid. The substation will convert the exported power from HVDC to HVAC, to 400kV (grid voltage). This also contains equipment to help maintain stable grid voltage.
Onshore project substation temporary construction compound	Land adjacent to the onshore project substation which would be temporarily required during construction of the onshore project substation.
The Applicant	Norfolk Vanguard Limited.
The OWF sites	The two-distinct offshore wind farm areas, Norfolk Vanguard East and Norfolk Vanguard West.

The project	Norfolk Vanguard Offshore Wind Farm, including the onshore and offshore infrastructure
Transition pit	Underground structures that house the joints between the offshore export cables and the onshore cables within the landfall
Trenchless crossing zone (e.g. HDD)	Temporary areas required for trenchless crossing works.
Workfront	The 150m length of onshore cable route within which duct installation would occur

4 SITE SELECTION AND ASSESSMENT OF ALTERNATIVES

4.1 Introduction

1. This chapter of the Environmental Statement (ES) provides a description of the site selection process and the approach undertaken by Norfolk Vanguard Limited (the Applicant) to identify the various elements of the Norfolk Vanguard Offshore Wind Farm (OWF) project (herein 'the project') areas. The process includes consideration of both the offshore and onshore development and associated infrastructure, and the assessment of reasonable alternatives as the project has developed throughout the pre-application process. An important part of the Environmental Impact Assessment (EIA) process is to describe the reasonable alternatives considered during the evolution of the project, such as development design, technology, location, size and scale, and to set out the main reasons for selecting the chosen option.

2. For the offshore development, the former East Anglia Zone (Zone 5) within which the project is located (as shown in Figure 4.1) was identified as part of The Crown Estate Round 3 Offshore Wind Farm (OWF) development process. As such, project site selection was limited to areas within the former East Anglia Zone. Where alternatives have been considered, for example as part of the offshore cable corridor selection process, these are discussed within this chapter and included in appendices.

3. This chapter outlines the site selection process for Norfolk Vanguard, however due to the strategic approach of developing both Norfolk Vanguard and the sister project Norfolk Boreas (see Chapter 1 Introduction and Chapter 5 Project Description for further details on the relationship between Norfolk Vanguard and Norfolk Boreas), the site selection process has also considered co-location of both projects.

4. A key driver for the process of developing and refining the design of both Norfolk Vanguard and Norfolk Boreas has been the development of potential efficiencies and synergies between the projects. A benefit of this approach is, for example, the opportunity for one main construction period for the duct installation process for the onshore cable route (as the DCO will allow for onshore ducts to be installed for both projects at the same time as part of the Norfolk Vanguard construction, thereby reducing the construction period and associated potential impacts). Onshore cables would then be pulled through the pre-installed ducts in a phased approach at later stages. Norfolk Vanguard Limited has discussed this from an early stage of the project, and will continue to discuss its proposed approach with relevant consultees.

4.2 Key Components of Norfolk Vanguard

5. The project will comprise the following main offshore components (see Chapter 5 Project Description):

- Offshore wind turbines and their associated foundations;
- Scour protection around foundations as required;
- Offshore electrical platforms supporting required electrical equipment, and possibly incorporating offshore facilities (e.g. accommodation);
- Offshore accommodation platforms to house workers offshore as required;
- Subsea cables and cable protection - array cables, interconnector cables, export cables and fibre optic cables;
- Meteorological masts (met masts) and their associated foundations; and
- Monitoring equipment including Light Detection and Ranging (LiDAR) and wave buoys.

6. The main onshore components of the project include:

- Up to two ducts installed under the cliff at landfall by Horizontal Directional Drilling (HDD). (Note: An additional drill is included in the impact assessment worst case scenario where applicable, to provide a contingency in the unlikely event of a HDD failure);
- Onshore export cables installed in ducts and associated infrastructure including transition pits and joint bays;
- Trenchless crossing points at roads, railways and sensitive features and habitats (e.g. rivers and sites of conservation importance);
- Running track;
- Temporary and operational accesses;
- Temporary mobilisation areas;
- Onshore project substation; and
- National Grid extension works including overhead line modifications.

7. Further details on the key components of infrastructure can be found in Chapter 5 Project Description.

4.3 Legislation and Guidance

4.3.1 Environmental Impact Assessment Regulations

8. The consideration of alternatives and major design decisions made during the development of a project has been part of Environmental Impact Assessment (EIA) legislation since the adoption of the original EIA directive in UK law under the European Union (EU) EIA Directive 85/337/EEC (as amended by Directives 97/11/EC, 2003/35/EC and 2009/31/EC).

9. The Infrastructure Planning (Environmental Impact Assessment) Regulations (2009) require the applicant to provide "*an outline of the main alternatives studied by the applicant or appellant and an indication of the main reasons for his choice, considering the environmental effects*".

10. The new EIA Regulations (2017) amend the wording slightly but do not significantly change the position. The new Regulations require an Environmental Statement (ES) to include "*a description of the reasonable alternatives (for example in terms of development design, technology, location, size and scale) studied by the developer, which are relevant to the proposed project and its specific characteristics, and an indication of the main reasons for selecting the chosen option, including a comparison of the environmental effects*".

4.3.2 The National Policy Statement EN 1

11. The National Policy Statement (NPS) is clear that 'from a policy perspective this NPS EN-1 does not contain any general requirement to consider alternatives or to establish whether the proposed project represents the best option'. It does however note that in the execution of a competent EIA 'applicants are obliged to include in their ES, as a matter of fact, information about the main alternatives they have studied.'

4.3.3 The Planning Inspectorate Advice Note Seven

12. The Planning Act 2008 (as amended), and related secondary legislation, establishes the legislative requirements in relation to applications and proposed applications for orders granting development consent for Nationally Significant Infrastructure Projects (NSIPs).

13. The Planning Inspectorate Advice Note Seven suggest the EIA needs to explain *'the reasonable alternatives considered and the reasons for the chosen option considering the effects of the Proposed Development on the environment'*.

4.4 Site Selection Process

14. The siting, design and refinement of the project has followed a site selection process, taking account of environmental, physical, technical, commercial and social considerations and opportunities as well as engineering requirements, with the aim of identifying sites that will be environmentally acceptable whilst also enabling, in the long term, benefits of the lowest energy cost to be passed onto the consumer. A multi-disciplinary design team was formed to undertake the site selection process, which included a team of specialists comprising engineers and EIA consultants whose expertise were drawn upon throughout the site selection process. The site selection

process is shown in Plate 4.1. This plate shows the chronological order in which the main site selection decisions were taken.

15. Each stage of the site selection process forms part of an iterative design process undertaken to identify the most suitable locations and configuration, based on criteria outlined above for project infrastructure. The framework for the site selection process is based upon a set of design principles and engineering requirements for project infrastructure.

16. Norfolk Vanguard Limited has undertaken extensive pre-application engagement with stakeholders, communities and landowners in order to both seek input to refine the final project design, and to communicate decisions on refinements (for further information see the Consultation Report (document 5.1)). The Scoping Report (Royal HaskoningDHV, 2016) and the Preliminary Environmental Information Report (PEIR) (Norfolk Vanguard Limited, 2017) set out the process for the development of the onshore and offshore elements of the projects, showing a series of search areas for the landfall, onshore and offshore cable corridors, cable relay station (CRS) locations (no longer required) and onshore project substation locations.

17. Consultation on refinements in the project layout and configurations have been undertaken through the informal and formal pre-application stages (20 month period) between scoping in October 2016 and the final ES, and feedback received has been taken into consideration throughout, through a range of means including (but not exclusively limited to):

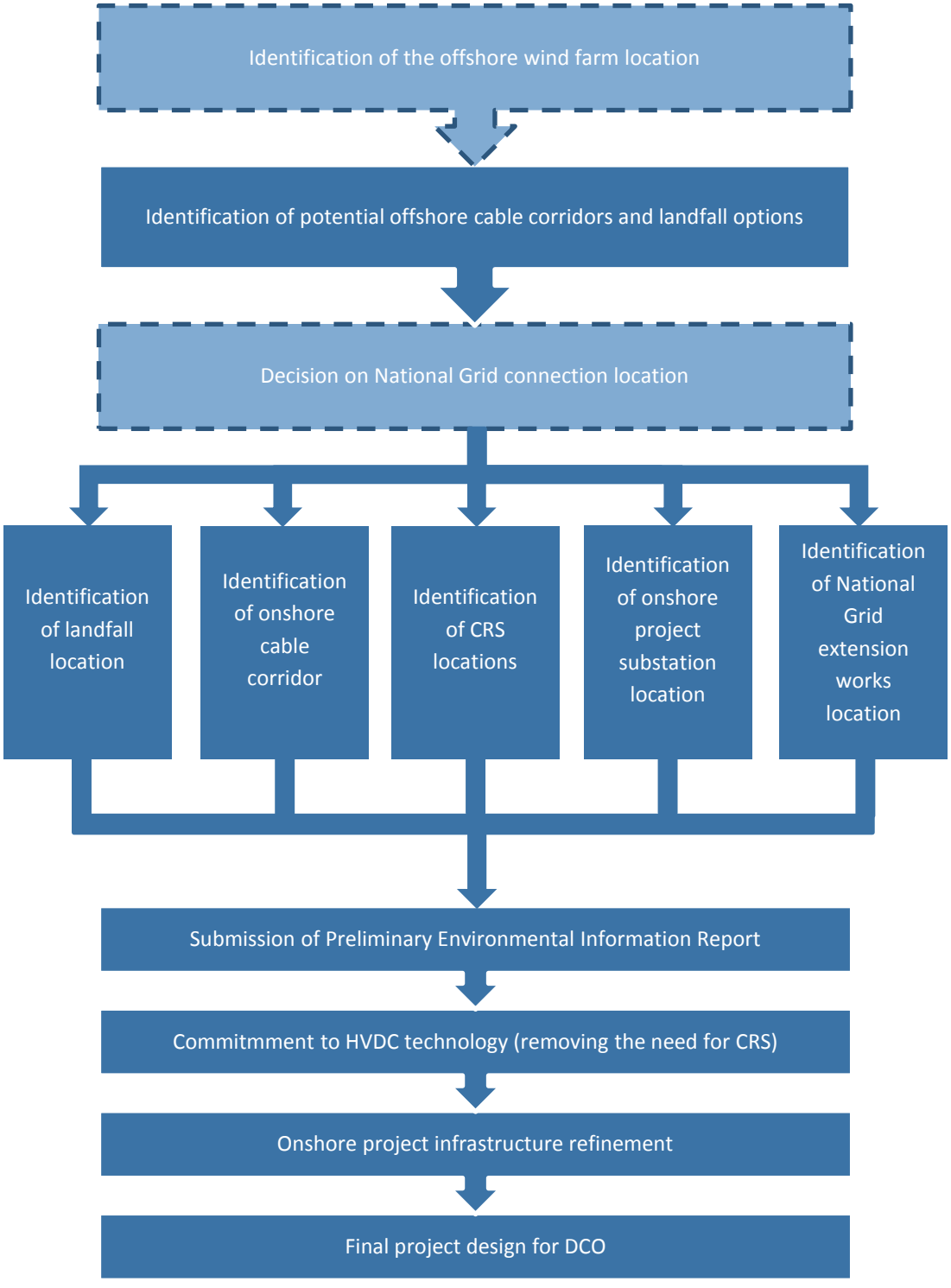
- Drop in Exhibitions held at locations within and adjacent to the onshore project area;
    - October 2016;
    - March/April 2017; and
    - November 2017.
- Reports of community feedback shared with all registered participants, key local and community stakeholders, and on the project website[1];
    - Hearing your Views, I, II and III;
- Community engagement events;
- Direct discussions with landowners;
    - Norfolk Vanguard Limited have engaged with over 350 different land interests including landowners, tenants, occupiers and other parties with

[1] https://corporate.vattenfall.co.uk/norfolkvanguard

land rights; specifically, engaging with over 100 affected landowners and comments taken on board

- Norfolk Vanguard Limited have engaged with landowners regarding survey access, through consultation meetings and during the land referencing process. Letters were sent to all affected parties offering to meet to discuss the project proposals;
- Norfolk Vanguard Limited's land agents have met with over 95% of the affected landowners and have liaised with the land agents representing those not met directly. A number of onshore cable route change suggestions have been put forward by those affected by the red line boundary and Vattenfall have been able to incorporate a number of those suggestions into the final design.

- Newsletters distributed throughout the Scoping Area (October 2017), and subsequently provided to those within the Primary Consultation Zone, as described in the Statement of Community Consultation and the Consultation Report. These newsletters were distributed on the following dates:
  - October 2016;
  - March 2017;
  - June 2017;
  - October 2017; and
  - February 2018.
- Provision of a dedicated project website; and
- Regular and targeted discussion with regulators and other stakeholder bodies through various means including 42 Expert Topic Group meetings, where the siting of project infrastructure was discussed in detail. More information is detailed in Chapter 7 Technical Consultation and in the Consultation Report (document reference 5.1).



[2]

Plate 4.1 Site selection process for Norfolk Vanguard (and Norfolk Boreas)

[2] *Strategic decisions regarding fundamental project locations such as the offshore wind farm location and grid connection point have been made in conjunction with the Crown Estate and National Grid respectively.*

4.5 Project Alternatives

18. A number of alternatives have been considered as part of the decision-making process. The early strategic project consideration of alternatives which fed directly into the site selection process are detailed in Table 4.1.

19. A number of additional project alternatives have also been considered to inform the project design and site selection process. These are discussed further throughout the chapter and are summarised in Table 4.14.

Table 4.1 Strategic project alternatives considered

Alternatives considered	Decision	Main Environmental Benefits
• Strategic approach to concurrently delivering Norfolk Vanguard and Norfolk Boreas • No elements of Norfolk Boreas considered within the design envelope for Norfolk Vanguard	**To take a strategic approach to delivering Norfolk Vanguard and Norfolk Boreas.**	Through the decision to install cable ducts for the Norfolk Boreas project during the construction for Norfolk Vanguard, this strategic approach would allow the main civil works for the onshore cable route to be completed in one construction period and in advance of the delivery of cables for the cable pull phase, preventing the requirement to reopen the land at a later date for the construction of Boreas, which minimises the construction periods to reduce impacts on sensitive receptors, and in order to minimise disruption. Co-location of onshore project substations for both projects will keep these developments contained within a localised area and, in so doing, will contain the extent of potential impacts.
• Overhead lines along the ~60km route from landfall to grid connection location • Buried onshore cables within ducts along the ~60km route from landfall to grid connection location	**Buried onshore cables within ducts**	The environmental benefits of burying cables as opposed to overhead lines and pylons is the minimisation of visual impacts.
• Ducts laid in a sectionalised approach to enable cable pull through at a later stage • Open cut and	**Ducts laid in a sectionalised approach to enable cables to be pulled through the ducts at a later stage**	The environmental benefit of installing ducts and backfilling the trenches in discreet sections, rather than installing ducts along the entirety of the route before backfilling would minimise the amount of land being worked on at any one time and would also minimise the duration of works on any given section of the route.

Alternatives considered	Decision	Main Environmental Benefits
direct lay of onshore cables along the full length of the cable route		

4.6 Identification of the Offshore Wind Farm Location

4.6.1 Former East Anglia Zone

20. The former East Anglia Zone (Zone 5) (see Figure 4.1) was originally identified by The Crown Estate as a suitable area offering 'potential for offshore wind' as part of the Round 3 Offshore Wind Zone tendering process in 2008. All Round 3 Zones were defined using an iterative process that took account of a number of constraints imposed by existing or future use of the sea.

21. The proposed Round 3 Zones were the subject of the Offshore Energy Strategic Environmental Assessment (OESEA) which assessed the implications of developing offshore wind farms within the Zones. The results of this strategic level analysis showed that the Zones represented suitable 'areas of opportunity' for offshore wind projects, and had the ability to deliver the required capacity of offshore wind within acceptable environmental limits. The Zones were subject to an offshore tender round in 2009.

4.6.2 Offshore Wind Farm Sites

22. Following the offshore tender round in 2009, The Crown Estate awarded East Anglia Offshore Wind (EAOW) the rights to develop Zone 5 (the former East Anglia Zone). The former Zone is located off the coast of East Anglia and has a target capacity of 7,200MW.

23. The first projects within the former Zone were identified through the Zonal Appraisal and Planning (ZAP) process conducted by EAOW which commenced in 2010. This resulted in the formation of a Zonal Development Plan (ZDP) in 2012 which identified areas with the least environmental and technical constraints.

24. Where potentially significant cumulative and in-combination impacts were identified, further targeted research was initiated to better understand these impacts. This included studies on shipping, birds and marine mammals.

25. Following the decision to split the former East Anglia Zone, Vattenfall Wind Power Ltd (VWPL) took control of all development activities for projects in the northern half of the Zone, and ScottishPower Renewables (SPR) in the southern half of the Zone.

Commercial agreements to finalise this arrangement were completed in February 2016.

26. During 2015, VWPL revisited the ZDP for the northern half of the former Zone. The locations of Norfolk Vanguard (and Norfolk Boreas) were identified using a three-step process:

- Step 1: Potential development areas which had been identified in the ZDP were reviewed through spatial constraints mapping using up-to-date data. The key environmental and stakeholder constraints considered were:
    - Shipping and navigation;
    - Existing infrastructure, including cables and pipelines and oil and gas platforms;
    - Aggregate dredging grounds;
    - Other offshore wind farms;
    - Nature conservation designations;
    - Commercial and natural fisheries activity; and
    - Civil and military radar coverage and helicopter main routes.
- Step 2. The areas identified were subject to a review of the following technical aspects:
    - Wind resource to provide production estimates;
    - Metocean data to understand weather downtime;
    - Bathymetry and available seismic and borehole data to assess monopile feasibility;
    - Sandwave data in relation to cable burial;
    - Electrical design and grid connection options; and
    - Development of a preliminary Operations & Maintenance (O&M) strategy.
- Step 3. A cost comparison model was set up for those sites deemed to be technically feasible, to identify which sites would provide the lowest cost of energy. This exercise was based on the following indicative parameters, which are considered to be the base-case scenario:
    - One 75 x 8MW (600 megawatt (MW)) phase of a wind farm;
    - A High Voltage Alternating Current (HVAC) connection;
    - Monopile foundations;
    - 75kV inter-array cables;
    - 220-245kV export cables;
    - Two export cables;
    - One offshore substation; and

- A connection to the National Electricity Transmission System (NETS) close to the coast.

27. Based on the review of known site characteristics, the parameters which were deemed differentiable between project areas at this early stage of development were wind farm production, offshore operational costs, offshore transmission costs and foundation installation costs. Preliminary results showed that the location of the wind farms within Norfolk Vanguard (NV) East and NV West would provide the lowest cost of energy to consumers (in line with Government targets), whilst minimising environmental impacts; with Norfolk Boreas providing the next best site. The development of Norfolk Boreas in such a way as to maximise potential efficiencies and synergies between the projects enhances cost benefits and reduces potential environmental impacts which could arise if the projects were developed entirely separately.

28. The main considerations when identifying the location of the offshore wind farm sites are shown in Figure 4.2 and outlined below. Located:

- Beyond 35km from the shore, therefore avoiding shore to sea visual amenity impacts and reducing interaction with inshore fisheries interests;
- Outside the International Maritime Organisation (IMO) route and within area of relatively low density shipping in the context of the former Zone;
- Outside any existing active oil and gas infrastructure;
- Outside dredging and aggregate extraction areas;
- Outside known Ministry of Defence (MoD) danger and exercise areas;
- Outside existing Natura 2000 sites and MCZ, (at the time of selection). A candidate Special Area of Conservation (cSAC) for harbour porpoise has since been proposed for designation, however as plans currently cover the entire former Zone, the area, if designated, cannot be avoided through site selection;
- Outside any areas of known significant ornithological activity; increased distance from the nearest existing Special Protection Areas (SPA) for breeding birds (>210km from Flamborough Head and Bempton Cliffs and >100km from the Alde-Ore Estuary) reduces the potential for interaction with breeding and foraging bird species;
- Outside any sandeel, herring or cod spawning areas; and
- To reduce the number of cable and pipeline crossings likely to be required.

29. In 2016, an Agreement for Lease for Norfolk Vanguard was awarded to VWPL (and subsequently transferred to Norfolk Vanguard Limited) from The Crown Estate. This required a rigorous review process to demonstrate that the site does not conflict with any other developments, that it represents the best and most efficient use of the seabed, and that its development is in accordance with relevant legislation.

30. An Agreement for Lease was also awarded to VWPL for Norfolk Boreas, following a similar process.

4.7 Identification of Provisional Offshore Cable Corridor and Landfall Area

31. Following the definition of the offshore project areas for Norfolk Vanguard and Norfolk Boreas, site selection for all other infrastructure was assessed in a strategic manner such that the areas identified would be sufficient for both projects in order to minimise potential impacts. The site selection of the offshore cable corridor was undertaken in consultation with The Crown Estate.

32. Possible landfall locations were reviewed within an area from The Wash to Harwich. The majority of the coastline in this area is covered by high level designations (see Figure 4.3), including:

- North Norfolk Coast Area of Outstanding Natural Beauty (AONB) - from Hunstanton to Mundesley, just north of Bacton;
- The Wash and North Norfolk Coast Special Area of Conservation (SAC);
- North Norfolk Coast Ramsar;
- North Norfolk Coast Special Protection Area (SPA);
- North Norfolk Coast Site of Special Scientific Interest (SSSI);
- Broads National Park - from Sea Palling to Lowestoft; and
- Suffolk Coast and Heaths AONB - from Kessingland, south of Lowestoft to Felixstowe.

33. In order to avoid these designations, potential landfall areas were identified (Figure 4.3), as follows:

- Mundesley to Sea Palling (Bacton area);
- Gorleston-on-Sea; or
- Lowestoft to Kessingland (Lowestoft area).

34. In parallel with the landfall assessment, Norfolk Vanguard Limited's in-house mapping team identified options for provisional offshore cable corridors from NV East and NV West to each of the three landfall options (see Figure 4.3). Offshore constraints included in this exercise were:

- Other offshore wind farms;
- Shipping and navigation route ;
- Existing offshore cables;
- Oil and gas infrastructure including platforms and pipelines;
- Military Practice and Exercise Areas (PEXAs);
- Aggregate dredging grounds;
- Nature conservation designations;

- Commercial fishing; and
- Sensitive seabed features.

35. Due to the complex nature of the offshore area, both from a technical perspective and given the large number of activities and designations, a comprehensive assessment was then undertaken to better understand the risks associated with each landfall / offshore cable corridor option. Two external studies were commissioned by Norfolk Vanguard Limited:

- HDD feasibility report (Riggall and Associates Ltd, 2016), see Appendix 4.1. This report provides a subjective ranking of indicative 13[3] landfall sites (Table 4.2) from Bacton to Lowestoft (see Figure 4.4). ranking, expressed as a series of 4 tiers of site suitability for HDD, was undertaken on the basis of both offshore and onshore risks, including access, distance from residences, environmental constraints, geology and coastal erosion; and
- Cable constructability assessment (Global Marine Systems Ltd (GMSL), 2016), Appendix 4.2. This study assessed geology and seabed topography along offshore cable corridor options to the Bacton area and Gorleston-on-Sea. Cable installation risk and design considerations were assessed, and proposed refinements made to reduce the risks identified. The route to Lowestoft was not included in this study as at the point of commissioning the study this option had been discounted (see paragraph 38).

36. A summary of the outcome of the ranking process within the HDD feasibility report is provided in Table 4.2.

Table 4.2 Landfall ranking results

	Bacton to Sea Palling	Gorleston-on-Sea	Lowestoft to Kessingland
Total sites assessed	7	5	3
Number of 'Tier 1' sites (sites suitable for HDD)	3	0	0
Number of 'Tier 2' sites (sites suitable for HDD with mitigation)	2	0	1
Number of 'Tier 3' sites (significant risks in relation to HDD)	2	3	2
Number of 'Tier 4' sites (not suitable for HDD)	0	2	0

37. Of the seven possible sites between Bacton and Sea Palling, five sites were assessed to be 'Tier 1' or 'Tier 2', suggesting that there are several suitable landfall options in this area. Conversely, of the five possible sites around Gorleston-on-Sea, no sites were assessed as 'Tier 1' or 'Tier 2'. South of Lowestoft, of the three sites assessed, no sites were assessed as 'Tier 1', one site was assessed as 'Tier 2' and two sites

[3] The 13 later became 15 with the addition of 3a and b and 4a and b.

were assessed as 'Tier 3'. Landfall south of Lowestoft would therefore be feasible but limited. The conclusion of the report was that the central zone around Gorleston-on-Sea and Lowestoft to Kessingland had fewer favourable landfall options.

38. The constraints mapping exercise, which takes a broader view than the HDD feasibility report, showed that the offshore cable route to a potential landfall in the Lowestoft area would be considerably longer than the other routes as well as being more complex, requiring a high number of cable/pipeline crossing agreements. The cable route to Lowestoft was therefore considered to be the least preferred.

39. GMSL (2016) reviewed the offshore cable corridor options into the area of Bacton and Gorleston-on-Sea, see Appendix 4.2. The conclusion of this report was that the corridor to Gorleston-on-Sea was less favourable than the corridor to Bacton for the following reasons:

- The approaches to the Gorleston-on-Sea landfall option are within an area of highly mobile sandwaves;
- The cable corridor for the Gorleston-on-Sea landfall option is close to both existing and potential aggregate dredging areas which increases the potential for interaction; and
- Both the Bacton and Gorleston-on-Sea options require routeing through the Haisborough, Hammond and Winterton SAC.

40. Although the Gorleston-on-Sea landfall itself would be outside the Broads National Park (see Figure 4.3), all onshore routes from the Gorleston-on-Sea landfall location would have to be routed through the Broads National Park. The cable corridor to Gorleston-on-Sea (Figure 4.3) was therefore discounted from further consideration.

41. The provisional offshore cable corridor to the Bacton area (between Bacton and Sea Palling, and encompassing Happisburgh South) was considered most favourable for the following reasons:

- It is one of the shortest routes from the Norfolk Vanguard OWF sites to landfall;
- There are fewer cable / pipeline crossings required (up to nine cable crossings and two pipeline crossings);
- Where cable / pipeline crossings are required, routeing at close to 90° is possible which will minimise physical, and in the case of cables, electromagnetic interaction which could affect cable performance;
- It crosses the shipping deep water route using the shortest distance;
- It avoids the areas of inshore seabed mobility off Gorleston-on-Sea;
- It is around 6km from the aggregate dredging grounds off Lowestoft thereby reducing any interaction;

- The available corridor width of 2km could accommodate both Norfolk Vanguard and Norfolk Boreas export cables; and
- It allows for onshore routeing options outside the Broads National Park.

4.8 Identification of National Grid Connection Point

42. Developers wishing to connect new electricity generation to the NETS must make a connection application. A modification application is also required when developer's proposals change significantly. When the proposed development is an offshore wind farm, the connection options are comparatively assessed to identify the most appropriate connection location.

43. The identification of the project connection point to the NETS was undertaken by National Grid Electricity Transmission plc (NGET) in conjunction with Norfolk Vanguard Limited. This process resulted in a grid connection offer being made by National Grid plc to Norfolk Vanguard Limited.

44. The aim of the process was to provide an efficient, coordinated and economical assessment of appropriate options to connect the project to the NETS. The process facilitated an appraisal of appropriate connection options and from this identified a short list of preferred onshore connection points. National Grid and Norfolk Vanguard Limited considered the possible onshore connection points from an economic and strategic perspective, which included consideration of the additional cost and investment required for the connection, the capacity required and the predicted timing of the connection. One important element of this assessment was the cost that would be passed on to the consumer (the public and businesses) as a result of the works required to ensure the network could accommodate the project.

45. As part of the economic assessment, the whole life cost of the connection was considered by assessing both the capital and projected operational costs to the onshore network (over the project's lifetime) to determine an economic and efficient design option. Whilst Norfolk Vanguard Limited contributed to the process, the final offer of a connection point was determined by National Grid plc.

46. In July 2016, following the process outlined above, an offer was made by National Grid for a connection point at the existing Necton National Grid substation and this was accepted by Norfolk Vanguard Limited in November 2016. Following this, the Norfolk Vanguard onshore scoping area was defined and the onshore scoping process commenced. The onshore scoping area included search areas for the onshore infrastructure which, at that time, included the onshore project substation, CRS and onshore cable corridor, as well as the landfall search area.

47. In line with a strategic approach to the development of Norfolk Vanguard and Norfolk Boreas, all search areas were identified on the basis that they could accommodate infrastructure for the National Grid connection point for Norfolk Boreas as well as Norfolk Vanguard.

48. A guidance note on the National Grid website explains how the assessment is carried out[4]. The process looks at technical, commercial, regulatory, environmental, planning and deliverability aspects to identify the preferable connection for the consumer. The Electricity Act 1989 requires National Grid when formulating proposals, to be efficient, co-ordinated and economical whilst also having regard to the environment. When the development being connected is offshore, the offshore aspects need to be considered in that evaluation too. The assessment process therefore looks to minimise the total capital and operational cost whilst taking into account other key considerations as outlined.

4.8.1 Refining the Offshore Cable Corridor

49. After the National Grid plc connection point was defined and allocated, the offshore cable corridor was refined. When defining the offshore cable corridor, a minimum width of 2km was used in accordance with advice from GMSL on required cable separations (GMSL, 2016).

50. The exception to this is where the cable bends south close to Newarp Bank, where the cable corridor has been widened. The bend in the route is to allow the offshore cable corridor to continue to follow the Bacton to Zeebruge gas pipeline and then to enable the cable route to cross the pipeline at as close to 90° as practicable to minimise physical interaction. The greater width in this 'dog leg' section of the cable route is required to provide additional space to allow the export cable to be installed using a large cable plough with a wide turning radius (600m) whilst maintaining a safe operating buffer from the gas pipeline. In order to minimise impacts on other marine stakeholders, the cable corridor has been placed as close as practicable to the existing Bacton to Zeebrugge and Bacton to Balgzand pipelines, whilst retaining a 250m buffer along the majority of the cable route.

51. An Agreement for Lease for the cable corridor was agreed with The Crown Estate in February 2017.

52. The nearshore area of the offshore cable corridor was refined in parallel with the onshore site selection to ensure the offshore cable corridor aligned with the landfall area.

[4] The Connection and Infrastructure Options Note (CION) Process Guidance Note Issue 3 https://www.nationalgrid.com/uk/electricity/connections/applying-connection.

4.9 Identification of Landfall Location

53. Following the decision for the landfall to be located between Bacton and Sea Palling (section 4.7), the landfall search area was divided into three sectors (Figure 4.5) in order to understand the constraints and opportunities associated with these areas, and to allow more targeted feedback from consultation:

- L1 - Bacton Green to Rudram's Gap;
- L2 – Rudram's Gap to Beach Road; and
- L3 – Beach Road to Bush Estate.

54. Information from the engineering feasibility review undertaken by Riggall and Associates Ltd (2016) (Appendix 4.1 and Appendix 4.5) allowed the landfall search areas to be narrowed down to three potential landfall locations (Figure 4.6):

- Bacton Green;
- Walcott Gap; and
- Happisburgh South.

55. To assist with the selection of a preferred landfall site, a number of studies were undertaken including a study to better understand coastal erosion at these locations (Appendix 4.3). This study considered the coastal geomorphology and coastal management policies along the Bacton Gas Terminal to Eccles-on-Sea frontage in order to assist the landfall selection and design.

56. The report concluded that there was significant uncertainty regarding the erosion dynamics on this stretch of coastline, in particular in relation to the sandscaping scheme proposed for the Bacton Gas Terminal. The site to the south of Happisburgh Village was considered to be least affected by the potential changes in sedimentation (which might take place if the sandscaping project at Bacton Terminal proceeded). However, the report noted that the Happisburgh South site was subject to natural erosion which would need to be considered as part of the engineering design for the project if this site was taken forward.

57. In addition to the coastal erosion report, a constraints mapping exercise and engineering review were undertaken to identify the preferred landfall location, these studies can be found in Appendices 4.4 and 4.5 respectively. This was an iterative process which considered potential onshore CRS locations (outlined in Plate 4.1). Areas of sensitivity, including potential impacts on heritage setting, flood risk, proximity to populated areas, access and archaeology were considered. Consultation with key regulators, such as Natural England, was undertaken and discussions with the operators of the Bacton Gas Terminal site, and North Norfolk District Council (NNDC) also informed the process. Happisburgh South was selected as the preferred landfall location for the following key reasons:

- Avoids the nationally designated MCZ (the Cromer Shoal Chalk Beds);
- Allows co-location of Norfolk Vanguard and Norfolk Boreas landfall and reduces total amount of area directly impacted;
- Avoids populated areas as far as possible;
- Avoids areas at risk of flooding as far as possible;
- Provides opportunities associated with Happisburgh archaeology - consultation ongoing with Natural History Museum, British Museum, Queen Mary University of London and Norfolk County Council Historic Environment Service; and
- Avoids technical engineering and feasibility risks associated with locating infrastructure in the brown field site within the Bacton Gas Terminal land.

58. In choosing the landfall location and the location of the associated transition pits, areas with residential dwellings and areas of high amenity value (e.g. footpaths) were avoided as far as possible.

59. The preferred landfall site (Figure 4.7) lies to the south of Happisburgh (herein 'Happisburgh South') in an area fronted by unprotected cliffs which are eroding. The proposed HDD drilling compound and transition pit are proposed to be located in an agricultural field and suitably set back from the cliff edge to ensure natural coastal erosion should not affect the drilled cable or transition pits within the conceivable lifetime of the project (approx. 30 years). The transition pits will be buried to ground or just below ground level to ensure visual and land management impacts are minimised.

60. A specific, independent academic steering group has been established with respect to coastal, intertidal and nearshore archaeological considerations at the landfall. Early consultation is already underway with members of the Ancient Humans of Britain (AHOB) research team, Historic England and Norfolk County Council's Historic Environment Service (NCC HES). The project is seeking to maximise opportunities and knowledge gained from pre-construction and construction activities with support and assistance from the AHOB project. Further details are provided within Chapter 28 Onshore Archaeology and Cultural Heritage.

61. The project will use the long HDD technique at landfall which requires no works on the beach or construction vehicular access to the foreshore. This will result in no restrictions or closures to the beach and maintains access to the beach for the public.

4.10 Identification of Onshore Cable Corridor

62. Following identification of the landfall search area and the connection point at Necton, the onshore cable corridor was identified. As discussed in section 4.8, in order to minimise permanent visual impacts during the operational life of the

project, the onshore cables between the landfall and the electrical connection point will involve a new underground (buried) cable system rather than any new overhead lines.

63. In considering options for the onshore cable corridor, a number of key design principles were followed wherever practical. These guiding principles were:

- Avoid proximity to residential dwellings;
- Avoid proximity to historic buildings;
- Avoid designated sites;
- Minimise impacts to local residents in relation to access to services and road usage, including footpath closures;
- Seek to utilise open agricultural land;
- Minimise requirement for complex crossing arrangements, e.g. road, river and rail crossings;
- Avoid areas of important habitat, trees, ponds and agricultural ditches;
- Install cables in flat terrain maintaining a straight route where possible for ease of pulling cables through ducts;
- Avoid other services (e.g. gas pipelines) or aim to cross services at right angles where crossings are required;
- Minimise the number of hedgerow crossings, utilising existing gaps in field boundaries; and
- Minimise impacts on agricultural practices and access, avoid rendering parcels of agricultural land inaccessible during construction and installing cables along field boundaries preferentially.

64. An iterative and multidisciplinary approach incorporating engineering, buildability, cost, environmental, landowner, community, and stakeholder considerations was used in the development of cable corridor options. A series of internal project team workshops were held to ensure each of the factors were considered effectively.

65. Appendix 4.6 presents the findings of the various stages of site selection work which have led to the identification of the preferred option for the Norfolk Vanguard onshore cable route. These stages were:

- Identification and characterisation of the onshore project area;
- Refinement of the cable corridors into a study area (shown at Scoping stage) and identification and assessment of more detailed cable 'branches';
- Production of the chosen cable corridor option;
- Review of the preferred cable corridor option;
- Production of the cable corridor option for PEIR consultation;
- Review of the cable corridor following PEIR consultation; and

- Final cable route option for ES.

66. Each one of these stages is outlined below.

4.10.1 Identification and Characterisation of the Onshore Project Area (Scoping Area)

67. As a first step in the assessment process, an onshore study area was developed (the Scoping Area). This involved identifying the preferred landfall location (between Bacton and Sea Palling) and applying a 10km buffer around the Necton National Grid connection location. A broad area of land was then identified to join these two geographical areas, which was then further refined to avoid the settlements of Fakenham and Briston to the north and Norwich and surrounding settlements to the south. An area south-west of Sea Palling was also removed as this encompassed a large area of The Broads National Park. Using the study area identified, an exercise of mapping environmental considerations was undertaken.

68. To aid consideration following the identification and characterisation of the study area, a number of broad cable corridors (3km in width) were identified. These were developed using high-level design principles, which were applied during different stages of the site selection process, and are shown in Plate 3 of Appendix 4.6.

4.10.2 Refinement of the Cable Corridors into a Study Area (shown at Scoping Stage) and Identification and Assessment of more Detailed Cable 'Branches'

69. After the grid connection offer of Necton was taken forward into the site selection process, indicative Cable Corridors A and B were taken forward as the Cable Corridor Study Area, as shown in Plate 4 of Appendix 4.6 (and shown at Scoping stage). The Cable Corridor Study Area was defined from the western edge of the Reactor Station Study Area, along Corridors A and B and to the eastern edge of the Substation Study Area. Cable Corridor options were then identified within each section (as shown in Plate 5 of Appendix 4.6). Each 200m 'branch' of the cable route options was given a unique code to allow for identification. Relevant considerations within each of the 200m cable 'branches' were identified. Following this, a classification was attributed to each element based on a qualitative assessment and expert judgement. A preferred cable corridor for the site selection process was subsequently selected, based upon environmental and engineering considerations and other key factors as identified above.

4.10.3 Review of the Preferred Cable Corridor Option

70. The next stage of the cable corridor site selection process was reviewing the preferred cable corridor option identified (as shown in Plate 6 of Appendix 4.6), primarily to remove features such as clipped land registry boundaries, road margins, access tracks and areas of sensitive habitats, whilst still maintaining up to 200m

cable corridor width (where possible) to allow for engineering flexibility. The review also considered a minimum cable corridor of 100m in order to allow for the co-location of both Norfolk Vanguard and Norfolk Boreas. The review primarily consisted of aligning the cable corridor along land registry boundaries and field margins to avoid isolating parcels of land where possible. The overall benefits of the cable corridor review process included:

- Reducing the number of potentially affected landowners;
- Avoiding direct impacts to a number of sensitive habitats and features;
- Reviewing the engineering feasibility and constructability; and
- Identifying potential cable pinch points.

4.10.4 Production of the Cable Corridor Option for PEIR Stage

71. The preferred cable corridor presented at PEIR stage was a single 200m wide onshore cable corridor to accommodate either HVAC or HVDC options, as shown in Plate 7 of Appendix 4.6. The approach to the cable installation work is discussed in detail in Chapter 5 Project Description.

4.11 Identification of Onshore Cable Route

72. Following PEIR, the project design was subsequently refined in response to consultation feedback. This included a decision to deploy HVDC technology as the export system. The commitment to HVDC technology (compared to the alternative HVAC solution which was also presented as part of PEIR) significantly minimises environmental impacts through the following design considerations;

- HVDC requires fewer cables than the HVAC solution. During the duct installation phase, this reduces the cable route working width (for Norfolk Vanguard and Norfolk Boreas combined) to 45m from the previously identified worst case of 100m. As a result, the overall footprint of the onshore cable route required for the duct installation phase is reduced from approximately 600ha to 270ha;
- The width of permanent cable easement is also reduced from 54m to 20m;
- Removing the requirement for a CRS as permanent above ground infrastructure; and
- Reducing the total number of jointing bays for Norfolk Vanguard from 450 to 150.

73. As a result of design responses to consultation feedback received, the cable route was refined as shown in Figure 4.8.

4.12 Identification of Cable Relay Station Location

74. Pre-application consultation was undertaken on the basis of two options for the electrical transmission system, an HVAC or an HVDC system. The HVAC option required a CRS to ensure the efficiency of the HVAC transmission. In response to consultation feedback, a HVDC export system will be deployed which removes the requirement for a CRS as permanent above ground infrastructure. This is discussed further in Chapter 5 Project Description.

75. Prior to this decision, two potential CRS locations were identified; Appendix 4.7 provides further detail on how the CRS locations were identified (whilst CRS are no longer required, appendix 4.7 provides useful information regarding the CRS site selection process). This included consideration of National Grid's Guidelines on Substation Siting and Design (The Horlock Rules) which document National Grid's best practice for the consideration of siting of electricity network infrastructure.

4.13 Identification of Onshore Project Substation Location

76. The onshore project substation will consist of up to two HVDC converter stations housing DC filter equipment and power electronics to convert HVDC to HVAC power for connection to National Grid, and the following:

- 2x outdoor HVAC compounds – each compound will contain one or more 400kV transformers, plus HVAC filters, busbars and cable sealing ends;
- Control building – housing SCADA and protection equipment;
- Access roads – for operation and maintenance access to equipment; and
- Associated connections between equipment via overhead busbar and cabling, including buried earthing system.

77. In order to identify the most appropriate location to site the onshore project substation, National Grid's Guidelines on Substation Siting and Design (The Horlock Rules) have been taken into consideration. These guidelines document National Grid's best practice for the consideration of relevant constraints associated with the siting of substations. The Horlock Rules have been considered as part of the development of the onshore project substation location and this is outlined within Table 4.3.

Table 4.3 Application of Horlock Rules to onshore project substation

National Grid's Approach to Design and Siting of Substations (Overall System Options and Site Selection)	Norfolk Vanguard onshore project substation considerations
In the development of system options including new substations, consideration must be given to environmental issues from the earliest stage to balance the technical benefits and capital cost requirements for new developments against the consequential environmental effects, in order to keep adverse effects to a reasonably practicable minimum	Environmental constraints and opportunities have been considered throughout the development phase of the project and reported within the ES.

National Grid's Approach to Design and Siting of Substations (Overall System Options and Site Selection)	Norfolk Vanguard onshore project substation considerations
Amenity, Cultural or Scientific Value of Sites	
The siting of new National Grid Company substations, sealing end compounds and line entries should as far as reasonably practicable seek to avoid altogether internationally and nationally designated areas of the highest amenity, cultural or scientific value by the overall planning of the system connections.	Internationally and nationally designated sites have been avoided and the onshore project substation is not located within a: - National Park; - AONB; - Heritage Coast; - World Heritage Site; - Ramsar Site; - SSSI; - National Nature Reserve; - SPA; and/or - SAC. Consideration has also been given to historic sites with statutory protection. See Chapter 28 Onshore Archaeology and Cultural Heritage.
Local Context, Land Use and Site Planning	
Areas of local amenity value, important existing habitats and landscape features including ancient woodland, historic hedgerows, surface and ground water sources and nature conservation areas should be protected as far as reasonably practicable.	Areas of local amenity value in the location of the onshore project substation have been protected as far as reasonably practicable as part of the site selection process. See Chapter 30 Tourism and Recreation. Consideration has been given to existing habitats and landscape features including ancient woodland (e.g. Necton Wood, Great Wood, North Grove) historic hedgerows, surface and ground water sources and nature conservation areas (e.g. County Wildlife Sites). See Chapter 22 Onshore Ecology.
The siting of substations, extensions and associated proposals should take advantage of the screening provided by land form and existing features and the potential use of site layout and levels to keep intrusion into surrounding areas to a reasonably practicable minimum.	The onshore project substation benefits from relatively substantial existing hedgerows and woodland blocks within the local area (e.g. Great Wood and Necton Wood). These provide a level of mitigation of landscape and visual effects from the outset and can be strengthened with planting proposals during the construction phases of the proposed project to ensure robust screening. See Chapter 29 Landscape and Visual Impact Assessment for further details. In addition, the project has made a further commitment to incorporate effective, appropriate and suitable landscape screening and planting (as part of the ongoing onshore project substation design) in order to reduce landscape and visual impacts, as well as any indirect impacts upon the setting of heritage assets (an Outline Landscape and Ecological Management Plan (OLEMS) (document reference 8.7) has been prepared and is submitted with the DCO application).

National Grid's Approach to Design and Siting of Substations (Overall System Options and Site Selection)	Norfolk Vanguard onshore project substation considerations
The proposals should keep the visual, noise and other environmental effects to a reasonably practicable minimum.	Visual, noise and other environmental effects have been minimised as far as possible through the site selection. For example, consideration was given to existing screening and locating away from built up areas. See Chapter 29 Landscape and Visual Impact Assessment and Chapter 25 Noise and Vibration. Noise reduction technology and design approach is discussed in Chapter 25 Noise and Vibration of the ES. Suitable mitigation measures will be incorporated in the detailed substation design to ensure that noise emissions will not exceed the permitted noise levels of the existing Necton substation. This has been agreed in principle with the Environmental Health Officer at Breckland Council.
The land use effects of the proposal should be considered when planning the siting of substations or extensions.	The effects on land use have been considered as part of the site selection process. The impacts on land use are considered within Chapter 21 Land Use and Agriculture.
Design	
In the design of new substations or line entries, early consideration should be given to the options available for terminal towers, equipment, buildings and ancillary development appropriate to individual locations, seeking to keep effects to a reasonably practicable minimum.	Landscape and visual impact will be minimised by avoiding the use of tall structures and buildings wherever possible. The onshore project substation will be subject to detailed design post consent.
Space should be used effectively to limit the area required for development consistent with appropriate mitigation measures and to minimise the adverse effects on existing land use and rights of way, whilst also having regard to future extension of the substation.	The permanent footprint for the onshore project substation is based on maximum preliminary layouts. More space-efficient solutions may be developed during the detailed design process; if so, this would reduce the area required for development. The location of the onshore project substation has avoided direct impacts to public rights of way (see Chapter 30 Tourism and Recreation for further information).
The design of access roads, perimeter fencing, earth shaping, planting and ancillary development should form an integral part of the site layout and design to fit in with the surroundings.	The design of access roads, perimeter fencing, earth shaping, planting and ancillary development will be subject to final detailed design, however these will be designed in accordance with principles of the Design and Access Statement (DAS) (document reference 8.3) to minimise impacts on surroundings.
Line Entry	
In open landscape especially, high voltage line entries should be kept, as far as possible, visually separate from low voltage lines and other overhead lines so as to avoid a confusing appearance.	All cables to the connection point will be buried underground. Modifications to the existing overhead line structures adjacent to the National Grid substation

National Grid's Approach to Design and Siting of Substations (Overall System Options and Site Selection)	Norfolk Vanguard onshore project substation considerations
The inter-relationship between towers and substation structures and background and foreground features should be studied to reduce the prominence of structures from main viewpoints. Where practicable the exposure of terminal towers on prominent ridges should be minimised by siting towers against a background of trees rather than open skylines.	would be required to provide a double turn-in arrangement[5]. The net new number of towers required to accommodate the works is one, and will be in close proximity to the existing corner tower (to the north east of the existing Necton National Grid substation). The design approach taken would be confirmed at detailed design phase, post consent but would be in keeping with the existing substation design.

78. An initial high-level desk based exercise was undertaken to map sensitive features in the vicinity of the connection point; this is shown in Appendix 4.8. This included consideration of designated sites of nature conservation, historical sites, local amenity value, important existing habitats and ancient woodland, surface and ground water sources, areas at risk of flooding and nature conservation areas.

79. In order to minimise the distance to the existing Necton National Grid substation from the onshore project substation (and to mitigate transmission losses), the onshore project substation search area was defined as a 3km radius from the existing Necton National Grid substation (see Figure 4.9). The search area was divided into separate sectors in order to identify the constraints and opportunities associated with the onshore project substation search area.

80. The search area was consulted upon as part of the Scoping Report (Royal HaskoningDHV, 2016), as well as during community drop in exhibitions, and meetings with landowners, stakeholders and regulators. The search area was also presented widely through the project website and newsletter distributions.

81. Following the Horlock Rules outlined in section 4.1, "*consideration must be given to environmental issues from the earliest stage*", and therefore the areas with relatively fewer sensitive features were considered to be preferred in order to identify the location for the onshore project substation.

82. The least constrained areas were within sector 1 and sector 5 of the onshore project substation search area due to the absence of PRoWs and environmental designations e.g. for ecological and archaeological features within these sectors, as well as being less influenced by the residential buffer zones; these sectors were therefore considered areas of least environmental impact, and therefore preferred for identifying a suitable location for the onshore project substation.

[5] Each overhead line tower carries two 400kV circuits. In this arrangement, both circuits are turned into the substation busbar structure.

83. The benefits of these areas were that:

- Sector 1 (pink sector): Contains existing natural screening (in accordance with the Horlock Rules) afforded by Great Wood, Necton Wood and a network of hedgerows in order to potentially reduce landscape and visual impacts.
- Sector 5 had the advantage of aggregating electrical infrastructure in proximity to the existing National Grid substation which not only reduces transmission losses but also keeps intrusion of electrical infrastructure into surrounding areas to a reasonably practicable minimum.
- With the proposed cable corridor approaching from the east, these sectors also represented areas which would allow the most direct cable route to reduce transmission losses.

84. As a result of this assessment and along with feedback from stakeholders, the substation search area was refined to a 'keyhole' shape, as shown in figure 4.10. This refined 'keyhole' onshore project substation zone was presented as part of the March 2017 community events and stakeholder meetings, as well as being circulated through the project website and newsletter.

85. Since March 2017, the onshore project substation zone has been further refined through more detailed consideration of constraints, drawing on a range of engineering and environmental expertise and informed by further discussion with landowners and stakeholders, as detailed below.

86. The specific design principles / requirements used in identifying preferred location options for the onshore project substation locations included:

- An area of 250m x 300m area for Norfolk Vanguard (see Chapter 5 Project Description for the onshore project substation dimensions);
- An area of 200m x 100m area for a temporary construction compound;
- Access from A47 during construction and operation;
- Use of existing features present (woodland and topography) to aid screening;
- Avoid Public Rights of Way (PRoW);
- Avoid siting under overhead lines and other utilities;
- Avoid siting within Flood Zones 2 and 3[6];
- Avoid residential properties;
- Avoid where possible key archaeological assets; and
- Avoid where possible ecological habitats.

[6] For further details on flood zones, see https://www.gov.uk/guidance/flood-risk-and-coastal-change#flood-zone-and-flood-risk-tables

87. Due to the strategic nature of the development of Norfolk Vanguard and Norfolk Boreas, the potential to co-locate the onshore project substations for both projects was also a key consideration in identifying location options.

88. Following the initial constraints mapping exercise, as well as consideration of technical constraints and information gathered at site visits and consultation events, four sites were identified for further investigation, shown in Figure 4.11. Appendix 4.9 provides detail on the further assessments undertaken to identify the substation locations.

89. In July 2017, Norfolk Vanguard Limited held a meeting with local residents and representatives, to present the four site options and request their views, including identifying key issues and opportunities associated with each option, and to consider options that might reduce concerns. Participants were also shown photomontages which featured examples of the potential planting schemes that would help to reduce visual impacts.

90. During consultation, it was recognised that noise is a sensitive issue; minimising noise through careful siting and investment in further mitigation measures was therefore an important consideration in the development of the project design. Noise impacts and mitigation are considered in detail in Chapter 25 Noise and Vibration.

91. Taking feedback into account, the team considered the four options, and Option 4 (Figure 4.11) was discounted due to concerns relating to visibility from nearby properties and Necton Village. It was also considered to present a potentially high risk of buried archaeological impacts. Other factors, including potential impact and need for diversion or removal of field drainage systems, were also highlighted in respect to Option 4.

92. Option 3 (Figure 4.11) was also considered a less favourable site choice primarily due to concerns in relation to the likely presence of buried archaeological features. The site was also considered to be more visible from nearby properties in comparison to other options. The site is located adjacent to a disused common clay and shale pit which posed potential ground contamination issues when undertaking excavations in this area.

93. Option 1 and Option 2 (Figure 4.11) were therefore preferred, with option 1 considered to have slightly greater noise, ecology, traffic and access issues compared to Option 2. Of the four substation options, Option 2 was considered to be the preferred option for the following reasons:

- It provides a site within the original substation search area (in proximity to the Necton National Grid substation) and allows a comparatively simple alignment of cables coming from the onshore cable corridor, through the onshore project substation site and joining to existing infrastructure at the Necton National Grid substation;
- The site has good ground conditions, with comparatively low risk from flooding;
- The site is deemed to have comparatively less potential impact associated with known buried archaeology;
- It poses the lowest potential noise impacts;
- It has good potential for the development of screening planting and other mitigation measures that will be provided to help to mitigate the impacts of the development; and
- Existing mature hedge lines will be retained and used as natural screening.

94. Traffic and access to the site and the potential presence of foraging bats along the hedgerows were highlighted as areas for further consideration and mitigation (see Chapter 22 Onshore Ecology and Chapter 24 Traffic and Transport for further information).

95. As a result of this process of option development and evaluation, Option 2 has been taken forward as the preferred development site for the Norfolk Vanguard onshore project substation (see Figure 4.12).

4.14 Identification of National Grid Extension Works Location

96. The existing Necton National Grid substation would require an extension to accommodate both the Norfolk Vanguard and Norfolk Boreas connection points. The Necton National Grid substation would need to accommodate the circuit breakers which are the connection points for both projects with associated busbar structures (metal bars that conduct electricity within a substation) and which allow connection onto the existing 400kV overhead line for generation to be transmitted onto the wider National Grid system. In addition to the Necton National Grid substation itself, modifications to the existing overhead line structures adjacent to the substation would be required to provide a double turn-in arrangement[7].

97. The existing Necton National Grid substation outdoor busbars will be extended in a westerly direction for the Norfolk Vanguard connection, to a total length of 340m (inclusive of existing Necton National Grid substation), with seven new AIS bays installed along the busbar extension for Norfolk Vanguard. Five further AIS bays

[7] Each overhead line tower carries two 400kV circuits. In this arrangement, both circuits are turned into the substation busbar structure.

would be required as part of the Norfolk Boreas project to the east, with a total busbar length (Norfolk Vanguard extension, Norfolk Boreas extension and existing substation) of 470m, which will be consented separately to Norfolk Vanguard, under the Norfolk Boreas DCO application. These parameters are considered to be the maximum worst case scenario, as assessed in line with the Rochdale Envelope principles.

98. Two new overhead line towers will be required to accommodate Norfolk Vanguard and Norfolk Boreas in close proximity to the existing corner tower (to the north east of the existing Necton National Grid substation) with a maximum height of 55m. The existing corner tower will be demolished such that the net new number of towers is one. The design approach taken would be confirmed at detailed design phase, post consent.

99. The location of the National Grid substation extension, and associated overhead line works is largely determined by the location and configuration of the existing Necton National Grid substation. The extension works would need to be oriented in line with the existing busbar infrastructure to ensure the most efficient use of space and most effective operation of the extended onshore project substation.

100. An indicative development area for the extension works to the existing Necton National Grid substation and overhead line modifications was provided in the material provided to stakeholders, communities and landowners and in public drop in exhibitions in March 2017 and consulted on as part of the PEIR stage.

101. The existing Necton National Grid substation, the National Grid substation extension, overhead line modifications and the temporary works area are shown on Figure 4.13.

102. Norfolk Vanguard Limited are continuing to work closely with National Grid as more detailed designs are developed.

4.15 Onshore Project Infrastructure Refinement

103. Following PEIR consultation, a review of consultation feedback and additional data and information available was undertaken, including:

- Landowner and community feedback;
- Ecological survey data;
- Results from the priority programme of archaeological geophysical survey; and
- Landscaping design proposals.

104. This information has helped to refine the project design further (for details see Chapter 5 Project Description).

4.15.1 Landowner Consultation

105. Non-statutory pre-application consultation has been undertaken with landowners since March 2017 (for details see Consultation Report (document 5.1)). Comments and suggestions put forward by landowners have helped to refine the final project design and resulted in changes to the location of the project infrastructure. Landowner comments can be summarised broadly as follows:

- Aligning to field boundaries during construction;
- Requests to reroute the cable corridor as far from residential properties as possible (in some instances); and
- Reducing the amount of land that is required for the project.

106. More detail regarding the ongoing consultation with landowners is discussed in section 4.4.

107. Norfolk Vanguard Limited's land agents have met and liaised with the land agents representing those not met directly. Where possible, the site selection of the onshore project infrastructure, with particular respect to the onshore cable route, has been revised to take into account this consultation and incorporate the feedback into the final design.

4.15.2 Onshore Ecology and Recreational Features

108. In response to comments from stakeholders through the Evidence Plan Process (particularly The Wildlife Trust, Natural England, local authorities and the Environment Agency), the project design has been refined as follows:

4.15.2.1 Country Wildlife Sites

109. Trenchless crossing techniques (e.g. HDD) will be employed at all CWS and proposed CWS crossed by the onshore project area in order to minimise the impacts upon the habitats contained within these sites. This includes proposed trenchless crossing techniques (e.g. HDD) at the following locations:

- Wendling Carr CWS (CWS no. 1013);
- Little Wood CWS (CWS no. 2024),
- Land South of Dillington Carr CWS (CWS no. 1025),
- Kerdiston proposed CWS (no CWS number);
- Marriott's Way CWS (CWS no. 2176) (in two locations); and
- Paston Way and Knapton Cutting CWS (CWS no. 1175).

110. At five of these six locations, no works will be undertaken within the CWS boundary. At one location, Wendling Carr CWS, a running track will be required to pass through

the CWS in order for the trenchless crossing works to take place. This will be a 6m by up to 180m road located within the CWS.

111. Trenchless crossings in these locations also have the benefit of reducing impacts to some recreational features such as the Marriot's Way long distance trail, impacts on which were also raised as a potential concern during the PEIR consultation process.

4.15.2.2 Hedgerows

112. The maximum size of the hedgerow gap created has been minimised within the project design as far as possible. Through the selection of a HVDC electrical solution, the maximum width of hedgerow gaps that are required has been further reduced. The maximum size of the hedgerow gap created during the two-year duct installation phase is 20m[8], thus reducing the amount of hedgerow removed during construction by over 50%.

113. Where hedgerow gaps are required beyond the two-year duct installation phase (i.e. for the duration of the subsequent two-year cable pull phase), the number of gaps required will be minimised as far as possible and the width will be no wider than 6m.

4.15.3 Onshore Archaeology and Cultural Heritage

114. Onshore archaeological and cultural heritage considerations have fed into the micrositing of onshore project infrastructure these are discussed below.

4.15.3.1 Avoidance, micrositing and route refinement

115. In addition to avoiding direct physical impacts on designated heritage assets from the outset (see Chapter 28 Onshore Archaeology and Cultural Heritage), non-designated above ground heritage assets and potential sub-surface archaeological remains have also been avoided by means of route refinement where possible. Heritage assets recorded by the Norfolk Heritage Environment Record (NHER), the results of the aerial photographic and LiDAR data assessment and the results of the priority programme of archaeological geophysical survey have been used in the iterative design process. This data has been reviewed throughout a series of workshops so that features and areas indicative of more substantial sub-surface archaeological remains identified to date have been avoided, wherever possible. This process has enabled the project design to be developed in a manner which takes into account known and potential features of likely high heritage significance (e.g. possible Prehistoric ring ditches) or concentrated areas of complex archaeological features indicative of Prehistoric, Roman and medieval enclosures and settlement

[8] This width assumes that the onshore cable route bisects each hedgerow in a perpendicular fashion. In reality, some hedgerows will be crossed at an angle, therefore increasing the maximum width of the gap required up to a possible 25m.

activity so that direct impacts can be avoided (where possible). This approach is directly in-line with the wider project aims of minimising the environment and historic environment impacts of the project, and represents a good practice example of detailed and methodical embedded mitigation.

116. In the event that non-designated heritage assets cannot be avoided, initial informative stages of mitigation work will be employed and undertaken post-consent, followed by additional mitigation measures, as required (see Chapter 28 Onshore Archaeology and Cultural heritage).

4.15.4 Strategic Landscape Mitigation

117. The project has made a further a commitment to incorporate effective, appropriate and suitable landscape screening and planting (as part of the ongoing onshore project substation design) in order to reduce landscape and visual impacts, as well as any indirect impacts upon the setting of heritage assets to a level that is considered to be non-significant in EIA terms, wherever possible.

118. Mitigation measures associated with the onshore project substation, National Grid substation extension and A47 form part of a strategic approach to enhancing landscape character and biodiversity in the local area. Figure 29.12 in Chapter 29 Landscape and Visual Impact Assessment shows how mitigation planting will contribute to the wider landscape structure of the area and help consolidate green corridors for wildlife.

119. Mitigation planting for the onshore project substation is shown in Figure 29.9a in Chapter 29 Landscape and Visual Impact Assessment. This has been designed to help screen the onshore project substation as far as possible. Details of the mitigation planting are presented in section 29.7.1 of Chapter 22 Onshore Ecology and Outline Landscape and Ecological Management Strategy (OLEMS) (document 8.7).

120. Mitigation planting for the National Grid substation extension is shown in Figure 29.10a in Chapter 29 Landscape and Visual Impact Assessment. This has been designed to screen the National Grid substation extension in views from Necton. Details of the mitigation planting are presented in section 29.7.1 of Chapter 22 Onshore Ecology and the OLEMS (document 8.7).

4.16 Summary

121. In summary, Norfolk Vanguard Limited has considered options and alternatives in an objective way which has led to the refinement of the project description provided in Chapter 5 Project Description of the ES. The options and the process of refining the original project design from the broad search areas for the offshore infrastructure, landfall, onshore cable route, onshore project substation and National Grid

substation extension have been informed by community, stakeholder and landowner consultation alongside environmental considerations and engineering requirements. Table 4.4 gives an overview of the site selection decisions that have been discussed throughout sections 4.6-4.15.

Table 4.4 Summary of site selection decisions

Infrastructure element	Options considered	Decision	Main environmental benefits
Subsea cable route	Northern Route to Mundesley to Sea Palling Middle Route to Gorleston on Sea Southern Route to Lowestoft	Northern Route to Mundesley to Sea Palling with a landfall at Happisburgh South	Cable route is short and direct, avoids need to cross The Broads National Park, minimises active cable and pipeline crossings and avoids MCZ to the North.
Landfall	Initial landfall search area was Bacton to Sea Palling. The area was then divided into sectors (L1, L2 and L3), with the following sites taken forward: Bacton Green Walcott Gap Happisburgh South	Happisburgh South	Avoids the nationally designated MCZ (the Cromer Shoal Chalk Beds), allows co-location of Norfolk Vanguard and Norfolk Boreas landfall and reduces total amount of area directly impacted. It avoids populated areas and those at risk of flooding as far as possible. Provides opportunities associated with Happisburgh archaeology and avoids technical engineering and feasibility risks associated with Bacton Gas Terminal land (Appendix 4.4)
Cable relay station	The decision for an HVDC export system removed the requirement for a CRS as permanent above ground infrastructure (Appendix 4.7 however outlines the process of site selection taken).		
Onshore cable route	Option A Option B Option C (Appendix 4.6, plate 3). Cable Corridors A and B were taken forward as the Cable Corridor Study Area (Plate 5 of Appendix 4.6).	Refinement of Cable Corridor Study Area based upon design principles listed in section 4.10 was undertaken. The preferred cable corridor presented at PEIR stage was a single 200m wide onshore cable corridor as shown in Plate 7 of Appendix 4.6. As a result of design responses to consultation feedback (including HVDC decision), the	The cable route proposed was selected based upon guiding design principles (section 4.10) and a cable corridor refinement process which included consultation feedback.

Infrastructure element	Options considered	Decision	Main environmental benefits
		cable route was refined as shown in Figure 4.8.	
Onshore project substation	Options 1-4	Option 2 (Appendix 4.9)	This option is in close proximity to the Necton National Grid substation, has good ground conditions, (with comparatively low risk from flooding). There is less potential impact associated with known buried archaeology and had the lowest potential noise impacts. It also had good potential for the development of screening planting with existing mature hedge lines used as natural screening.
National Grid connection point	An appraisal of appropriate connection options was undertaken and from this a short list of preferred onshore connection points. A grid offer was made by National Grid for a connection point at Necton and this was accepted by Norfolk Vanguard Limited in November 2016.		
National Grid Extension Works	The location was largely determined by the location and configuration of the existing Necton National Grid substation. The options considered are limited to within the National Grid substation extension (see Figure 4.13) and the National Grid overhead line modifications and the National Grid temporary works area.		

122. This site selection and assessment of alternatives chapter explains this process and presents the final project design included within the ES and DCO submission. The parameters for the final project design included within the ES and DCO submission are included in Chapter 5 Project Description and shown in Figures 4.14 to 4.1.

4.17 References

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