

East Anglia THREE

Chapter 5

Description of the Development

Environmental Statement

Volume 1

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Chapter 5 Description of the Development figures are presented in Volume 2: Figures and listed in the table below.

Figure number	Title
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5 DESCRIPTION OF THE DEVELOPMENT

5.1 Introduction

1. This chapter provides a full description of the components required for construction, operation and decommissioning of the proposed East Anglia THREE project and includes a consideration of the methods used for installation, maintenance and decommissioning.
2. This document has been written in conjunction with other documents that form part of this Development Consent Order (DCO) application, these include:
 - The Outline Offshore Operation and Management Plan (OOOMP);
 - Code of Construction Practice (CoCP); and
 - Outline Landscape and Ecological Management Strategy (OLEMS)
3. A brief overview of the project is presented in section 5.3 followed by a summary of consultation responses which have helped shape the project and this document in section 5.3. An outline of the key project characteristics is presented in section 5.4. with detailed descriptions of all aspects of the project provided in sections 5.5 and 5.6 which are divided into:
 - 5.5 Offshore - wind turbines, offshore collector stations and converter stations, accommodation platform, meteorological masts and their foundations, and offshore export cables (up to the intertidal), fibre optic cables, interconnection cables, platforms link cables and inter-array cables; and
 - 5.6 Onshore - landfall (intertidal to transition bay), onshore export cables, the onshore substation(s), and work to construct and access these components.

5.1.1 Project Design Envelope

4. Section 3.5 of Chapter 3 Policy and Legislative Context provides a background to the design envelope approach.
5. The project design envelope sets out a series of design options for the project. The project design envelope has a reasoned minimum and maximum extent for a number of key parameters. The final design would lie between the minimum and the maximum extent of the consent sought, for all aspects of the project; this includes spatial, temporal and the proposed methodology to be employed. The project design envelope is used to establish the extent to which the project would

impact on the environment. The detailed design of the project could then vary within this ‘envelope’ without rendering the assessment inadequate.

6. Therefore, the information presented in this chapter covers the range of potential design and activity parameters upon which the subsequent impact assessment chapters are based.

5.1.2 Project Description Terminology

7. This project description uses specific terms for different site areas offshore and onshore. These terms are also used within the technical chapters (Chapter 7 to Chapter 29). For clarity these are summarised in *Table 5.1*.

Table 5.1 Project Description Terminology.

Terminology	Site Location and Description
The proposed East Anglia THREE project	The complete project being proposed, consisting of all wind turbines, offshore electrical platforms, offshore accommodation platform, inter-array cables, interconnection cables, platform link cables, operational meteorological masts, floating LiDARs (Light Detection and Ranging), wave buoys, guard buoys, offshore export cables, fibre optic cables, landfall infrastructure, onshore cables and ducts, onshore substation(s) and cable connection from the proposed onshore substation to the National Grid at Bramford.
East Anglia THREE site	The 305km ² area within the offshore windfarm boundary including the following infrastructure: wind turbines, inter-array cables, platform link cables, fibre optic cables, offshore electrical platforms, offshore accommodation platform, operational meteorological masts, floating LiDARs wave buoys and guard buoys.
Offshore cable corridor	The corridor is up to 166km long and between 1km and 2.5km wide for the majority of the route, and up to 8km wide at its widest point. Up to four individual offshore export cables and up to two fibre optic cables would be laid from the East Anglia THREE site to the landfall location. This comprises the export cable corridor and interconnector cable corridor.
Export cable corridor	The corridor of seabed within which the, up to four, export cables would be located. This is displayed in (<i>Figure 5.1</i>)
Interconnector cable corridor	The corridor of seabed within which the, up to four, interconnector cables would be located. This is displayed in (<i>Figure 5.1</i>)
Landfall location	The area where the offshore export cables would make contact with land (within the intertidal area) and connect to the onshore cables.

Terminology	Site Location and Description
Onshore cable route	37km long and 75m wide corridor within which up to 12 (single core) cables and up to two fibre optic cables would be installed in ducts to connect the proposed East Anglia THREE project to the onshore substation.
Onshore substation	Onshore substation refers to either the onshore converter(s) contained within one or more converter halls under the high voltage direct current (HVDC) solution, or the low frequency alternating current (LFAC) substation and a compound containing electrical and other associated equipment.
Onshore substation location	The location of the onshore substations for the proposed East Anglia THREE project at Bramford. The substation compound (which could contain up to two substations) would cover a maximum area of 160m by 190m.

5.2 Consultation

8. Under Phase IIa of the Section 42 consultation (See the Consultation Report (Which is being submitted as part of this application) section 11 for further detail) East Anglia THREE Limited (EATL) consulted on the Preliminary Environmental Information report (PEIR). Responses to this consultation that were relevant to the project description are present in *Table 5.2*.

Table 5.2 Consultation Responses.

Consultee	Date /Document	Comment	Response / where addressed in this ES
SCC, MSDC, SCDC*	Response to PEIR May 2014	The joint response from these councils highlighted their concerns about Scenario 2 which was included in Chapter 5 Description of the Development of the PEIR	Scenario 2 (open trenching) is no longer being considered.
SCC, MSDC, SCDC*	Response to PEIR May 2014	<i>We note the construction timetable anticipating completion in 2022 at the earliest (paragraph 14) was later than the connection date recorded on National Grid's TEC Register (April 2021). We would welcome clarification on the anticipated connection dates of this and future EAOW projects.</i>	It is not possible to define a connection date prior to consent for the project being granted; further information would be provided should consent be granted.
SCC, MSDC, SCDC*	Response to PEIR May 2014	<i>If EA ONE construction commences in 2017, those works are likely to be completed and the land reinstated before the commencement of EA THREE (if indeed it is 2020). This potentially leads to the scenario</i>	Section 5.6.6.2.2 explains that the requirement to reinstate is included with the East Anglia

Consultee	Date /Document	Comment	Response / where addressed in this ES
		<i>of removal and fairly soon after, partial reinstatement of the haul road and Construction Consolidation Sites. Consideration should be given to how this scenario can be avoided and the mechanisms that could be used to retain the CCSs and haul road (potentially in its entirety) for use for East Anglia THREE.</i>	ONE DCO. EATL is investigating whether material laid down for East Anglia ONE could be left in situ. However, EATL must consider the worst case throughout the Environmental Impact Assessment (EIA) of full reinstatement following East Anglia ONE completion and installation of new haul road.
SCC, MSDC, SCDC*	Response to PEIR May 2014	<i>We noted that there is a potential for an offshore accommodation block (paragraph 16). This could have socio-economic implications in that it may result in a greater number of workers originating from outside the region. Some further detail on the shift patterns in such a scenario was sought.</i>	Further information is provided within section 5.5.6 on the numbers of workers that will be accommodated on the platform.
SCC, MSDC, SCDC*	Response to PEIR May 2014	Requested further information on indicative jointing bay locations	EATL commissioned AECOM to provide indicative jointing bay locations, these are displayed in <i>Figures 5.2a - j</i> however, stakeholders should be mindful that final positions would be dictated post-consent by engineering design and installation contractors
SCC, MSDC, SCDC*	Response to PEIR May 2014	<i>Minimising the impact of the converter station(s) at Bramford is a key concern of the local authorities and the local community. Every effort should be made to minimise the Rochdale Envelope in light of emerging technologies and evidence emerging through the procurement of the</i>	Chapter 29 Landscape Seascape and Visual amenity assesses the impact of the onshore substations and detail how the

Consultee	Date /Document	Comment	Response / where addressed in this ES
		<i>EA ONE converter station. We would also stress that similarity in form, mass and appearance of the converter stations for each phase of development will be important in minimising the cumulative impacts and every effort should be made to assimilate this aspect of the development into the surrounding countryside.</i>	impacts would be mitigated
Swillan and Witnesham Parish Council	Response to PEIR May 2014	<i>As we understand it, once the underground cabling for EA1 and the duct for future use (EA3) have been laid there will be full reinstatement for the landowners. This covers the removal of the temporary haul roads.</i>	The requirement to reinstate is included with the East Anglia ONE DCO. EATL is investigating whether material laid down for East Anglia ONE could be left in situ. EATL will also have similar commitments to reinstate temporary haul road.
Swillan and Witnesham Parish Council	Response to PEIR May 2014	<i>As we understand it, you are planning to use, where possible, existing roads/country lanes/etc. For access as the haul roads will no longer exist</i>	EATL do plan, where possible to use existing roads lanes and tracks as described in section 5.6.6, however, there would be a requirement to install haul road in sections that cannot be accessed from existing roads and tracks.

Consultee	Date /Document	Comment	Response / where addressed in this ES
Swillan and Winesham Parish Council	Response to PEIR May 2014	<i>In our Parish, your maps show "Strugglers Lane" as a cable pit access route. Given the size of equipment and vehicles likely to be used, we wish to register, that in our opinion, this Lane is entirely unsuitable. "Struggler's Lane" is narrow, difficult to access from the B1077, is only partially made up and is part of the Fynn Valley walker's route in an area classified for its natural beauty. On the information that we currently have, it is impossible to see how this route can withstand your intended use. We ask that you consider alternatives such as retaining an appropriate stretch of haul road</i>	The proposed access at Strugglers Lane has been removed from East Anglia THREE plans. Figure 5.2h and Table 5.42
Natural England	Response to PEIR May 2014	Further detail as to the destination of drill arisings and its subsequent disposal, sea bed preparation and cable protection is required.	A marine licence will be applied for to dispose of dredged or drilled material within the windfarm site and offshore cable corridor. The application will be supported by a Site Characterisation Report which is being submitted as part of this application.
Natural England	Response to PEIR May 2014	Natural England advises that, in our view, the use of pre-installed ducts which would be installed during construction of East Anglia 1 would be the most favourable option from an ecological perspective. This option would lessen the time spent working on the cabling and hence the level of disturbance to birds associated with the Deben Estuary SPA. The second approach would likely result in concurrent works, leading to a greater period of disturbance.	East Anglia ONE Limited has committed to installing ducts during the construction of East Anglia ONE.

Consultee	Date /Document	Comment	Response / where addressed in this ES
Natural England	Response to PEIR May 2014	Natural England notes that in addition to the infrastructure described, Low Frequency Alternating Current (LFAC) infrastructure may be required. It is not clear whether this is within the footprint of East Anglia 1 and/or 3 and therefore whether baseline data for the area has been collected. Confirmation that the foot print will stay the same.	This description of the development includes the LFAC electrical solution throughout the ES and is described in detail throughout this chapter.
Natural England	Response to PEIR May 2014	<i>"We note that the disposal area for the deposition of dredged sand during sea bed preparations has not yet been established. Further explanation as to the destination of material removed from the site, and the origin of material being placed within the project boundaries during seabed preparation, is required."</i>	A marine licence will be applied for to dispose of dredged or drilled material within the windfarm site and the eastern end of the cable corridor. The application will be supported by the Site Characterisation Report which is being submitted as part of this application.
Natural England	Response to PEIR May 2014	It is stated that drilling would generate some spoil material that would require disposal. This material would be disposed of within the windfarm with the spoil 'subsequently winnowed away by the natural tide and wave driven processes'. Natural England requires further justification for this statement, as the potential for such side cast mounds to winnow away has not always proven to be realistic from the past experiences of other offshore wind farms.	Further justification for this is provided in Chapter 7 Marine Geology, Oceanography and Physical processes

Consultee	Date /Document	Comment	Response / where addressed in this ES
Natural England	Response to PEIR May 2014	We note that there would be up to two cables interconnecting the East Anglia three and East Anglia One projects. We are concerned that, since the areas where these cables are laid will be between the two sites, these areas may not have been included in the East Anglia 1 or East Anglia 3 ecological assessments. Confirmed that this will be covered and mapped in final ES and use existing data set. Assuming on Western edge of EA ONE is where the cable will connect	An assessment of the interconnector cables is included within this Environmental Statement (ES). The corridors within which the interconnectors would be installed are displayed in <i>Figure 5.1</i>
Natural England	Response to PEIR May 2014	Natural England notes that offshore cables will be left in situ at the decommissioning stage. This approach is sufficient providing that, should cables become exposed or start degrading, consideration is given to the potential leaching of metals into the marine environment. We would welcome further information on how this will be assessed and what actions will be taken if this situation arises. Agreed that this will be considered as part of the Decommissioning plan.	All offshore cables would be impervious to water. The potential environmental impacts arising from cable failure leading to leaching of metals into the sea would be addressed within the detailed decommissioning plan.
Natural England	Response to PEIR May 2014	We appreciate that the wind turbine layout has been described in general terms at this stage. We would just like to remind the applicant that the placement of the turbines should take into account the need to avoid any environmentally sensitive areas.	Pre-construction surveys would be used to inform the micro- siting of foundations away from ecologically sensitive areas
Natural England	Response to PEIR May 2014	Whilst we appreciate the range of cable protection options discussed, without knowing the depths of onshore and offshore cabling and likely exposure area, it is not possible to assess the effect of the protection at this stage.	Section 5.5.14.4 details the type of cable protection that would be used.

Consultee	Date /Document	Comment	Response / where addressed in this ES
Natural England	Response to PEIR May 2014	Natural England questions whether temporary works areas have been considered and included within the assessments throughout the ES? This was discussed and agreed that clarity should be given through the document what is considered to be temporary. In the workshop temporary works were identified as those only occurring during construction.	Further detail is provided on temporary works within section 5.6
Natural England	Response to PEIR May 2014	Natural England highlights that its preference is for cable protection that can be easily removed at the time of decommissioning to be used to ensure that the area returns to the baseline conditions.	The preferred method for cable protection would be mattresses; which if used could be removed.
Natural England	Response to PEIR May 2014	<i>Jacket Dimensions – this table is not very clear what the figure relate to e.g. a single foundation with a total footprint of X and across the site using this foundation the footprint would be X.</i>	<i>Table 5.18 presents the total area of foundation footprints and scour protection under the worst case scenario for that parameter which is gravity base foundations.</i>
Natural England	Response to PEIR May 2014	Further detail should be provided [in the ES] on ancillaries	Further information has been included in section 5.5.10
Natural England	Response to PEIR May 2014	<i>It is Natural England's preference for any cables to be buried at optimum depths and for any consideration pertaining to the placement of linear cable protection should be as a last resort; after all other alternatives have been thoroughly exhausted and the actual need for the cable protection demonstrated i.e. post installation survey evidence presented. At this stage consideration should also be given to the most appropriate type of cable protection or combination of cable protection and not just focusing on the most economical and/or technically reliable option.</i>	It is EATL's preference to bury cables to the optimum depths, to avoid any type of unnecessary interference.

Consultee	Date /Document	Comment	Response / where addressed in this ES
Natural England	Response to PEIR May 2014	<i>Maintenance over life time of the project needs to be fully considered in the licence. Including number of jack up per year</i>	Further detail on maintenance has been added to this description of the development throughout.
English Heritage	Response to PEIR May 2014	<i>We note that to support installation of gravity base foundation it will be necessary to conduct ground preparation works inclusive of dredging (0.1 to 5m) and that suction bucket foundation designs will penetrate the seabed to a depth of 15m. It is therefore essential that if this foundation design is selected that all necessary seabed and sub-seabed surveys are completed to a standard sufficient to support professional archaeological interpretation and analysis given that material of archaeological interest might require recovery to avoid direct impact.</i>	The pre-construction geotechnical surveys would be subject to analysis by a suitably qualified archaeological expert details of likely methods are presented in Chapter 17 Offshore archaeology and cultural heritage. Section 5.5.4.3, details expected suction bucket depths as 10m.

*SCC is Suffolk County Council, MSDC is Mid Suffolk District Council and SCDC is Suffolk Coastal District Council

5.3 Overview of the Project

9. The proposed East Anglia THREE project would consist of between 100 and 172 wind turbines, each having a rated capacity of between 7 and 12MW, with a total installed capacity of up to 1,200MW.
10. EATL are currently considering both a High Voltage Direct Current (HVDC) and a Low Frequency Alternating Current (LFAC) electrical solution for the proposed East Anglia THREE project. A decision on the final electrical solution for the project would be made post-consent during the final design stage of the project and it would be based on the best available technology, balanced with providing the best cost to benefit for electricity consumers. Unless specified the range of values presented in this document would therefore cover both the HVDC and the LFAC solution.
11. Under the HVDC solution up to four offshore collector stations and two offshore converter stations would collect electricity from the wind turbines and transport it to shore via up to four export cables. Under the LFAC solution up to four High Voltage

Alternative Current (HVAC) offshore collector stations would collect electricity for transportation to shore via up to four cables.

12. An accommodation platform may be installed within the East Anglia THREE site to provide accommodation for the workforce during construction, and during the operational lifetime of the project for the operation and maintenance work force.
13. Once onshore up to 12 buried cables (four single core for HVDC or 4 3-core, i.e. 12 for LFAC) with bundled fibre optic (FO) cables would transport electricity to the connection point with the National Grid at Bramford substation in Suffolk.
14. The East Anglia THREE offshore cable corridor would follow a similar offshore cable corridor to that proposed within the East Anglia ONE DCO. An additional section joins East Anglia THREE cable corridor with that of East Anglia ONE.
15. The DCO for the East Anglia ONE Offshore Windfarm comprises its offshore and onshore export cables, the onshore substation at Bramford and onshore cable ducts for two further projects (one of which is East Anglia THREE and the other is a future project which has not yet been defined) planned to connect to the grid at Bramford. To minimise disruption to local communities, this ducting would be installed at the same time as the cables are laid for East Anglia ONE. This assessment is therefore based on the assumption that ducts would be installed for the East Anglia THREE cables during construction of East Anglia ONE. These would be installed along the entire length of the onshore cable route and all horizontal directional drilling (HDD) operations would be undertaken at the same time.
16. EATL is currently considering constructing the project in either a Single Phase or in a Two Phased approach. Under the Single Phased approach the project would be constructed in one single build period and under a Two Phased approach the project would be constructed in two phases each consisting of up to 600MW.
17. Construction for the proposed East Anglia THREE project, under either approach would commence between 2020 and 2025
18. Under the Single Phase approach it is expected that the construction period for the proposed East Anglia THREE project (offshore and onshore) would span approximately 41 months. Under a Two Phased approach the proposed East Anglia THREE project would be built in a staggered way, with the construction of Phase 2 commencing a maximum of 18 months after the start of onshore construction of Phase 1. The total construction period would span 45 months.

5.4 Key Project Characteristics

19. This section summarises the key characteristics of the project design. The key offshore components of the proposed project are likely to comprise:
- Offshore wind turbines and their associated foundations;
 - Offshore electrical platforms – up to four collector stations and up to two converter stations supporting some of the windfarm’s electrical equipment, and possibly incorporating offshore facilities (including accommodation) for operation and maintenance of the windfarm.
 - Sub-sea cables
 - Inter-array cable: These cables typically link / join / connect wind turbines with each other and with offshore platforms.
 - Platform link cable: Would link or connect two or more offshore platforms within the East Anglia THREE site. These cables can be of several different sizes and have different configurations depending on the length of the link. For instance, they could be HVAC, HVDC, LFAC, bundled or unbundled, etc.
 - Export cable: Usually the cable that joins the last electrical offshore platform with the landfall area. These cables have typically bigger cross section than the platform link or inter-array cable.
 - Interconnector cable: These would be platform link cables between platforms in the proposed East Anglia THREE project and platforms in East Anglia ONE to provide redundancy in the event of an export cable failure in either windfarm
 - Fibre optic cables which may be buried along with some or all of the electrical cables.
 - A possible separate accommodation platform with associated foundations.
 - Scour protection around foundations and cable protection on inter-array, platform link, interconnection and offshore export sub-sea cables as required.
 - Up to two meteorological masts (met masts) and their associated foundations for monitoring wind speeds during the operational phase (additional to measurement met masts within the East Anglia Zone, which are subject to a separate consent application).

- Monitoring equipment including up to two floating Light Detection and Ranging (LiDAR) and two wave buoys.
20. The key onshore components of the proposed project would comprise the following:
- The landfall site with associated transition bays to connect the offshore and onshore cables;
 - Up to four onshore electrical cables (single core in the case of HVDC solution and 3-core i.e. 12 in the case of LFAC solution);
 - Up to 62 jointing bay locations each with up to two jointing bays;
 - One transition bay location with up to two transition bays containing the connection between the offshore cable and the onshore cable;
 - One onshore substation compound (for up to two electrical substations);
 - Up to two onshore fibre optic cables; and
 - Landscaping and tree planting around the substation location.
21. The above characteristics encapsulate the HVDC and LFAC electrical solution as well as the Single Phase and Two Phased approach. The key differences between the HVDC and LFAC solution are as follows:
- The LFAC solution does not require offshore converter stations, whereas the HVDC solution requires up to two offshore substations to convert the Alternating Current (AC) current produced by the turbines to HVDC for export to shore;
 - The HVDC solution requires a greater amount of electrical cable to be installed offshore than the LFAC solution; and
 - The LFAC solution would require a slightly larger compound area for the onshore substation.
22. Therefore, generally the HVDC solution represents the worst case scenario in terms of the maximum parameters with the exception of the size of the onshore substation. The assessments in chapters 7 to 29 considers the worst case parameter whether that be from the HVDC or LFAC solution. The assessment chapters assess the Single Phase and the Two Phased approach to construction for each impact separately.

5.5 Offshore

5.5.1 Offshore Site Description

23. The East Anglia THREE site is located in the southern North Sea within the East Anglia Zone. The East Anglia THREE site is located approximately 69km from its nearest point to the port of Lowestoft on the East Anglian coast. The East Anglia THREE site, interconnection and offshore cable corridor are shown in *Figure 5.1* and the onshore cable route is shown in *Figure 5.2*. *Table 5.3* presents distances from the boundary of the East Anglia THREE site to settlements along the United Kingdom (UK) coastline, and to the nearest point of land in the Netherlands and Belgium.

Table 5.3 Distances from the Nearest Point of the East Anglia THREE site to Other Selected Geographical Locations.

Geographic Location	Distance from East Anglia THREE site (km)
Lowestoft	69
Southwold	76
Great Yarmouth	69
Walberswick	78
Aldeburgh	89
Felixstowe	115
Netherlands (nearest point to coast)	101
Belgium (nearest point to coast)	132

24. Within the East Anglia THREE site, water depths are recorded to be typically 35 to 45m relative to the lowest astronomical tide (LAT), with a maximum depth of 49m (relative to LAT) and a minimum depth of 25m (relative to LAT). *Figure 7.2* presents water depths across the East Anglia THREE site based on data collected during the 2012 geophysical surveys commissioned by EATL.

5.5.2 Offshore Infrastructure Summary

25. This section outlines the key characteristics of the offshore elements of the project. Key characteristics are listed in *Table 5.4* below and are discussed in more detail separately within the text.

Table 5.4 Project Characteristics Offshore

Parameter	Characteristic
Capacity	Up to 1,200MW
Number of wind turbines	100 - 172 units

Parameter	Characteristic
East Anglia THREE area (offshore)	305km ²
Water depth	Generally <45m but up to 49m
Distance from East Anglia THREE to shore (closest point of site to Lowestoft)	69km
Maximum offshore cable corridor length	166km
Maximum export cable corridor area	454km ²
Number of export cables	Up to four
Maximum interconnector cable corridor area	238km ²
Offshore cable corridor (taking account of overlap between the interconnector cable corridor and the export cable corridor).	571km ²
Number of interconnector cables	Up to four
Proposed turbine capacity	7 - 12MW
Turbine rotor diameter	154 – 220m
Hub height	99 - 150m Mean Sea Level (MSL)
Tip height	178 - 247m (LAT)
Minimum clearance above sea level	22m (Mean High Water Springs)
Indicative minimum separation between turbines	In row spacing 675m
	Inter-row spacing 900m
Number of wind turbine models	Up to three
Wind turbine foundation type options	Jackets (on piles or on caissons), gravity base structures, suction caissons, monopiles
Number of met masts	Up to two
Height of met masts (maximum)	160m (LAT)
Met mast foundation type options	Jacket (on piles or on caissons), gravity base, suction caisson or monopile
Offshore electrical platforms	Up to two HVDC converter stations and four* HVAC collector stations
Accommodation platform	One
Offshore platform foundation type options	Jacket and gravity base
Buoys	Up to 12 which could include LiDAR, wave monitoring or guard.

*Under a Single Phase approach a maximum of three collector stations would be required

5.5.3 Wind Turbines

26. The proposed East Anglia THREE project would consist of between 100 and 172 wind turbines, each having a rated generation capacity of between 7 and 12MW, with a total installed generation capacity of up to 1,200MW. The maximum wind turbine hub height used would be 150m above Mean Sea Level (MSL) with maximum rotor diameter likely to be 220m, and a maximum tip height of up to 247m above LAT. It is possible that more than one and up to a maximum of three wind turbine models would be used.
27. It is expected that the rotor diameter and hub height of the wind turbines would increase with the increase of nominal power. However, this is not a directly proportional relationship and a range of variables would always be considered for each individual case and wind turbine rated power.
28. Each wind turbine would comprise a tubular steel tower atop a foundation structure, a nacelle secured at the top of the tower and a rotor with three blades rotating around a horizontal axis. *Diagram 5.1* presents a typical wind turbine; the dimensions of various characteristics of the wind turbines to be used would be within the range shown in *Table 5.4*.

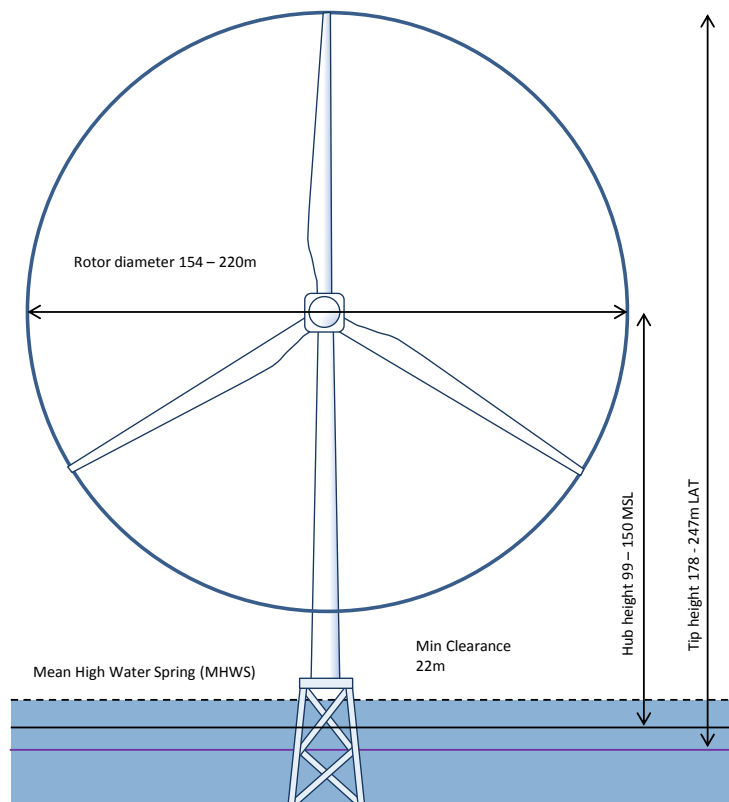


Diagram 5.1 Key Dimensions of the Proposed Offshore Wind Turbines

29. The nacelle contains mechanical and electrical generating components displayed in *Diagram 5.2*.

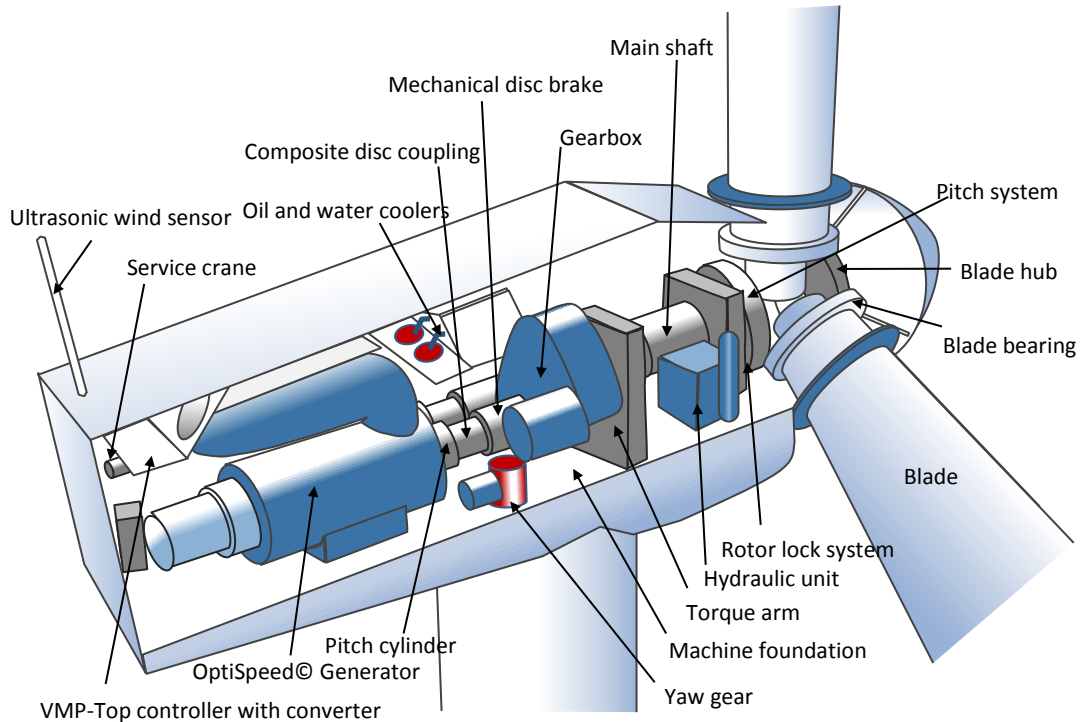


Diagram 5.2 General Internal Structure of a Wind Turbine Nacelle.

5.5.3.1 Wind Turbine Layout

30. The layout of the windfarm, including wind turbines, inter-array and platform link cables and offshore collector and converter station locations, has not yet been specified. Therefore exact locations are not included in the DCO application. This is due to the requirement for flexibility on layout pending further ground investigation, detailed design and commercial negotiations with turbine suppliers. In developing the final layout, EATL would aim to optimise the layout of the windfarm in order to minimise environmental impacts (e.g. through micro-siting) and impacts to other users whilst maximising energy yield and cost efficiency.
31. It is likely that the site would host more than one wind turbine type. The final windfarm layout would be governed by the choice of wind turbine model (or models). Wind turbines of each type would be grouped together, i.e. there would be up to three groups of different turbines.
32. The wind turbine layout can be described in general terms at this stage. It would have some form of regularity in plan, i.e. wind turbines would be set out in rows.

33. Based on the maximum number of wind turbines proposed, the minimum separation between wind turbines is:
- In-row spacing - 675m; and
 - Inter-row spacing - 900m.
34. The in-row spacing is the distance separating turbines in the main rows, which are generally orientated perpendicular to the prevailing wind, or as close to this as is practical. Inter-row spacing is distance between the main rows. The orientation of the rows is not yet decided. It would depend on a number of factors, such as prevailing wind direction, buildable areas and proximity to site boundaries.
35. In-row spacing and inter-row spacing (spacing between rows) may vary across the site area. There could be up to three broad layouts because up to three wind turbine groups could be installed within the East Anglia THREE site.
36. It should also be noted there may be empty spaces within the windfarm. This could be for wake recovery but more likely due to less favourable ground conditions, e.g. locations with large mobile sand waves.

5.5.4 Foundations

37. EATL are considering a number of different foundation designs for the proposed East Anglia THREE project. Up to 172 foundations would be required to support wind turbines, up to seven foundations would be required to support offshore platforms (converter, collector and accommodation) and up to two foundations to support met masts.
38. *Diagrams 5.3 to 5.6* illustrate examples of the foundation types under consideration i.e. (5.3) jackets, (5.4) gravity base structures, (5.5) suction caissons and (5.6) monopiles.

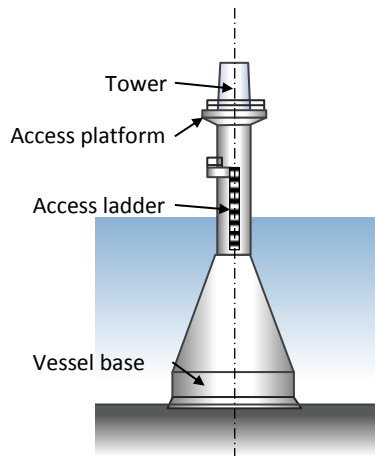


Diagram 5.3 Typical Gravity Based Structure

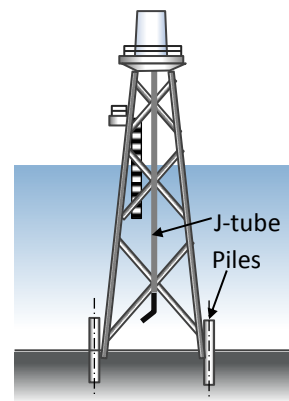


Diagram 5.4 Typical Jacket Structure

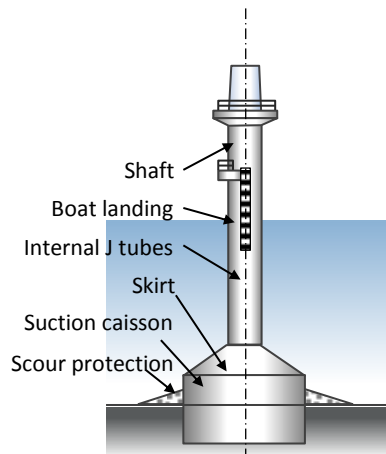


Diagram 5.5 Typical Suction Caissons

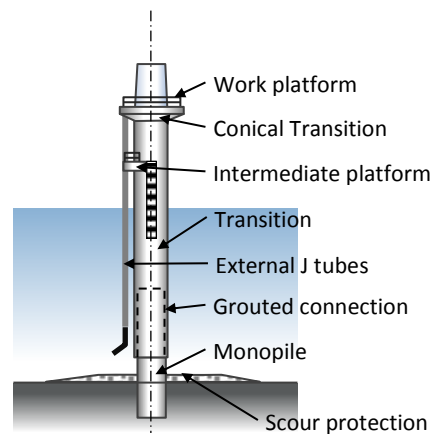


Diagram 5.6 Typical Monopile Structure

¹⁾ Note - these are examples of the typical foundations in use within the industry, nevertheless many other different designs are possible for each type of foundation.

39. Foundation types would be selected following detailed design, based on suitability of the ground conditions, water depths and wind turbine models. There could be a combination of different foundation types used across the East Anglia THREE site.
40. At this stage, the preference is to consider locations with water depths of 45m or less. However, for the proposed East Anglia THREE project it may be necessary to build at locations with greater water depths, possibly up to 49m (relative to LAT). There are no areas within the East Anglia THREE site deeper than 49m (relative to LAT).
41. The foundations would be manufactured onshore and delivered to site as a fully assembled unit with all secondary structures attached. Piles, if required, would be installed separately and attached to the main structure at the offshore location.

42. Fabrication, construction methods and requirements would all differ significantly depending on the foundation type selected.

5.5.4.1 Jacket Foundations

43. There are many variants of the jacket structure but there are four main categorisations:

- Pre-piled or post-piled;
- Three-legged or four-legged jacket structures;
- Straight or angled legs; or
- Fixed with pin piles or fixed with suction caissons.

44. Footprint sizes are outlined in the *Table 5.5* below. These are dimensions between pin pile centres based on a square footprint. Triangular footprints would be smaller but of a similar magnitude.

Table 5.5 Jacket Dimensions for Four-legged Jacket

Wind turbine size (MW)	Maximum diameter (m)	Indicative penetration (m)	Maximum dimensions (m)	Maximum Footprint Size (m ²)
Piles				
7	3.5	50	33.5 x 33.5	1,123
12	3.5	50	43.5 x 43.5	1,893
Suction caissons				
7	8	8	38 x 38	1,444
12	10	10	50 x 50	2,500

45. Pin pile penetrations for jacket or tripod foundations could be up to 58m depth below sea bed but are expected to typically be down to 50m. Piles are generally expected to be driven but drilling may be required at some locations. Other techniques, such as vibration, may also be required at some locations. This would be determined following the undertaking of a pre-construction geotechnical survey and receipt of interpretative reporting. Pin pile diameters would vary depending on the specific design but are expected to be up to 3.5m in diameter in case of a square footprint foundation (as shown in *Table 5.5*), and up to 4m for three legged

(triangular) jackets. Piles are usually installed vertically but concepts are being considered that install piles at an angle.

46. It is possible that suction caisson foundations could be used at the base of the jacket or tripod instead of pin piles. These would be of greater diameter, possibly up to 10m with penetrations of up to 10m (*Table 5.5*).

5.5.4.1.1 Material Requirement for Jacket Foundations

47. Jacket foundations usually comprise mainly of steel. However, it is possible that some secondary structures, such as handrails, gratings and ladders, could be produced using other metals, such as aluminium, or composites. Also, concrete could be used at the top of the jacket structure as part of a transition piece arrangement or to form the working platform. The connection between the jacket structure and anchoring piles is often formed using cement grout.

5.5.4.1.2 Sea Bed Preparation and Penetration for Jacket Foundations

48. Generally, jacket foundations do not require significant sea bed preparation. However, depending on the jacket concept and installation method selected, there could be a requirement to carry out minor flattening at some locations; this would be to provide a more level formation for placement of a pile installation template and may be required to allow suction caisson foundations to be used. An estimate of the maximum volume of sea bed material that would be displaced per jacket foundation for differing sea bed conditions is provided in *Table 5.6*.

Table 5.6 Displaced Volumes of Sea bed Material to Level Sea Bed for Pile Installation Template, per Foundation.

Sea bed condition	Displaced volume per foundation (m ³)
Sand waves up to 0.5 m height	up to 537
Sand waves up to 3m height	up to 5,856
Sand waves up to 5m height	up to 14,712

49. The methods used to calculate these figures are the same as those used for gravity base foundations described in section 5.5.4.2.2 below using the maximum dimensions for jackets provided in *Table 5.5*.
50. EATL are applying for a licence to designate the East Anglia THREE site and the part of the offshore cable corridor which is located within the East Anglia Zone as a disposal site. Should this application be successful any sediment dredged from the sea bed would be disposed of within this licenced area (further information on the

proposed East Anglia THREE disposal site can be found in the Site Characterisation Report which is being submitted as part of this application.

5.5.4.1.3 *Installation Method of Jacket Foundations*

51. For jacket foundations employing a piled approach to anchoring to the sea bed, the piles could be pre-piled (before the jacket structure is placed on the sea bed) or post-piled (piles installed through the sockets in the jacket structure). It is anticipated that piles would generally be driven but alternative installation techniques, i.e. drilling or vibration, may be suitable or required depending on ground conditions. More novel pile solutions, e.g. screw piles, would also be considered as part of the detailed design engineering process.
52. For pre-piled jackets, the overall installation methodology would typically be as follows:
 - Confirmation investigation of sea bed to ensure no obstructions or hazards are present (this would be on-going throughout the installation process);
 - Piles and pile installation template transported to site via barge (or by installation vessel);
 - Vessel (likely a jack-up rig) with pile installation equipment and heavy craneage set up at pile installation;
 - Pile installation template placed on sea bed;
 - Piles positioned on sea bed within template and driven to design depth;
 - Pile installation template removed and installation vessel demobilised from foundation location;
 - Installed pile locations surveyed and jacket dimensions adjusted;
 - Delivery of jacket to site via barge (or by installation vessel) (see section 5.5.15.9 for vessel profiles);
 - Lifting of jacket onto piles via floating heavy lift or jack-up vessel (see section 5.5.15.9 for vessel profiles); and
 - Levelling of jacket, grouting and / or mechanical locking of jacket-to-pile connections.

53. For post-piled jackets, the sequence would typically be as follows:
- Jacket and piles transported to site via barge or by installation vessel;
 - Jack-up rig (alternatively floating vessel) with pile installation equipment and heavy craneage set up at jacket installation location;
 - Sea bed preparation carried out if required;
 - Lifting of jacket from barge and lowering onto sea bed;
 - Lifting of piles from barge and stabbing into sleeves on jacket;
 - Piles driven to depth;
 - Levelling of jacket via jacking off piles; and
 - Grouting and / or mechanical locking of jacket to pile connections.

5.5.4.1.4 Piling Energy

It has been calculated that a hammer energy of 1,800kilojoules (kJ) should be sufficient to drive a 4m diameter pile to the required depth of 50m below the sea bed. The estimated time for each pile would be 86 minutes (at 30 blows per minute).

5.5.4.1.5 Spoil Removal and Disposal for Jacket Foundations

54. For jacket foundation solutions, the amount of spoil requiring disposal is likely to be limited compared to gravity base foundations.
55. Some dredging may be required for levelling the sea bed prior to the installation of a pile template (if used) or placement of the suction caisson. For further information on how dredged material would be disposed see section 5.5.4.1.2
56. Based on preliminary geotechnical information, it is thought likely that pile driving would be possible across the entire East Anglia THREE site; however this would be confirmed at the pre-construction phase. Pile driving is unlikely to generate spoil material. However, until more detailed geotechnical assessments are carried out, the possibility of drilling must be considered at some locations. For the purposes of this assessment a precautionary approach has been taken which assumes that drilling could be required for up to 50% of locations (up to 344 piles).
57. Drilling would generate some spoil material that would require removal and disposal. The estimated quantity of spoil per pin pile is 240m³, therefore up to 82,560m³ of spoil may be created if 50% the piles are required to be drilled. It is

proposed the spoil would be disposed of within the windfarm site, adjacent to each location from where the material was derived, with the spoil subsequently winnowed away by the natural tide and wave driven processes (further information of this process is provided in Chapter 7 Marine Geology, Oceanography and Physical Processes).

5.5.4.1.6 *Type of scour protection for jacket foundations*

58. The requirement for scour protection cannot be ruled out until the jacket designs are developed further and the scour risks have been quantified.
59. If required, it is likely that the procedure would involve the establishment of several layers of rock protection. The lower (filter) layer would typically consist of a 300 to 500mm thick layer of stones with diameter range 30 to 100mm. This layer is likely to be installed before the pile is driven. The upper layer would typically consist of larger stones and would be approximately 600mm to 1000mm thick. An estimate of the maximum required area of scour protection is provided in *Table 5.7* below.

Table 5.7 Scour Protection Area for Jacket Foundations

Type	Diameter (m)	Scour protection Area (m ²)	Rationale for scour protection
Pin pile	3.5	1,893	It is likely to be same area as the footprint of the foundation structure
Suction caisson	8	1,810	1 diameter on either side of the 8m caissons
	10	2,827	1 diameter on either side of the 10m caissons
Worst case maximum scour protection area across all wind turbine foundations		1,944,976	688 10m suction caissons × 2,827m ²

60. Alternative scour protection systems are also being considered, such as the Seabed Scour Control System (SSCS) Frond System. SSCS comprises continuous lines of overlapping buoyant polypropylene fronds that when activated create a drag barrier which prevents the sediment in their vicinity from being transported away.
61. The scour protection material described in this section is relevant to all foundation types including scour protection proposed for met mast and offshore platform

foundations (see sections 5.5.4.2 to 5.5.4.4 below). The worst case maximum area in *Table 5.7* includes these (see section 5.5.9 for a summary of all foundations).

5.5.4.1.7 Decommissioning of Jacket Foundations

62. The overall removal methodology for jacket foundations would typically be as follows:

- Removal of wind turbine, mast, switchgear and ancillaries (see section 5.5.10), and cutting of cables (leaving buried inter-array cables in situ);
- Local jetting and / or suction around legs of jacket to a depth of approximately 1 to 2m;
- Deployment of underwater remote abrasive cutting equipment from service vessel;
- Mobilisation of heavy lift Dynamic Positioning (DP) vessel or jack-up rig and attachment of crane slings to jacket;
- Abrasive cutting of pile legs at a depth of approximately 1 to 2m below the sea bed level;
- Lifting of jacket by crane on DP vessel or jack-up rig onto barge; and
- Transportation of jacket to port and dry dock for dismantling and reuse and recycling where possible.

63. Note that it would not be intended to reinstate the local excavations remaining at the pile leg locations as it is anticipated that these would refill naturally over time.

5.5.4.2 Gravity Base Structures

64. There are many possible shapes and sizes being proposed by manufacturers for gravity base structures. Gravity base structures usually comprise a base, a conical section and a cylindrical section. One of the main factors affecting size would be whether the structure is to be transported on a barge or vessel and lifted into place or whether it would be floated or semi-floated with the assistance of a barge or pontoon. The buoyant structures which can be floated to site are significantly larger in size.

65. Most types of gravity base structure are similar in form (*Diagram 5.3*). Usually the base is hexagonal, octagonal or circular. Bases with a cruciform plan shape are also being considered, occupying a similar size of footprint.

66. The base is typically 1 to 12m high depending on the design. The shaft is usually cone shaped at the bottom, tapering to a cylinder at the top with an outer diameter of approximately 5 to 9m.
67. Some alternative gravity base concepts do not have a cone transition, just a cylindrical shaft, with an outer diameter of approximately 5 to 9m. The bases of these flat base gravity structures are much deeper, typically up to 12m, but the footprint sizes are similar and within the same envelope.
68. Footprint sizes for the base are outlined in *Table 5.8* below:

Table 5.8 Gravity base structure dimensions

Wind turbine size (MW)	Maximum diameter (m)	Maximum Footprint per base (m ²)
7	40	1,257
12	60	2,828

69. Gravity base structures might also use a skirt at their base which penetrates the sea bed giving more stability to the structure. The penetration could vary from approximately 0.1 to 5m. Grouting may also be used to strengthen the soil beneath the foundation and fill small voids in the sea bed.
70. For conical base gravity structures, the top of the base is usually 1 to 2m above sea bed or slightly more if a bedding layer is used to provide a level formation. However, in areas where sand waves are present, it is possible that the top of the base would be installed below sea bed level.

5.5.4.2.1 Material Requirement for Gravity Base Structures

71. Gravity base structures are generally concrete with steel reinforcement and pre-stressing strand. They are produced in a range of sizes, depending on design water depths and whether the structure is intended to be buoyant during installation. There are also hybrid concepts that include a steel tower with a concrete base.
72. Secondary structures, such as handrails, gratings, fenders and ladders, would be produced using steel (or possibly another metal or composite material). The working platform could also be made from steel or concrete.
73. The ballast material used is commonly sand or other sea bed material. Other materials may be considered as an alternative. However, it is most likely that sand dredged locally to the site would be used, depending on the suitability of the material.

74. Some gravity base structure solutions may require the injection of a cement grout mix under the foundation to strengthen the sea bed and / or fill voids to ensure structural integrity.

5.5.4.2.2 Sea Bed Preparation and Penetration for Gravity Base Structures

75. Gravity base structures may require sea bed preparation to level the sea bed in order to provide a base with adequate bearing capacity and to ensure adequate contact between foundation base and sea bed.
76. Within the East Anglia THREE site, sand waves of varying magnitude are known to be present. Gravity base structures are not usually suitable in areas of very large and mobile sand waves but they could be used in areas where smaller sand waves are present. At these locations the sea bed may need to be excavated to the trough of the sand wave and the underside of the base would be placed at this level on a bedding layer.
77. At some locations, excavation of upper sediments may be required to reach a competent formation level.
78. Sea bed preparation would consist of dredging works and the installation of a bedding and levelling layer. The dredging works are likely to be carried out using a trailer suction hopper dredger. The bedding and levelling layer installation would be undertaken by a fall pipe vessel.
79. The dredged sand would be deposited at an agreed disposal area as close as possible to the installation operations. EATL would seek to designate the East Anglia THREE site and part of the offshore cable corridor as the disposal area for dredged materials (as described in the Site Characterisation Report). However, for locations requiring significant excavation, it is likely that some of this dredged material would be used later for infill works, and as ballast material.
80. The preference is that gravity base structure foundations are installed where no or limited ground preparation is required and micro-siting would be used to minimise any dredging requirements. *Table 5.9* below shows two scenarios, based on a 7MW and 12MW gravity base structures.

Table 5.9 Dimensions of Excavation for Gravity Base Structures

Wind turbine size (MW)	Max. overall dredge area per turbine (m ²)	Max. volume of excavation (m ³)
7	1,257	17,500
12	2,828	26,000

81. The figures provided in *Table 5.9* are calculated based on the shape of a pit illustrated in *Diagram 5.7* and *5.8* using following assumptions:
- No sand waves larger than 5m would be excavated;
 - Pit gradient assumed to be between 1 in 8 and 1 in 3;
 - Due to the above assumptions the entire excavated area would not occur within a sand wave; and
 - The flat area at the bottom of the pit would be $70 \times 70\text{m}$.

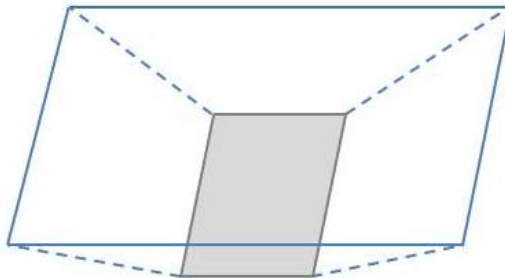


Diagram 5.7 Shape of pit excavated for gravity base foundation

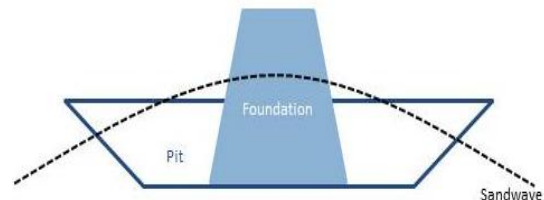


Diagram 5.8 Side view of pit excavation for gravity base foundation

5.5.4.2.3 Installation Method for Gravity Base Structures

82. A gravity base structure would be delivered to site via one of two methods, depending on the foundation design:
- Buoyant structures towed to site and sunk via ballasting and flooding; or
 - Transported to site by barge and installed by heavy lift crane.
83. For the first solution, it is possible that a bespoke barge would be used to support the foundation during its journey to site. For the second solution, it is likely that a heavy lift vessel would be required to perform the installation. This could be a jack-up or floating vessel.
84. Irrespective of the type of gravity base structure, the sea bed is expected to require some element of preparation prior to receiving the foundation. This may involve removal of some material up to a depth of several metres and / or placement of rock in order to form an adequate level platform suitable to bearing the load of the gravity base foundation see section 5.5.4.2.2.

85. The overall installation methodology would typically be as follows:
- Confirmation investigation of sea bed to ensure no obstructions or hazards are present (this would be on-going throughout the installation process);
 - Prepare sea bed (if necessary);
 - Gravity base structure transported to site via barge or floated to site, hauled by tugs;
 - Mobilise heavy lift floating crane (if foundation is non-buoyant solution);
 - Lift foundation from barge and lower to prepared area of sea bed, or adjust buoyancy of floating foundation and sink to prepared area of sea bed;
 - Install ballast as necessary; and
 - Install scour protection (likely to be rock dumping).
86. Ballast works, if required, would be undertaken by a trailer suction hopper dredger. The scour protection works would typically be installed by a DP rock dumping vessel equipped with a fall pipe. The scour materials would be placed in one or multiple layers.
87. It is proposed the spoil would be disposed of within the windfarm site, adjacent to each location from where the material was derived, with the disposed material subsequently winnowed away by the natural tide and wave driven processes (for further detail on this process please refer to Chapter 7 Marine Geology, Oceanography and Physical Processes).

5.5.4.2.4 Spoil Removal and Disposal for Gravity Base Structures

88. For gravity base sea structures bed preparation would be required dependent on the nature of the ground conditions present. Examples of the volume of materials requiring excavation are given in *Table 5.9*. In these examples it would be preferable to use some of this material as ballast but in an extreme case all of it may need to be removed.

5.5.4.2.5 Type of Scour Protection for Gravity Base Structures

89. Scour protection may be necessary around the base of gravity base structures to protect against currents and waves that may cause erosion of the sea bed. The material used for scour protection would be the same as that used for other foundation types as described in section 5.5.4.1.6. As with jacket foundations

alternative scour protection systems are being considered for gravity base foundations.

90. It is possible that scour protection may not be required dependent on the particular gravity base foundation and ground conditions.
91. More scour protection would be needed when the base is buried at depth due to sand waves. Here the scour protection could extend to cover the full dredge area – up a diameter of 180m. Furthermore, there could be a requirement to lay the scour protection material on the seabed prior installing the foundation and the foundation would then be placed on top of this material. This area is not included within the scour protection calculations in the second column of *Table 5.10* as it would be occupied by the footprint of the foundation. Worst case calculations for the footprint of scour protection and the combined area of foundation footprint and scour protection are shown in *Table 5.10* (note total footprints for other infrastructure within the East Anglia THREE site are provided in sections 5.5.5 to 5.5.9).

Table 5.10 Wind Turbine Gravity Base Structure and Scour Protection Footprints

Gravity base diameter (m)	Scour protection (m ²)	Total footprint of foundation and scour protection (m ²)	Rationale for scour protection
40	10,053	11,310	1 diameter (40m) around foundation
60	22,620	25,500	1 diameter (60m) around foundation
Total maximum across the windfarm site	2,262,000	2,550,000	Only the largest (12MW turbines) would be supported by the 60m foundations and the smaller 7MW turbines would be supported by smallest (40m) foundations. $172 \times 11,310\text{m}^2 = 1,945,320\text{m}^2$ Yet $100 \times 25,500\text{m}^2 = 2,550,000\text{m}^2$

92. The scour protection works are likely to be installed by a DP stone dumping vessel equipped with a fall pipe. The scour materials would be placed in one or multiple layers. Alternative methods of installing scour protection are also under consideration, see section 5.5.4.1.6 for details.

5.5.4.2.6 Decommissioning of Gravity Base Structures

93. The removal methodology for gravity base structures would typically be as follows:
- Removal of wind turbine, met mast, switchgear and ancillaries, and cutting of cables (leaving buried inter-array cables in situ):

- Mobilisation of heavy lift DP vessel or fleet of tugs (dependent on whether foundation design is buoyant or requires heavy lift).
- Removal of marine growth and sediment from base and jetting under base plate to remove adhesive effects of grout (if present) or cohesive bearing material if required. If a deep skirt has been used, the skirt may require cutting away and removal.
- It may also be necessary to locally remove scour protection via grabbing or dredging.
- For buoyant design: controlled de-ballasting of foundation using remote pumping equipment and / or installation of buoyancy aids. Disposal of the ballasting material (i.e. whether it is disposed of locally or requires to be transported to a particular offshore disposal area) would be agreed with the regulators as part of the decommissioning plan.
- For design requiring heavy lift: lifting of foundation from sea bed onto barge (as per installation, a bespoke transportation barge may be required dependent on the design).
- For buoyant design: foundation would become buoyant on de-ballasting.
- Transportation of foundation to port and dry dock (via towing or on barge dependent on foundation type) for deconstruction and reuse and recycling of materials where possible.
- Scour protection would either be removed or left in situ depending on which is considered most beneficial by the regulator at that time.

5.5.4.3 Suction Caisson Foundations

94. The suction caisson (*Diagram 5.4*) has only previously been used as a prototype for offshore wind turbines or a met mast, although in the oil and gas industry suction buckets have been used as alternatives to piles at the base of jackets.
95. Existing suction caissons comprise a steel cylindrical tower (the shaft) with a diameter of approximately 5 to 9m, a transition structure (the lid) and a large diameter cylindrical skirt, which penetrates into the sea bed.
96. Footprint sizes and skirt penetration depths for the base are outlined in *Table 5.11* below.

Table 5.11 Suction Caisson Dimensions Footprints

Wind turbine size (MW)	Foundation skirt diameter (m ²)	Skirt penetration depth (m)	Footprint (m ²)	Footprint of foundation and scour protection m ²
7	25	10	491	4,418
12	30	20	707	6,362

97. The base height of the skirt above sea bed is typically 5m or more, although it may be possible to install it below sea bed to reduce scour effects.
98. There are other foundation concepts comprising a cluster of smaller diameter suction piles, instead of a single larger diameter caisson. However, the overall maximum footprint and penetration is expected to be of a similar magnitude.

5.5.4.3.1 Material Requirement for Suction Caisson Foundations

Suction caisson foundations usually comprise mainly steel. However, it is possible that some secondary structures, such as handrails, gratings and ladders, could be produced using other metals, such as aluminium, or composites. Also, concrete could be used to form the working platform.

5.5.4.3.2 Sea bed Preparation and Penetration for Suction Caisson Foundations

99. In areas where the sea bed is level, the suction caisson foundation may not require significant sea bed preparation. However, measures may be required in areas in which sand waves are present to provide a level formation for the installation and to allow scour protection to be later placed around the foundation. Ground preparation requirements in terms of the maximum volume of excavation are shown in *Table 5.12* below.

Table 5.12 Suction Caisson Dimensions: Excavation

Wind turbine size (MW)	Foundation skirt diameter (m ²)	Plan size of excavation at base (m)	Scour protection area (m ²)	Max. volume of excavation (m ³)
7	25	35 x 35	4,418	11,875
12	30	40 x 40	6,362	13,500

100. It should be noted that the maximum volume of excavated material is significantly less than the maximum volume required for gravity base foundations (see section 5.5.4.2.2).

5.5.4.3.3 Installation Method for Suction Caisson Foundations

101. Suction caisson foundations are most likely to be towed to site by tugs as they are designed to be buoyant. The caisson skirt and shaft are generally delivered and installed as a single part.

102. The overall basic installation methodology would typically be as follows:

- Prepare sea bed (if necessary) prior to installation;
- Confirmation investigation of sea bed to ensure no obstructions are present (this would be on-going throughout the installation process);
- Suction caisson foundation towed to site on a barge;
- Suction caisson foundation is ballasted and lowered to sea bed;
- Initial penetration occurs under foundation self-weight;
- Pumps are attached to caisson and water evacuated. Typically there are a number of chambers within the caisson in order to implement a controlled installation and to control levels. Water jetting may be used at the tip of the skirt to facilitate penetration;
- Where required by design, grout may be pumped to fill any voids under the lid of the caisson;
- Install scour protection (likely to be rock dumping); and
- Spoil removal and disposal for suction caisson foundations.

103. It is proposed the excavated material would be disposed of within the windfarm site, adjacent to each location from where the material was derived, with the spoil subsequently winnowed away by the natural tide and wave driven processes.

5.5.4.3.4 Type of Scour Protection for Suction Caisson Foundations

104. Scour protection would be provided around the installed suction bucket. The expected maximum area required for scour protection is presented in *Table 5.11*. The materials used for scour protection would be the same as those proposed for use for other foundation types (see section 5.5.4.1.6).

5.5.4.3.5 Decommissioning of Suction Caisson Foundations

105. The overall removal methodology for suction caisson foundations would typically be as follows and would be agreed with regulators in the decommissioning plan:

- Removal of wind turbine, met mast, switchgear and ancillaries, and cutting of cables (leaving buried inter-array cables in situ);
- Mobilisation of service vessel with pumping equipment and ROV, and mobilisation of tugs. It may also be necessary to mobilise a DP vessel with craneage to facilitate with the refloating and subsequent manipulation of the foundation;
- Removal of sediment and marine growth from suction caisson lid, and jetting of pump connections on lid. It may also be necessary to locally remove scour protection via dredging;
- De-ballasting or adding of buoyancy aids to foundation as required by design;
- Connection of pumping equipment to suction caisson valves;
- Controlled pumping of water into caisson chambers. The caisson would rise from its installed position to the surface as the internal pressure overcomes the side wall friction. Some manipulation from craneage on a DP vessel may also be required; and
- Towing of foundation to port and dry dock for dismantling and reuse and recycling where possible.

5.5.4.4 Monopile Foundations

106. Monopile foundations are the most common wind turbine foundation type used to date. They comprise a steel cylindrical pile and a steel cylindrical transition piece. Conical transitions are sometimes used to reduce the diameter of the structure at the top of the foundation. Dimensions for the monopile bases being considered are presented in *Table 5.13*.

Table 5.13 Monopile Dimensions

Wind turbine size (MW)	Maximum diameter (m)	Monopile penetration (m)	Maximum Footprint (m ²)	Scour Protection per turbine (m ²)*
7	10	40	79	1,964
12	12	40	113	2,828

* This assumes an area of 4 times as large as the diameter of the pile would be required for scour protection.

107. A drivability assessment was carried out by EAOW which concluded that monopiles of the diameters being considered in *Table 5.13* could be driven to depths of up to 40m below the sea bed.

5.5.4.4.1 *Material Requirement for Monopiles*

108. Monopile foundations usually comprise mainly steel. However, it is possible that some secondary structures, such as handrails, gratings and ladders, could be produced using other metals, such as aluminium, or composites. Also, concrete could be used to form the working platform.

5.5.4.4.2 *Sea Bed Preparation for Monopiles*

109. If sand waves are present, the sea bed might need to be levelled first by excavation to the trough of the sand wave. Based on the assumption that excavation to 5m depth is required, a worst case excavation volume of 8235m³ is anticipated, per pile. This is based on the same assumption and excavation pit shape as that detailed in section 5.5.4.2.2, for monopile foundations however the flat area required at the bottom of the pit would be 484m² (22 × 22m).

5.5.4.4.3 *Installation Method for Monopiles*

110. The installation of steel monopile foundations would typically consist of the following key stages:

- Confirmation investigation of sea bed to ensure no obstructions are present (this would be ongoing throughout the installation process);
- Prepare sea bed (if necessary) prior to installation; delivery of steel monopiles and transition pieces to site via barge or by installation vessel. It may also be possible to tow floated piles to site using tugs;
- Delivery of steel monopiles and transition pieces to site via barge or by installation vessel. It may also be possible to tow floated piles to site using tugs;
- Mobilisation of jack-up rig (alternatively floating vessel) with heavy craneage at installation location. It may also be necessary to mobilise a support vessel (vessel profiles are presented in section 5.5.15.9).
- Monopile upended by crane to vertical position;
- Monopile lowered to sea bed;
- Locating of driving hammer onto top of pile using craneage, and monopile driven to required depth. Where ground conditions are difficult, it may also be

necessary to carry out drilling using drilling equipment operated from the installation vessel before completing the driving;

- Lifting of transition piece on to top of monopile using craneage from installation vessel, levelling of transition piece and grouting of connection; and
- Installation of scour protection.

111. The drivability assessment calculated the maximum expected hammer energies needed to drive 10m and 12m diameter piles into the substrate that exists within the East Anglia THREE site. The results are provided in *Table 5. 14*.

Table 5.14 Monopile Dimensions and Expected Hammer Energies

Monopile diameter	Hammer energy needed (kJ)	Piling time (min)
10	2,700	184 @ 30 blows/min
12	3,500	227 @ 30 blows/min

5.5.4.4.4 Scour Protection for Monopiles

112. Dependent on the nature of the sea bed and metocean conditions along with the final monopile design, it may be necessary to install scour protection around the base of the foundation. The material used for monopile scour protection would be the same as that used for other foundation types as described in section 5.5.4.1.6, as with jacket foundations alternative scour protection systems are being considered for monopile foundations.

113. Scour protection, if required for monopiles, would be pre-installed as a filter layer and would then be piled through. The maximum expected areas required for scour protection are displayed in *Table 5.13*.

5.5.4.4.5 Decommissioning of Monopiles

114. The removal methodology for steel monopile foundations would typically be as follows:

- Removal of wind turbine, met mast, switchgear and ancillaries, and cutting of cables (leaving buried inter-array cables in situ);
- Mobilisation of service vessel;
- Local jetting and / or suction around base of monopile to a depth of approximately 1 to 2m;

- Deployment of underwater remote abrasive cutting equipment from service vessel;
 - Mobilisation of heavy lift DP vessel or jack-up rig and attachment of crane slings to top of monopile and transition piece;
 - Abrasive cutting of monopile at a depth of approximately 1 to 2m below the sea bed;
 - Lifting of combined monopile and transition piece by crane on DP vessel or jack-up rig onto barge; and
 - Transportation of monopile and transition piece to port and dry dock for dismantling and reuse and recycling where possible.
115. Note that it would not be intended to reinstate the local excavations remaining at the monopile locations as it is anticipated that this would refill naturally over time.

5.5.5 Offshore Platforms

5.5.5.1 Converter and Collector Stations

116. As outlined in section 5.3 EATL are currently considering both a HVDC and a LFAC electrical solution for the proposed East Anglia THREE project. Under the LFAC solution offshore converter stations are not required as there is no need to convert the AC voltage produced by the turbines to Direct Current (DC) voltage for export to shore. Therefore:

- For East Anglia THREE there would be a minimum of two offshore HVAC collector stations. This would occur if the LFAC electrical solution is chosen (See *Diagram 5.10* and *Table 5.20*) ; and
 - The maximum case for East Anglia THREE is for six offshore stations comprising four HVAC collector stations and two HVDC converter stations. This would only occur under the Two Phased HVDC electrical solution (See *Diagram 5.12* and *Table 5.20*)
117. All offshore converter and collector stations (collectively referred to as electrical platforms) would be located within the East Anglia THREE site. The precise locations would be determined during detailed design work pre-construction.
118. The topside structure of collector or converter stations would be configured in a multiple deck arrangement at each substation. Decks would either be open with

modular equipment or the structure may be fully clad. All weather sensitive equipment would be placed in environmentally controlled areas.



Plate 5.1 Typical offshore AC Collector Station¹

119. The dimensions of the offshore collector and converter stations topsides would depend on the capacity and number of stations constructed. Sizes are given in *Table 5.15*.

Table 5.15 Offshore collector and converter station topsides sizes

Substation capacity	Width (m)	Length (m)	Height (m above LAT)
Minimum	26	41	70
Maximum	120	80	70

5.5.5.1.1 Offshore Electrical Platform: Foundation Type and Construction Method.

120. The offshore electrical platforms would require bespoke foundations on which to place the topsides and electrical equipment. The types of foundation under consideration include steel jacket (with either piles or caissons) or possibly a gravity based structure. The substation foundations would be greater in size than the turbine foundations due to the size and weight of the topsides. Estimates for the maximum footprints for offshore substations are presented in *Table 5.16*.
121. The material used for scour protection of offshore platforms would be the same as that used for wind turbine foundations as described in section 5.5.4.1.6, as with wind

Source: Vattenfall: Thanet Offshore Wind Farm. Ben Barden.

turbine foundations, alternative scour protection systems are being considered for offshore platform base foundations.

Table 5.16 Offshore Electrical Platforms Foundation Footprints

Foundation Type	Maximum Footprint (m ²)	Scour protection out width the foundation footprint (m ²)	Total Footprint (m ²)
Tubular Jackets (103m x 155m)	15,855	Within the base of the jacket structure footprint.	15,855
Gravity Base structures (77 m x 104 m)	8,011	8,789	16,800

122. An alternative option is a self-installing structure, which is towed to site and then lowers legs, jacks-up to an appropriate clearance above water before being fixed in situ, probably using pin-piles as would be used for a jacket foundation.
123. The installation of the offshore substation support structures would be as described in the section 5.4.4 relating to wind turbine foundation units (apart from the self-installing system summarised above).
124. The topsides may be installed via the following methods:
- By a suitable crane vessel (or vessels working together) in a single lift;
 - By a suitable crane vessel (or vessels working together) in separate lifts of deck and sub-modules;
 - Using a rail-skid transfer from a large jack-up; and
 - Self-installing.
125. As with foundations for the wind turbines there could be a requirement for sea bed preparation, this would involve the excavation of up to 73,225m³ per foundation (under the worst case scenario which would be jacket foundations).

5.5.5.1.2 Collector Station Specifics

126. The offshore collector stations which would be required under either the HVDC or the LFAC electrical solution would accommodate the transformers required to increase the distribution voltage (33 to 75kV) of the inter-array cables to a higher export voltage. This would typically be from 110 to 600kV under either the HVDC

solution or the LFAC solution. The collector stations would also accommodate the auxiliary components as reactive power compensation equipment and circuit breakers.

127. Each offshore collector stations would have a topside structure, which would typically accommodate the following:

- Power transformers;
- Switchgear: low, medium and high voltage (LV, MV and HV);
- Instrumentation, protection and control systems;
- Neutral earthing resistors;
- Reactive compensation;
- Standby / diesel generators;
- Fuel supplies;
- Auxiliary and uninterruptible power supply systems and transformers;
- Emergency shelter;
- Craneage;
- Metering stations;
- Meteorological equipment;
- Helipad (optional);
- Messing facilities; and
- Cooling facilities.

5.5.5.1.3 Converter Stations Specifics

128. Under the HDVC electrical solution offshore converter stations would also be required to convert the AC voltage to a DC voltage of typically + / - 300 to 600kV for transmission.

129. The offshore converter station(s) would have a topside structure, which would typically accommodate the following:

- Power transformers;
- AC equipment such as phase reactors and AC filters;
- AC / DC converter with switching devices: valves;
- DC equipment such as DC capacitors and DC filters and associated equipment;
- Switchgear;
- Cooling system;
- Instrumentation, protection and control systems;
- Standby generators;
- Fuel supplies;
- Auxiliary and uninterruptible power supply systems and transformers;
- Meteorological equipment;
- Emergency shelter / emergency equipment such as generators;
- Craneage;
- Helipad (optional);
- Messing facilities;
- AC equipment such as phase reactors and AC filters;
- AC / DC converter with switching devices: valves (typically Insulated-gate bipolar transistors (IGBT); and
- DC equipment, such as DC capacitors and DC filters and associated equipment.

5.5.6 Accommodation Platform

130. A single accommodation platform may be required to contain construction and operation and maintenance personnel and equipment. It is expected that this could accommodate up to 50 personnel during operation. This would require a foundation structure likely to be similar to that of the electrical platforms (section 5.5.5.1) with the gravity base structure option measuring 103m long by 155m wide. The maximum volume of excavated material required for sea bed preparation would be approximately 73,225m³. The topside would be up to 70m wide by 70m long and 38m high with the highest point being 60m above LAT.

131. Both oil waste and other wastes (waste water etc.) would be brought to shore in a secure container and disposed according to industry best practice procedures.
132. The scour protection material used for the accommodation platform foundation if required would be the same as that used for electrical platform foundations as shown in *Table 5.16*.

5.5.7 Meteorological Masts

133. Up to two operational meteorological masts (met masts) may be installed within the East Anglia THREE site, neither of which would exceed a height of 160m above LAT. The foundations used may be jacket, gravity base, suction caisson or monopile. *Table 5.17* illustrates the different size of foundation required to support met masts.
134. The scour protection material used for the met mast foundation if required would be the same as that used for wind turbine foundations as described in section 5.5.4.1.6. Indicative met mast footprints and scour protection are shown in *Table 5.17*

Table 5.17 Meteorological Mast Foundation Footprints

Foundation Type	Size (m)	Maximum Footprint (m ²)	Maximum Footprint with scour protection (m ²)
Jacket with pin piles	20 x 20	400	900
Jacket with suction caissons	25 x 25	625	900
Gravity Base	20	315	2830
Suction caisson	15	177	710
Monopile	8	30	1,964

135. As with foundations for the wind turbines there could be a requirement for sea bed preparation, this would involve the excavation of up to 10,375m³ per . Details on disposal of any dredged material can be found in section 5.5.4.1.2 and in the Site Characterisation Report

5.5.8 Buoys

136. It is anticipated that up to 12 buoys would be required across the East Anglia THREE site, these would be LiDAR, wave or guard buoys. Each buoy would be up to four metres wide and six metres high and would include a lantern suitable for use as a navigational aid.
137. These devices would be attached to the sea bed using mooring devices such as common sinkers (small block of heavy material such as concrete, steel, etc.) or

anchored by means of regular anchors. They could have one single mooring point or several points (usually up to three), with an anticipated total footprint of 4m² and a maximum sea bed penetration depth of one metre.



Plate 5.2 Typical LIDAR buoy (Source: Fugro)

5.5.9 Maximum total Footprints of all Offshore Structures

138. *Table 5.18* shows the maximum footprint of foundations and scour protection. The foundation type with the largest footprint is gravity base see section 5.5.4.2. This table does not include the total footprint for cable protection which is provided in section 5.5.13.4.

Table 5.18 Estimated maximum footprint of foundations and associated scour protection required for the proposed East Anglia THREE project

Infrastructure	Number	Total footprint foundation and scour protection (m ²)	Total (m ²)
60m Gravity Base for wind turbines*	100	25,500	2,550,000
Gravity Base foundation for meteorological masts	2	2,830	5,660
Gravity Base foundation for offshore platforms (Collector, converter and accommodation)	7	16,800	117,600
Total			2,673,260

*although there is potential for a greater number of turbines to be installed, foundation size would also decrease and the worst case footprint would be less than that presented here

5.5.10 Ancillary Works

139. Ancillary structures are likely to form part of the final design of the windfarm; however, the requirement and nature of these would be determined at the detailed design phase. Ancillary structures may include: temporary landing places, moorings

or other means of accommodating vessels in the construction and / or maintenance of the authorised development; buoys, beacons, fenders and other navigational warning or ship impact protection works; and temporary works for the benefit or protection of land or structures affected by the authorised development.

5.5.11 Oils, Fluids and Effluents

140. Oils in the wind turbines would be biodegradable where possible. All wind turbines would have provision to retain all spilled fluids within nacelle or tower. The volume of oil and fluids would vary depending on wind turbine design, i.e. whether conventional design or gearless or whether one or two rotor bearings are used in the design. It may also depend on the amount of redundancy designed into the system.

141. All chemicals used would be certified to the relevant standard. A brief summary of oils and fluids in the systems is given in *Table 5.19* below:

Table 5.19 Example of Volumes of Oils and Fluids in a Typical Wind Turbine

Component	Indicative Volume (l)	Comment
Gearbox	1,000	Mobilgear SHC XMP 320 or equivalent
Hydraulic pitch (if used)	500	ISO 32 biodegradable hydraulic fluid
Coolant systems	1,000	50% Glycol or water
Transformer:	1,500	Biodegradable ester based oil
Yaw and motors	Not determined	Soap based lithium grease

142. Examples of substances contained in the collector and converter stations are as follows:

- Diesel for the emergency diesel generators (in diesel storage tanks);
- Oil for the transformers;
- Deionised water for the valves cooling system;
- Glycol;
- Sewage and grey water;
- Lead acid for UPS and batteries;
- Engine oil; and

- SF6 (insulating gas for preventing electrical discharge).
143. To avoid discharge of oils to the environment the wind turbines, offshore electrical platforms collector and converter stations would be subject to best-practice design for example, with a self-contained bund to collect any possible oil spill. To avoid discharge or spillage of oils it is anticipated that the transformers would be filled for their life and would not need interim oil changes.
144. Any oil spillage from the diesel tank or from the transformer would be collected in a separate oil waste tank. Both oil waste and other wastes (waste water etc.) would be brought to shore in a secure container and disposed according to industry best practice procedures.

5.5.12 Navigation lighting Requirements and Colour Scheme

145. The windfarm would be designed and constructed to satisfy the requirements of the Civil Aviation Authority (CAA) and the Trinity House Lighthouse Service (THLS) in respect of marking, lighting and fog-horn specifications. CAA recommendations on “Lighting of Wind Turbine Generators in United Kingdom Territorial Waters”, November 2012 would be adhered to. THLS recommendations would be followed as described in “Renewable Energy Installation Farms and Fields-Provision and Maintenance of Local Aids to Navigation by Trinity House” and “the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) Recommendation O-139 on the Marking of Offshore Wind Farms, (IALA 2013)”.
146. The colour scheme for nacelles, blades and towers is typically RAL 7035 (light grey). Foundation steelwork is generally in RAL 1023 (traffic light yellow) up to the Highest Astronomical Tide (HAT) +15m or to Aids to Navigations, whichever is the highest.

5.5.12.1 Construction and Operation

147. During the construction phase, working areas would be established and marked in accordance with the IALA Maritime Buoyage System (MBS) and such areas and markings would be promulgated by appropriate means in advance.
148. During operations, lighting would be as per the above guidance and take into account any new directives from the current lighting trials being undertaken by the Navigation and Offshore Renewable Energy Liaison (NOREL) group. As a minimum, all turbines would comply with Paragraph 5 of IALA Recommendation O-117 and the wind farm Paragraph 6. For aviation lighting compliance, as a minimum, would be with Section 1, Part 28, and Paragraph 220 of CAP 393 Air Navigation: The Order and the Regulations.

5.5.13 Electrical Infrastructure

149. As previously stated EATL is currently considering both a HVDC and a LFAC electrical solutions for the proposed East Anglia THREE project in addition to considering constructing the project in a Single Phase, or in Two Phased approach. This section describes the infrastructure required for the following:

- HVDC electrical solution constructed in a single phase;
- LFAC electrical solution constructed in a single phase;
- HVDC electrical solution constructed in two phases; and
- LFAC solution constructed in two phases.

150. Unless stated otherwise the maximum value of any given parameter is stated for each of the above options. *Table 5.20* provides a comparison of the electrical infrastructure for each option and diagrams illustrating each option are presented in diagrams 5.9 to 5.12.

151. Under any of the four electrical solutions inter-array cabling within the East Anglia THREE site would be between 160 and 550km depending on the final layout of the turbines. Cables between turbines would typically be laid along the shortest separation between the turbines and longer cables would be laid between the last turbines of the array up to the offshore substation. The electrical layout would be designed to minimise length of cable, number of cables and electrical losses. Under a Two Phased approach the maximum distance of inter-array cabling would be approximately 275km per phase.

Table 5.20 Comparison of Maximum Electrical Infrastructure under HVDC, LFAC Single Phase and Two Phased approach (these are illustrated in Diagram 5.9 to 5.12)

Parameter	Single Phase		Two Phased	
	HVDC (lengths)	LFAC (lengths)	HVDC (lengths)	LFAC (length)
Offshore HVAC collector stations	3	2	4	4
Offshore HVDC converter station	2	None	2	None
Platform links (cables that provide a link between collector stations, converter stations or between collector and converter stations (see Diagram 5.9 to 5.12))	13 (× 15= 195km)	1 × 15 = 15km	16 (× 15 = 240km)	3 (×15 = 45km)
HVAC Export offshore three core cable	None	4 × 166 = 664km		4 × 166 = 664km
HVDC Export offshore single core cable	4 × 166 = 664km	None	4 × 166 = 664km	None
Interconnection cables with East Anglia ONE	4 laid in two trenches so (4× 95= 380km cables) and 2× 95=190km of trench.	2 (× 95 = 190km), in two trenches	4 laid in four trenches so (4× 95= 380km cables) and 4× 95=380km of trench.	2 (× 95 = 190km) in two trenches
Fibre optic cables which would be bundled and laid in the same trenches as electrical cables	2 (× 166 = 332km)	2 (× 166 = 332km)	2 (× 166 = 332km)	2 (× 166 = 332km)
Onshore substations	Two substations within a single compound	Two substations within a single compound	Two substations within a single compound	Two stations within a single compound

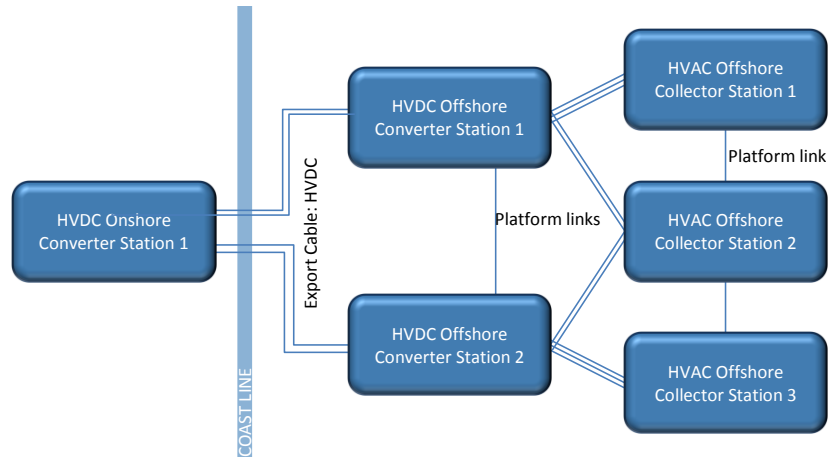


Diagram 5.9 Maximum Requirements HVDC Single Phase

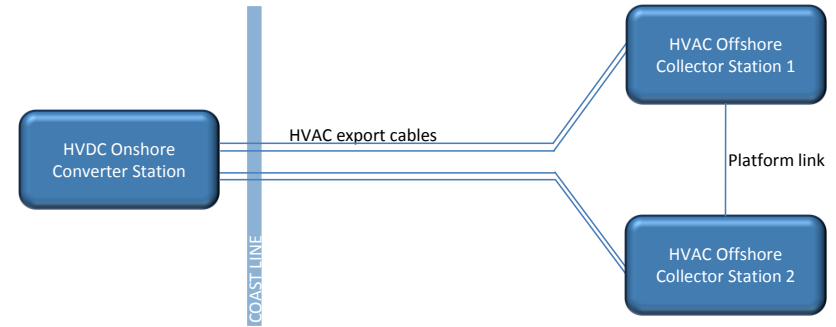


Diagram 5.10 Maximum Requirements HVDC Single Phase

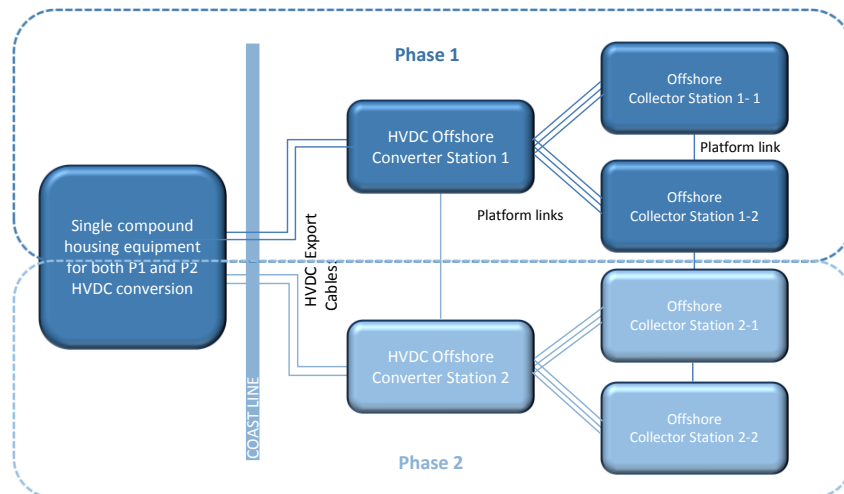


Diagram 5.11 Maximum Requirements HVDC Two Phased

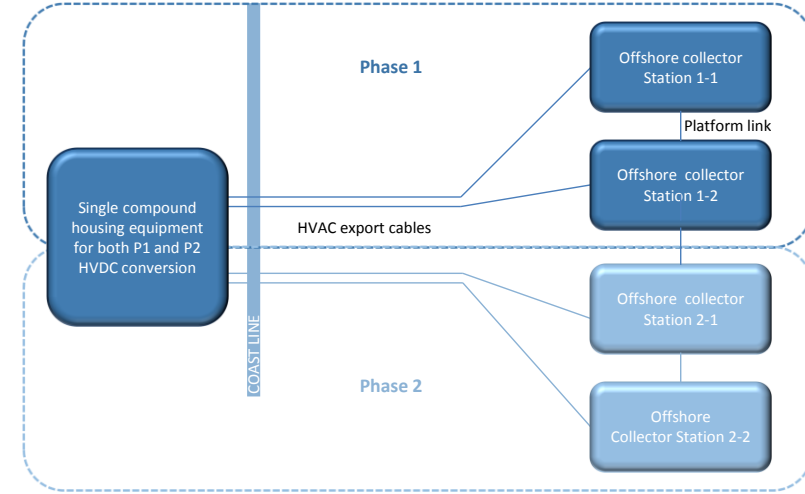


Diagram 5.12 Maximum Requirements LFAC Two Phased

152. It should be noted that the options displayed in *Table 5.19* and *Diagrams 5.9* to *5.12* represent the maximum case in terms of the amount of infrastructure required. The minimum requirements in each option could amount to significantly less infrastructure, as illustrated in *Diagram 5.13*.

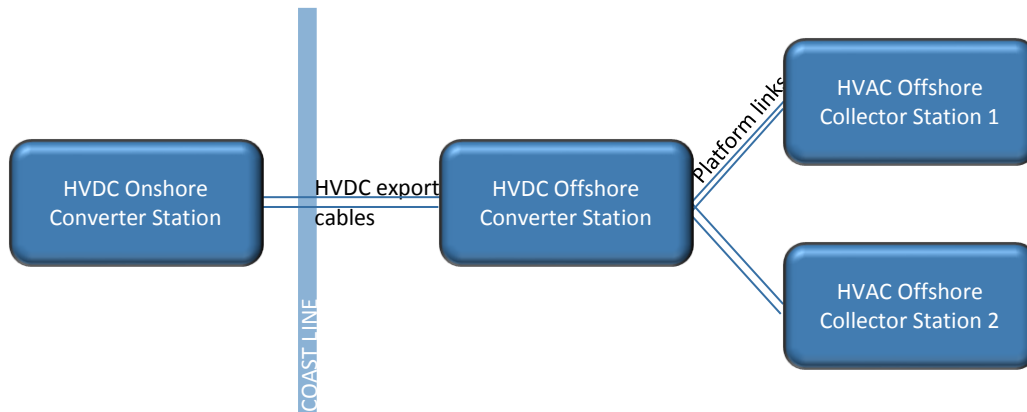


Diagram 5.13 Minimum Requirements for Electrical Infrastructure (Single Phase HVDC)

5.5.13.1 Interconnections between the proposed East Anglia THREE and East Anglia ONE projects

153. There would be up to four cables to interconnect the proposed East Anglia THREE and East Anglia ONE projects. These interconnections would consist of:

- Up to four HVDC cables installed in two trenches under a single phased approach (Under the HVDC solution)
- Up to four separate trenches under a two phased approach (Under the HVDC solution); or
- Up to two HVAC cables installed in two separate trenches (under the LFAC solution).

154. A single cable interconnector would be no more than 95km long and would be located within the interconnector cable corridor displayed in *Figure 5.1*.

5.5.13.2 Export Cables

155. The proposed East Anglia THREE project offshore export cables would join the East Anglia ONE offshore cable corridor at a location yet to be finalised (*Figure 5.3*). The East Anglia THREE offshore export cables would then follow the East Anglia ONE offshore cable corridor and onshore cable route to the substation at Bramford. The East Anglia ONE offshore cable corridor already identified is able to sufficiently accommodate the cables for the proposed East Anglia THREE project (in addition to those for East Anglia ONE) (*see Figure 5.2*).

156. The proposed East Anglia THREE project would be connected to the National Grid Transmission System by up to four export cables (either HVDC or HVAC). The offshore cables themselves each have a diameter of approximately 120 to 300mm and each consist of one copper or aluminium conductor with electrical insulation material, screens, communication fibre and protective armour layers. There would also be up to two offshore fibre optic cables which would be installed within the same trenches as the export cables.

5.5.13.3 Export and Interconnection Cables: Pre-lay Works Required

157. In areas with large ripples and sand waves the sea bed may first require levelling (subject to detailed studies) by dredging prior to cable being laid on the sea bed.

158. Before cable-laying operations commence, it would be necessary to ensure that the offshore cable corridor is free from obstructions such as discarded trawling gear and abandoned cables identified as part of the pre-construction survey. A survey vessel would be used to clear all such identified debris, in a pre-lay grapnel run (PLGR).

159. The offshore export cable would be routed as far as possible in soft sediments to allow it to be buried into the sea bed. In the event that boulders or debris are encountered on the sea bed, they would be removed before the cable is laid. If the grapnel tool cannot remove all obstructions completely, some hydraulic removal works or ploughing may take place. No blasting is planned to take place in the offshore cable corridor to remove bedrock.

160. If the offshore cable corridor crosses an out of service cable it may be recovered from the sea bed before laying the offshore export cable. The removal would be dependent on depth of burial, and accessibility.

161. Crossings preparation would need surveys to locate the asset and determine actual depth of burial. Following this, placement of protection would need to be carried out.

5.5.13.4 Export and interconnection Cables: Insulation, Armour, Electro Magnetic Fields (EMFs) and Heat Generated

162. EMFs would be minimised due to a balanced and screened three-core system, incorporating a metallic screen that cancels the electronic field.

163. Electro Magnetic Fields emitted by HVAC three cores offshore sub-sea cable are minimised due to the method of manufacture, with the three cores laid together in trefoil and as the phase currents are balanced, the magnetic fields of the three cores tend to zero. For that, the magnitude of the magnetic fields in the proximity of the cable is null and its presence in the sea bottom inert.

164. Heat loss per metre for a typical 1,000mm² offshore HVAC 132kV 3-core cable is 30W/m. Heat loss per metre for a typical 2,400mm² offshore HVDC cable is 70W/m.

5.5.13.5 Export and Interconnection Cables: Minimum Cable Spacing, Number and Width of Cable Trenches

165. The minimum separation of the sub-sea cables is determined primarily to reduce the risk involved of damaging a pre-laid cable during installation due to the inherent difficulty of ensuring that the cable burying plough is in the precise position. In addition, following installation of the cables, should any cable be required to be retrieved for maintenance, the separation distance allows confidence to recover a cable without disturbing others and to re-install a repaired cable on the sea bed without damaging the adjacent cable. The space required to install a repaired cable would depend on the water depth at the fault location. The primary factor that would influence this spacing and the burial depth would be the geology of the sea bed along the route with additional influences such as sea bed obstacles including wrecks and other sub-sea cables.

166. For two cables that need to be installed (but not bundled) there needs to be sufficient space between them to minimise risk of plough or other burial tools damaging installed cables. Additionally, cable separation in shallow water would need to allow room for barges to dry out without affecting installed cables. Spacing between cables also needs to be sufficient to allow for cable repairs, in particular for the cable required for the 'repair bight' to be laid out. This has given a general shallow water minimum spacing (up to 50m water depth) of 50m between the two cables.

167. If there are more cables required the adjacent spacing would be much greater and allow for the following:

- Placement of anchors;
- Final bights from repairs or installation requirements; and
- If necessary, separate Offshore Transmission Owner (OFTO) sea bed ownership/jurisdiction.

168. This spacing is generally 250m and allows for the above scenarios. If the sea bed is extremely soft in nature, this spacing may be widened to ensure a safe placement of anchors.

169. A practical cable corridor width has to allow for:
- Crossing of existing cables and pipelines as close as possible to a 90 degree angle;
 - An offshore export cable route that does not inhibit the operation and maintenance activities on existing cables and pipelines;
 - Clearance for installation;
 - Long-term operation and maintenance capability, including space to effect cable recovery and repairs;
 - Sea bed lease requirements from The Crown Estate and associated costs; and
 - The latest DNV-KEMA (2004) guidelines should be referred to for best practice.
170. When two sub-sea cables are installed there needs to be sufficient space between them to:
- Minimise the risk of plough or other burial tool over-run;
 - Ability for barges in shallow water to dry out without settling on top of the cable; and
 - Where repairs are needed the spacing allows the repair bight to be laid out.
171. A general shallow water minimum spacing (up to 50m water depth) of 50m between two unbundled cables has been assumed.
172. *Table 5.21* shows the different possible configurations and the maximum case is illustrated in *Diagram 5.14*.

Table 5.21 Indicative Swathe Widths for Different Cable Configurations

Cable configuration	Swathe width (m)
Four cables (HVDC or LFAC) in four trenches	$250 + 50 + 250 + 50 + 250 = \mathbf{850}$
Four cables (HVDC) in two trenches	$250 + 50 + 250 = \mathbf{550}$
Two cables (HVDC) in two trenches	$250 + 50 + 250 = \mathbf{550}$
Two cables (HVDC) in one trench	$250 + 50 + 250 = \mathbf{550}$

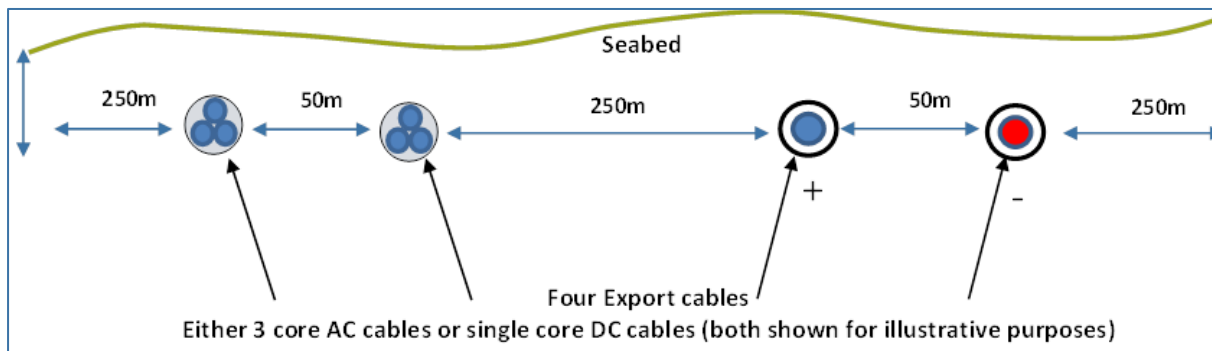


Diagram 5.14 Maximum Swathe Width for Export Cables

5.5.13.6 Export and Interconnection Cables: Jointing Infrastructure

173. The jointing of sub-sea cables offshore would require a significant good weather time window. Typically the jointing can take between one and ten days after both cable ends are secured on-board the jointing vessel. Additional time may be required to recover the cables pre-jointing and rebury the cable post-jointing.

5.5.13.7 Inter-array Cables: Cable Type, Diameter, Insulation, Armour EMF / Heat Generated

174. The inter-array cables connect the wind turbines into strings and then connect the strings to the offshore substation platform(s). The cables between adjacent wind turbines are relatively short in length, typically in the range of 675m to 2km. However, the cables between the offshore substation(s) and the wind turbine strings would be longer and possibly up to 10km in length. The components of an inter-array cable are presented in *Diagram 5.15*.

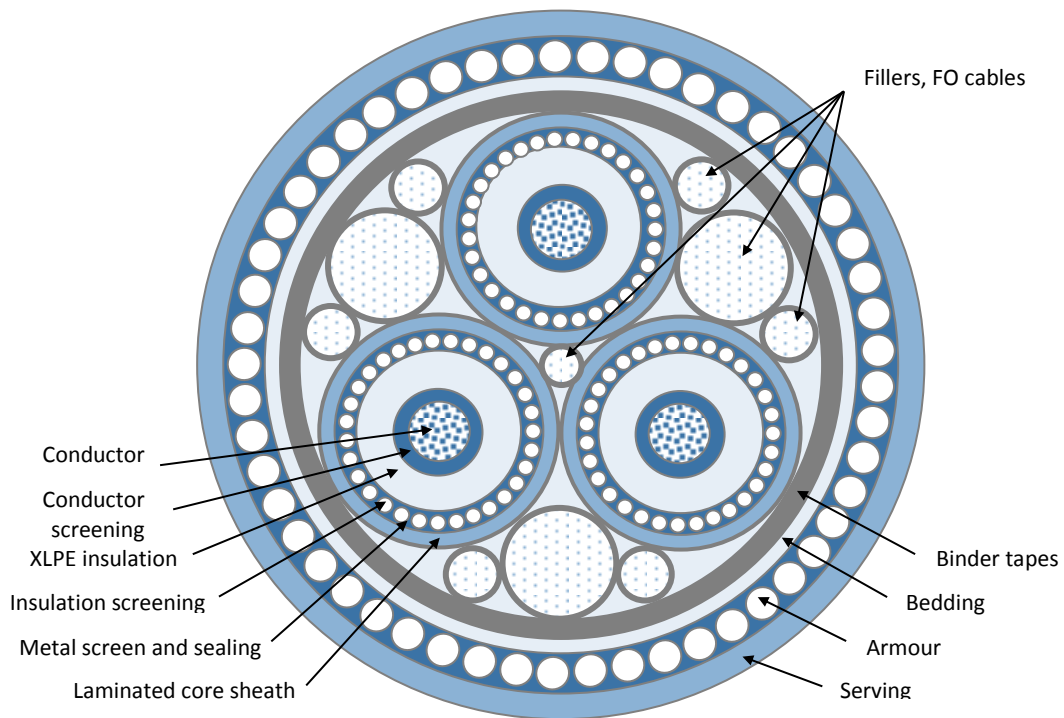


Diagram 5.15 Inter-array Cables

175. The AC inter-array cables would typically be rated at 33 to 75kV with 3-core copper conductors, insulation and conductor screening and steel wire armoured. All cables would contain optical fibres embedded between the cores for communication purposes.
176. A number of conductor sizes would be used, depending on the electrical load that the cable is required to carry. These are detailed in *Table 5.22*.

Table 5.22 Typical AC XLPE 33 kV 3-core Copper Submarine Cable Details²

Details	95mm ²	120mm ²	240mm ²	400mm ²	630mm ²	800mm ²
Overall diameter (mm)	104	107	118.9	129.9	145.1	154.4
Weight (kg/m)	19.5	20.7	25.9	32	40.9	47.2

² Source: ABB

[http://www05.abb.com/global/scot/scot245.nsf/veritydisplay/2fb0094306e48975c125777c00334767/\\$file/xlpe%20submarine%20cable%20systems%202gm5007%20rev%205.pdf2](http://www05.abb.com/global/scot/scot245.nsf/veritydisplay/2fb0094306e48975c125777c00334767/$file/xlpe%20submarine%20cable%20systems%202gm5007%20rev%205.pdf2)

177. EMF would be minimised due to balanced and screened three-core system.
178. Heat loss per metre for a typical 800mm² offshore HVAC 33kV 3-core cable is 40W/m.

5.5.13.8 Inter-array Cables: Spacing

179. Each section of inter-array cable would be laid separately in a single trench.
180. When approaching the substation or wind turbine foundations, several cables would come close together. In that case, the distance between each cable may be approximately 1m.
181. Methods for crossing other cables, pipelines etc. are the same as per export cables and are provided in section 5.5.14.5.
182. It is EATLs intention to design the windfarm layout so that none of the inter-array cables cross with any other cables thus reducing the risks of damage to the cables.

5.5.13.9 Inter-array Cables: Hook up Methods to Wind Turbines

183. It is not planned to use divers for cable installation. The hook up would be done by the support of Remotely Operated Vehicles (ROVs).
184. A typical methodology for installing the cable into a J-tube is as follows. However, alternative cable entry details and installation methods are being considered:
- A cable barge or a specialist cable installation vessel would be mobilised to the site. The cables would be supplied either on cable reels or as a continuous length.
 - The vessel transits to site and takes up station adjacent to a wind turbine structure and either holds station on DP or sets out a mooring pattern using anchors. A cable end is floated off from the cable reel on the vessel towards the wind turbine and connected to a pre-installed messenger wire in the J-tube. The messenger wire allows the cable to be pulled up the J-tube.
 - The cable is pulled up the J-tube in a controlled manner with careful monitoring. When the cable reaches the cable temporary hang-off (at a later date a cable jointer would terminate the cable and install the permanent hang-off), the pulling operation ceases and the cable joint is made. The cable is laid away from the J-tube on the first wind turbine towards the J-tube on the second wind turbine.

- When the cable installation vessel nears the J-tube on the second wind turbine structure, the cable end is taken from the reel, ready for pulling up the J-tube.
- The cable end is attached to the messenger wire from the bellmouth of the second J-tube. A tow wire is taken from the cable installation vessel and connected to the messenger line at the top of the J-tube and the pulling operation is repeated in the same manner as was employed at the first J-tube.

5.5.14 Cable installation methods

185. Prior to installation of offshore sub-sea cables there could be a requirement to level the sea bed.

5.5.14.1 Sea bed levelling

186. Sea bed levelling would serve two purposes firstly it would allow cable installation vehicles to operate in areas where steep sand waves occur and secondly the cables when buried, would be at a lower risk of becoming exposed.

187. It is likely that sea bed levelling would only be required in areas where the slope of sandwaves is greater than 10° . Sea bed levelling would include the dredging of sediment from the sea bed by a dredging vessel and disposal of this material in a different location. The maximum volume of material which could be dredged has been calculated as $136,000\text{m}^3$ from the East Anglia THREE site $324,484\text{m}^3$ from the export cable corridor and $147,493\text{m}^3$ from the interconnector cable corridor. The methodology used to calculate dredged quantities is included in Chapter 7 Marine Geology, Oceanography and Physical Processes sections 7.6.1, (specifically *Table 7.20* which provides the calculated values).

188. Once the material has been dredged from the sea bed it would require disposal. EATL are making an application for an area which includes the East Anglia THREE site and the area of the offshore cable corridor which falls within the East Anglia THREE Zone as a disposal site for this material (further information on this is provided in the Site Characterisation Report).

5.5.14.2 Cable Installation Vessels

189. A number of specialist vessels are available for the installation of cables. For smaller inter-array cable sizes (which generally comprise multiple short lengths) it is possible to use barges to lay the cable, however for large export cables, specialist vessels are generally required. The physical characteristics of cables have a significant impact on installation in offshore environments. The use of sub-sea cable joints is costly, and time consuming in the difficult offshore environment and it is preferred where practicable to lay long lengths of cable continuously to avoid joints.

190. For long cable installation campaigns there are only a few specialised vessels available. Smaller barge type vessels are more readily available but only capable of carrying relatively small amounts of cable, resulting in numerous sub-sea cable joints. A smaller low draught vessel may be more suitable at the shallow landfall approach before handing over to the larger vessel dependent on the cable landfall site and water depth.
191. The preferred construction technique and depth of burial for the offshore electrical infrastructure would be decided after the pre-construction geotechnical ground investigation, a risk assessment and a lifetime maintenance assessment. Each of the possible installation techniques (ploughing, jetting and trenching) have constraints within which they can be effectively utilised, e.g. shallow water, depth of burial required, sediment disturbance, sediment type and minimum bend radius.
192. The offshore export cables would be buried at a depth between 0.5m and 5m for the majority of the route.

5.5.14.3 Cable Burial Methods

193. The installation practices can be divided into the following broad methods:

- Cable pre-lay works as described in section 5.5.14.1.
- Cables are surface laid by a laying vessel, and burial is carried out in a post-lay mode using a separate vessel and trenching / jetting equipment spread depending on the method.
- Cables are laid and buried in a simultaneous operation with burial equipment being towed by the cable laying vessel or barge, in the case of plough or burial sled, or operated from laying vessel where a self-propelled ROV is utilised.
- A trench is dug and then cables are subsequently laid within that trench.

5.5.14.3.1 Burial Methods: Ploughing

194. Ploughing has been specified for major HVAC systems in the past and this generally produces better burial results than post-lay burial in some ground conditions. However, for HVDC if the cables are bundled, it is technically challenging due to the bundle having to pass through the plough, therefore ploughing has been substituted by post-lay burial on some projects.
195. A forward blade cuts through the sea bed laying the cable behind. Ploughing tools could be pulled directly by a surface vessel or could be mounted onto self-propelled

caterpillar tracked vehicles which run along the sea bed taking power from a surface vessel. The plough would usually insert the cable as it passes through the ground.

196. Even if the primary method adopted for laying the export cables is ploughing some locations may still require jetting or other methods to bury and protect the cable i.e. for any jointing loops, corners and areas and where the plough would be unable to negotiate obstacles, cable crossings, etc.

197. The dimensions of a typical plough are 15m long 6.5m wide and 7m in height.

5.5.14.3.2 Burial Methods: Trenching or Cutting

198. Trenching or cutting would only be used as the last option on areas where other methods for protecting the cable are not economically and / or technically feasible.

199. This method consists of three operations. First, a trench is excavated or cut while placing the sediment and fill next to the trench. The cable is subsequently laid in the trench and lastly the sediment or fill is returned to the trench. Trenching can be a difficult and relatively slow method to use compared with other methods listed here; however, this technique may be required for small sections of cable runs where other methods are not practical.

200. Pre-lay cutting of trenches (or “pre-trenching”) could also be used whereby a large trench is cut in one or multiple passes to the correct depth before the cable is laid back in trench at a later date. The trench can be backfilled naturally or if required with a backfill plough or other method of material replacement. The use of backfill ploughs is normally not favoured due to the danger of damaging the cable.

5.5.14.3.3 Burial Methods: Jetting

201. This method involves the use of a positioned cable vessel and a hydraulically powered water jetting device that simultaneously lays and embeds the cables in one continuous trench. The equipment uses pressurised water from water pump system on board the cable vessel to fluidize sediment allowing the cable to sink into the sediment.

202. Two methods of water jetting could be used:

- Laying the cable first and jetting at a later time - The cable is laid on the sea bed first and afterwards a jetting sledge is positioned above the cable. Jets on the sledge flush water beneath the cable fluidising the sand whereby the cable, by its own weight, sinks to the depth set by the operator. As the sediment is fluidised a minor amount of sediment re-suspension and loss is expected.

- Laying the cable and jetting at the same time - In this method water jets are used to remove large amounts of sediment to create a trench and the cable is laid into the trench behind the jetting lance.

203. Jetting tools can be pulled directly by a surface vessel or can be mounted onto self-propelled caterpillar tracked vehicles which run along the sea bed taking their power from a surface vessel. A typical example of a ROV jetting system would be 5m long, 4.2m wide and 3m in height.

5.5.14.3.4 Burial Methods: Vertical Injector

204. In shallow waters a vertical injector could be used. This is a large jetting and cutting shear which is strapped to the side of a barge and the cable is laid in the foot of the trench. This technique can provide deeper than traditional method of burial which can be used in areas of high sea bed mobility.

205. The burial depth is controlled by means of raising or lowering the tool and horizontal positioning, by means of adjusting the barge anchors.

5.5.14.3.5 Cable Laying and Burial Speeds

206. The type of installation vessel would have a bearing on the overall rate of installation. A DP vessel should not restrict the surface lay rate of installation however if an anchored barge were to be used, the barge would require resetting of its anchors at regular intervals, which is likely to reduce progress rates. An anchor reset may occur every 500m, with each anchor reset operation lasting several hours.

207. A DP vessel would therefore be EATL's preferred method for cable laying, however for some restricted locations, in bad weather or where a DP vessel may not be available, an anchored barge may be required.

208. The installation rates as presented below, during the normal movement of a barge should not restrict the progress rates. The speed of cable laying depends on the ground conditions, sea bed profile and depth. Factors affecting vessel manoeuvrability would also affect the speed of operation. Installation rates are shown in *Table 5.22*.

Table 5.22 Typical Cable Installation Rates for Different Burial Methods

Method	Speed (m/hour)
Surface lay (single cable)	300 to 400
Surface lay (bundled pair of cables)	300 to 400
Ploughing (single cable)	150 to 300
Jetting	150 to 450

Method	Speed (m/hour)
Trenching	30 to 80
Vertical injector (shallow water only)	30 to 80

5.5.14.3.6 Inter-array Cables: Installation and Burial Method

209. For smaller inter-array cable sizes it is possible to use barges to lay the cable and these are generally at multiple short lengths.
210. The cables would be supplied on drums, cages or carousels on board a cable vessel or barge.
211. Each section of cable is laid from the cable lay vessel either from a static coil or a revolving turn carousel, turntable or drum depending upon the characteristics of the cable. The cable is led via a cable pick-up arrangement and an associated cable track way through linear cable engines and is led over board through a cable chute or stinger usually mounted at the stern of the vessel.
212. The cable would be pulled into the foundation via a J-tube (or alternative cable entry system), and later connected to the wind turbine. The rest of the cable would be laid along the sea bed and at the next wind turbine the cable would be again pulled into the foundation and later connected to the wind turbine.
213. Due to the water depths, it is not planned to use divers for any installation work. ROVs would be used when needed.
214. The inter-array cables would be installed using a mix of the following methods. See section 5.5.14.3 for details of these methods:
- Surface lay;
 - Ploughing;
 - Pre-trenching or cutting; and
 - Jetting.

5.5.14.3.7 Offshore Trench Sizes for Cable Burial

215. The following descriptions are valid for all electrical solutions described above. Offshore electrical cable may be buried up to a maximum depth of 5m, except in areas where the burial is problematic.

216. It is in the best interest to EATL to bury the greatest amount of cable possible, since unburied cable is a source of Operation & Maintenance (O&M) issues and failures due to vessels' anchorage movements.
217. Offshore trench shape and width is usually driven by the installation method and tools (described above in section 5.5.14.3). In addition, its design and size is influenced by a number of factors: safety, soil characteristics, outer cable diameter, trench depth, minimum available width of excavator bucket, type of crossings, and any special purpose requirements for the above mentioned scenarios.
218. EATL has calculated the maximum trench widths and corridors of disturbance that would be required to bury cables at different depths. Due to the sediment conditions that exist across the East Anglia THREE site and cable corridor it has been assumed that the angle of the slope must be approximately 30°. This angle is subject to change based on further engineering studies. *Diagram 5.16* and *Table 5.24* illustrate the results of these calculations.

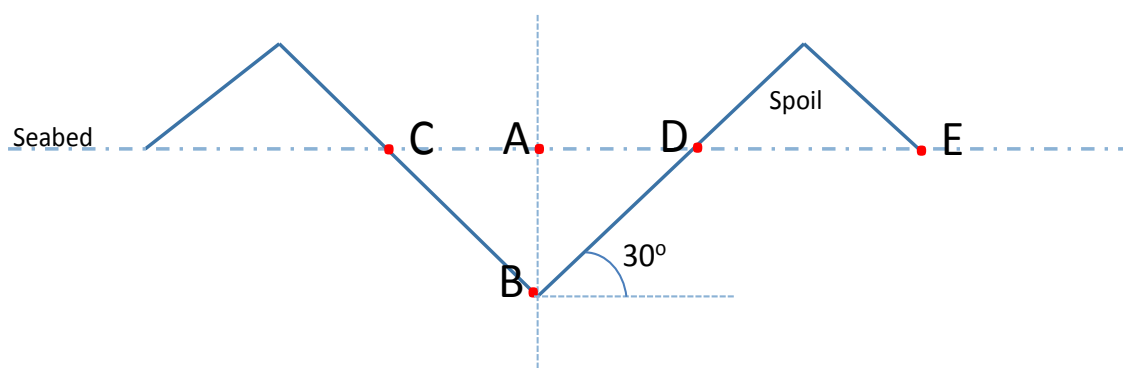


Diagram 5.16 Schematic of a Ploughed trench cross section. Not to scale.

Table 5.24 Calculated trench cross section dimensions

Depth (AB) (m)	Trench width (CD) (m)	Total Width of spoil (DE × 2)	Total trench width including spoil (AE × 2) (m)
1	3.4	6	9.4
2	5.2	12	18.9
3	6.9	18	28
4	8.6	24	37.8
5 (maximum)	17.3	30	47.3

219. *Diagram 5.16* and *Table 5.24* illustrate that if a cable was to be installed in a 5m deep trench the required trench width would be 17.3m and the width of the trench and disturbed area around the trench would be a width of 47.3m.
220. In principle, no material is expected to be permanently displaced for cable installation as the trench would be backfilled with its own material. Some material may be displaced before cable-laying if rocks need to be moved from the corridor route or if the sea bed needs to be levelled by dredging in areas with high and steep sand waves.

5.5.14.4 Cable Protection Where Burial is not Possible

221. EATL intend to work with the fishing industry and manufacturers to ensure that wherever possible, cable protection does not create a hazard for fishing activities. This would involve working through the EAOW commercial fisheries working group (further detail provided in Chapter 14 Commercial fisheries) and using the most appropriate product at the time of construction.
222. In some areas where unsuitable sea bed conditions exist it may not be possible to bury cables to the required depth. At these locations it could be necessary to use alternative methods for protecting the cables other than burial. Details of some of the techniques employed are given below:
- Concrete mattresses - prefabricated flexible concrete coverings that are laid on top of the cable, as an alternative to rock placement.
 - Grout or sand bags, are used similarly to concrete mattressing with mattresses filled with grout and / or sand used in place of the prefabricated concrete mattresses. This method is generally applied on smaller scale applications than concrete mattressing.
 - Rock placement - involves the laying of rocks on top of the cable to provide protection which is effective on crossings and other areas requiring protection. Where long sections of unsuitable sea bed are encountered this is a costly exercise and it is subject to environmental permitting restrictions.
 - Frond mattresses could be used to provide protection by stimulating the settlement of sediment over the cable. This method develops a sandbank over time protecting the cable but is only suitable in certain water conditions. This method may be used in close proximity to offshore structures although experience has shown that storms can strip deposited materials from the frond.

- Uraduct is effectively a protective shell which comes in two halves and is fixed around the cable to provide mechanical protection. Uraduct is generally used for short spans at crossings or near offshore structures where there is a high risk from falling objects or abrasion. Uraduct does not provide protection from damage due to fishing trawls or anchor drags.
223. The Burial Protection Index has been adopted in recent times. This approach assesses the level of protection afforded by the site- specific soil conditions and the threat level posed by third party interactions such as fishing gear and ship’s anchors.
224. The exact amount of cable protection required is not possible to predict with a reasonable degree of certainty until more knowledge of the site has been gathered and processed (from ongoing intrusive Site Investigations). However, assessment of the existing EAOW ground model which is founded on historical geological maps of the sea bed and a limited 2010 EAOW Reconnaissance Borehole Campaign indicates that no more than 10% of the total length of cables in the offshore environment would require protection.
225. The maximum required total for cable protection in the East Anglia THREE site and offshore cable corridor are presented in *Table 5.25*. These are based on a Two Phased approach as that would result in the maximum amount of installed cable and therefore maximum amount of cable protection.

Table 5.25 Maximum Cable Protection Requirements for the East Anglia THREE site and Offshore Cable Corridor based on 10% Protection Length

Type of cables	Max. number of cables (no.)	Total length (km)	10% of total value (m)	Cable protection area (with typical 6 x 3m mattress) (m ²)	Cable protection volume (with typical 6 x 3 x 0.3m mattress) (m ³)
Export cable	4	664	66,400	199,200	59,760
Platforms link cable (Single Phase approach)	16 (13)	240 (195)	24,000 (19,500)	72,000 (58,500)	21,600 (17,550)
East Anglia THREE Phase 1+2 – East Anglia ONE interconnection cable	4	380	38,000	114,000	34,200
Inter-array cable	-	550	55,000	165,000	49,500

Type of cables	Max. number of cables (no.)	Total length (km)	10% of total value (m)	Cable protection area (with typical 6 x 3m mattress) (m ²)	Cable protection volume (with typical 6 x 3 x 0.3m mattress) (m ³)
TOTAL		1,834	183,400	550,200	165,060
(Single Phased):		(1,789)	(178,900)	(536,700)	(161,010)

226. In the near shore, between the coastline and the Greater Gabbard Offshore Wind Farm and Galloper Wind Farms cable routes, where larger amounts of cable protection could adversely affect the physical processes, a limit of 2.5% would be set as an upper limit of the length of cable where cable protection is employed. Therefore the figures for cable protection of the export cable presented in *Table 5.25* above represent a precautionary maximum worst case.

5.5.14.5 Crossing Cables and Pipelines

227. There are several existing cables and a pipeline within the offshore cable corridor (see Chapter 18 Infrastructure and Other Users for details). The anticipated cable crossings are displayed in *Figure 5.4*. Each crossing requires a cable crossing agreement to be discussed on a commercial and technical basis and signed by the asset owners and EATL before works commence.

228. Where the offshore cable is required to cross an obstacle such as an existing gas pipeline or communications cables, the additional protection elements may be employed to protect the obstacle being crossed. Once protection is in place the East Anglia THREE cable would be placed on top of that protection and then further protection would be placed on top of the East Anglia THREE cable (see *Diagram 5.16*).

229. For a typical pipeline or cable crossing a concrete mattress would be deployed with typical dimensions of 6m long by 3m wide by 0.3m high. The number of mattresses required would depend on the size, type and vertical position of the asset to be crossed, the number of cables crossing and the separation of the cables that can be achieved at the point of the crossing. An alternative may be a bespoke designed concrete bridge which is installed over the existing pipeline or cable with the offshore export cable being installed perpendicular, over the bridge. A substitute to concrete mattresses may involve rock filter bags laid over the existing obstacle.

230. Other factors that need to be taken into account when considering an offshore crossing are:

- HVDC cables crossing HVAC cables are required to be perpendicular to prevent induced currents resulting in thermal hotspots and de-rating of the cable.
 - Avoid existing offshore cable joint locations (100m boundary) as these sites are more prone to failure and as such there exists a greater possibility for a requirement to recover the cable in the future.
 - Avoid existing crossings of cables and pipelines to prevent triple crossings which increase risk and difficulty of recovery should any of the elements require repair.
231. In addition, sand waves can result in scouring of the cable or cable spanning occurring over time. To prevent this, the cable would ideally be placed in the troughs of sand waves.
232. It is anticipated that where the East Anglia THREE export cable would cross existing cable or pipeline concrete mattressing, fronded concrete mattressing, rock dumping, bridging or gravel bags would be used for protection. The total maximum height of a cable crossing is predicted to be 4m for crossing a pipeline; however the majority of crossings would be much smaller, up to 1m in height above the sea bed.
233. A schematic of how a cable crossing using mattresses is displayed in *Diagram 5.17* below.

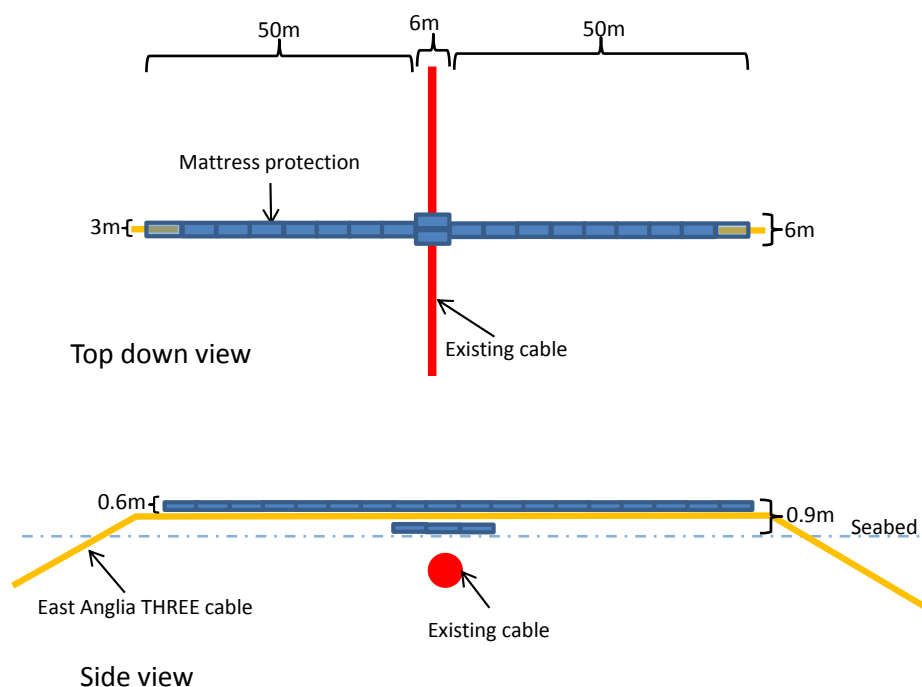


Diagram 5.17 Schematic of a Cable Crossing. Not drawn to scale.

234. In order to calculate what the maximum area for each cable crossing would be it has been assumed that cable crossing agreements would require a 100m safety area (50m on each side of the crossing point) where no trenching would be carried out as illustrated in *Diagram 5.16*. *Table 5.26* provides the calculations for the maximum area and volume of material required for each cable over cable crossing. It should be noted that the area may be slightly larger for a pipeline crossing, however there is only one existing pipeline that would be crossed by the East Anglia THREE export cables.

Table 5.25 Calculations for the Area and Volume of Material Required for a Single Cable Crossing

Protection location	No. of mattresses	Size (m)	Total Area per crossing (m ²)	Total volume per crossing (m ³)
Length	17	6	342 (19 × 18m ²)	215
Width	1 (apart from at the crossing point where it would be 2)	3		
Height	3	0.91		

¹ 0.9m is based on the assumption that two mattresses and one cable stacked

235. It has been anticipated that the maximum number of cable crossings (*Figure 5.4*) would occur under the HVDC electrical solution which was constructed using a Two Phased approach as illustrated in *Diagram 5.11* and *Table 5.20*). Under this option it is anticipated that there would be up to 100 export cable crossings (25 each for the four export cables), 32 platform link crossings, 16 interconnector crossings. *Table 5.27* provides calculations for the maximum anticipated area to be required for cable protection used in cable crossing.

Table 5.27 Calculations for the Area and Volume of Material Required for all East Anglia THREE Cable Crossings

Cable type	Max number of cables	Expected crossings per cable	Total crossings	Area per crossing (m ²)	Volume per crossing (m ³)	Total protection area (m ²)	Total protection volume (m ³)
Export cable	4	25	100	342	215	34,200	21,500
Interconnect or cables	4	16	64	342	215	21,888	13,760
Platform link cables	16	2	32	342	215	10,944	6,880
Total			196			67,032	42,140

¹ The maximum number of interconnection cables is two pairs of bundled cables in up to two trenches. However, when bundled cables make a crossing they may need to be unbundled over the crossing and bundled again after the crossing.

5.5.14.6 Maximum Total Footprint of Cable Protection

236. *Table 5.28* below illustrates the maximum footprint of cable protection required for the proposed East Anglia THREE project.

Table 5.28 Summary of Total Cable Protection for Cable Crossings and Where Cable Burial is not Possible.

Protected area due to crossings (m ²)	Protected area due to soil uncertainties (m ²)	Total protected area (m ²)	Protected volume due to crossings (m ³)	Protected volume due to soil uncertainties (m ³)	Total protected volume (m ³)
67,032	550,200	617,232	42,140	165,060	207,200

5.5.15 Construction Activities and Sequences

237. This section primarily considers the Single Phase construction approach. Many of the processes would be the same for the Two Phased construction programme however the timings may differ. The construction programmes for a Single Phase and a Two Phased approach are discussed in section 5.5.13.

5.5.15.1 Wind Turbine, Offshore Substations and Accommodation Platform Construction Activities

238. The key activities associated with the installation of the offshore windfarm, are likely to be as follows:

- Detailed pre-construction site investigations (e.g. cone penetration tests, boreholes and high resolution geophysics) - these works may be subject to separate licence applications;
- Installation of foundations (see section 5.5.4);

- Installation of transition pieces;
- Installation of offshore collector and converter stations;
- Installation of inter-array cables;
- Installation of wind turbine generators; and
- Installation of monitoring meteorological masts.

239. The offshore export cables would either be installed separately or in parallel with other elements of the offshore windfarm. Prior to installation of the cables some ground preparation may be required along the route.

5.5.15.2 Pre-construction Site Investigations

240. Pre-construction site investigations would be completed prior to construction and are likely to include:

- Geophysical Survey;
- Geotechnical survey;
- Pre-lay grapnel run;
- Unexploded Ordnance (UXO) survey and clearance; and
- ROV survey.

241. Geophysical survey data would inform the micro-siting of wind turbine foundations, cables and offshore electrical platforms. The geophysical data would also serve to identify the location of sand waves along the offshore cable corridor so that an assessment could be made as to whether such features could be avoided or, if not, what level of sea bed preparation (pre-lay sweeping) is required, and what the appropriate burial depth would be in stable (i.e. non-mobile) sea bed conditions.

242. Targeted geotechnical surveys would take a number of borehole samples, cone penetration tests (CPT) and vibrocores within the East Anglia THREE site and offshore cable corridor up to the landfall site.

243. A pre-lay grapnel run (PLGR) and ROV survey would take place to identify any obstacles that may be in the path of the proposed cable routes. If an obstacle is detected; it would either be removed or the cable would be installed in such a way as to avoid it. Where the obstacle is suspected to be UXO, specialist mitigation would be employed to either avoid or make the obstruction safe.

5.5.15.3 Installation of Foundations

244. The time taken to install foundations would vary depending on the type and installation method chosen. However, based on foundation installation at the West of Duddon Sands Offshore Wind Farm it can be assumed that each foundation installation would take no more than two days to complete (average foundation installation time at West of Duddon Sands Offshore Wind Farm was 15.9 hours)
245. It is expected that installation of all foundations would take up to 25 months under a Single Phase approach and 29 months under a Two Phased approach (including the period between phases). These timings would be reduced under a Single Phase approach if two foundation installation vessels were used to install foundations simultaneously. Maximum foundation installation timescales are presented in *Table 5.29* and indicative timescales for both the Single Phase and Two Phase approaches are displayed in *Tables 5.34* and *Table 5.37*.
246. Construction works would be undertaken 24 hours a day and seven days a week offshore, dependent upon weather conditions.

Table 5.29 Indicative Time Periods for Foundation Installation

Foundation Type	Total time required to install 172 foundations*
Jackets	Up to 15 months for piling and ten months for jacket installation (including weather down time), with one spread per activity
Monopiles	Up to seven months
Gravity Base	Up to 12 working months (i.e. two parallel installation spreads over min two summer seasons)
Suction Caisson	Up to 12 working months (i.e. two parallel installation spreads over min two summer seasons)

*This does not take into account downtime of transit of installation vessels or ground preparation time unless stated

5.5.15.4 Installation of Transition Pieces (TP) and Towers

247. Following foundation installation TPs would be fixed to the top of the foundation. The TP facilitates the connection between the foundation and the tower.
248. Both TPs and towers would be either be both transported to site and installed by the installation vessel or transported on a barge where they would be lifted off and installed by crane on a separate installation vessel. The most likely installation vessel would be a jack-up vessel, although DP vessels are also under consideration.

249. The TP serves several different purposes as it could be used to contain the necessary electrical and communication equipment and provide a landing facility for personnel and equipment from marine vessels.
250. The design and specifications of a TP are dependent on the type of foundation on which they sit. For jackets and gravity base structure foundations the TP is often integrated with the foundation at fabrication stage, and therefore there is no additional installation process. For monopiles however, a TP cannot be located on the foundation as the top side needs to be clear to allow it to be driven into the sea bed.
251. Once the TPs are in place the turbine tower would be lowered into place using a heavy lift vessel.

5.5.15.5 Installation of Wind Turbines

252. Wind turbines would be installed by jack-up Installation Vessels. Installation durations would depend on the number of turbines carried per round trip and wind turbine model specific procedures. However, based on turbine installation timings at the West of Duddon Sands Offshore Wind Farm it can be assumed that turbine installation would take up to one to two days (average wind turbine installation time at the West of Duddon Sands Offshore Wind Farm was 16.9 hours).
253. Mechanical and electrical completion, as well as commissioning, would take additional days after the departure of the installation vessels. Teams for those purposes would be transferred into the wind turbines by crew transfer vessels (CTVs - Wind Farm Service Vessels) or Accommodation Vessels. The number of teams and vessels would depend on the intensity required to follow the progress rate of the main installation vessel.
254. The nacelle and turbine blades would be either transported to site and installed by the installation vessel or transported on a barge where they would be lifted off and installed by crane on a separate installation vessel. The installation of the wind turbines would typically involve multiple lifting operations, with up to three tower sections erected, followed by the nacelle with pre-assembled hub, and then the blades.
255. *Plate 5.3* shows an example of a wind turbine under construction, TP tower, nacelle and two blades have been installed and only the third remaining blade requires installation



Plate 5.3 Wind Turbine Under Construction³

256. The installation of each wind turbine onto the pre-installed foundation is expected to take approximately one day, excluding transit times and weather downtime. To reduce time spent at sea installing the wind turbines, pre-commissioning works onshore would be maximised.
257. Traditional installation methods consist of tower segments lifted in place and bolted together, hub and nacelle conjoined in case of single blade installation. Also alternative installations would be considered, with two or all three blades pre-attached to the hub for onsite attachment to the nacelle.
258. Although not current practice, it is possible that wind turbines could be fully assembled and commissioned onshore and transported to site as a single unit installation. This method is being explored by the wind industry but it is not possible to commit to this method as it is not technically proven at this stage.

Source: Vattenfall: Ormonde Offshore Wind Farm. Tony West.

Image shows Repower 5MW wind turbine at a height of 163m. The proposed East Anglia THREE project is considering wind turbines of up to a height of 247m.

5.5.15.6 Installation of Inter-array Cables

259. Inter-array cable installation would be executed using a number of methods as discussed in section 5.5.14.3. The installation programme would be led by cable laying activities, and the other tasks would be planned to follow the cable laying rate (i.e. number of teams for burial, protection, terminations, etc.). The total duration for inter-array cable installation would be up to 14 months (not including down time) under a Single Phase approach and 28 months under a Two Phased approach, see Tables 5.34 and 5.37.

5.5.15.7 Installation of offshore platforms.

260. It is anticipated that the installation of the offshore platforms would take approximately one month to complete. The construction sequence would largely depend on what method of foundation was selected. Installation by either jackets with pin piles or by Gravity Base would follow the construction sequence as described in section 5.5.4

261. The topsides would be installed either:

- By a suitable crane vessel (or vessels working together) in a single lift;
- By a suitable crane vessel (or vessels working together) in separate lifts of deck and sub-modules; or
- Using a rail-skid transfer from a large jack-up.

262. An alternative option being considered is a self-installing structure, which is towed to site and then floods or fills its legs to sit on the prepared sea bed. Piles may be used to minimise future movement.

5.5.15.8 Construction Vessels and Logistics

263. The number and specification of vessels employed during the construction of the proposed East Anglia THREE project would be determined by the marine contractor and the EATL construction strategy following grant of consent to construct the project. It is anticipated that several types of construction vessel could work in parallel during the construction of the offshore windfarm.

264. The final selection of the port facilities required to construct and operate the proposed East Anglia THREE project has not yet been determined.

265. EATL has provided indicative vessel types required during the construction and operation stages as shown in *Table 5.30*.

Table 5.30 Indicative Vessel Requirements at Construction and Operation Stages

Activity	Vessel Type	Indicative number
Foundation Installation	Dredging vessel	1
	Tugs and barges storage and transport	3
	Jack-up vessel	2
	Dynamic Position Heavy Lift Vessel	2
	Support vessels	6
Wind turbine installation	Jack-up vessel	2
	Dynamic Position Heavy Lift Vessel	2
	Accommodation vessel	2
	Windfarm service vessel	4
	Support vessels	6
Collector or Converter station installation	Installation vessel	1
	Tug with accommodation barge	1
	Supply vessel	1
	Support vessels	5
Cable installation	Inter-array cable laying vessel	2
	Accommodation vessel	1
	Export cable laying vessel	2
	Export cable support vessel	3
	Pre-trenching/backfilling vessel	2
	Cable jetting and survey vessel	2
Regular operation (onshore option)*	Workboat	8
Regular operation (offshore option)*	Accommodation and supply vessel	2
	Workboat	1

* These options are explained in section 5.5.17.1

266. Under a Single Phased approach it is anticipated that typically up to 55 vessels could be on site at any time during the construction. From this total, approximately 75% would be crew transfer, survey, refuelling and maintenance, dive support and guard vessels, while the remaining 25% would be construction, transportation and support vessels.

267. Under a Two Phased approach the numbers of vessels on site at any given time are likely to be less than the 55 however, the percentages of the different types of vessels would be similar to that of the Single Phased approach.
268. *Table 5.31* provides indicative numbers of vessel movements associated with the construction of various components of the proposed East Anglia THREE project under both the Single Phase and Two Phased approaches. This is based on a worst case scenario, which is that 172 foundations would be laid and the maximum lengths of inter-array, platform link, interconnector and export cables would be laid. Based on a single Phase approach the total number of vessel movements is predicted to be up to 5,700. Under a Two Phased approach it is estimated that the total number of vessel movements (round tips) during the construction of Phase 1 would be approximately 4,000.

Table 5.31 Indicative Number of Vessel Movements Required for Single Phase and Two Phased Approaches

Activity	Indicative Number of Vessel Movements, Single Phase	Indicative Number of Vessel Movements Phase 1, (Phase 2)
Foundation installation (Jackets are the worst case)		
Installation of four piles per jacket	46	23 (23)
Installation of Jacket	75	38 (38)
Grouting	27	14 (14)
Scour protection	60	30 (30)
Support vessels and transfers	344	172 (172)
Offshore electrical platform installation		
Transport barges	24	16 (12)
Shuttling to and from platforms	384	256 (180)
Inter-array cable laying		
Cable laying vessel	38	19 (19)
Cable support vessel	40	39 (39)
Burial vessel if required (depends on chosen method for burial)	24	22 (22)
Termination & Testing	40	39 (39)
Crew transfer vessel	1680	1,680 (1,680)
Export cable installation		
Cable laying vessel	24	18 (18)

Activity	Indicative Number of Vessel Movements, Single Phase	Indicative Number of Vessel Movements Phase 1, (Phase 2)
Crew transfer vessel	48	24 (24)
Cable protection	49	25 (25)
Platform link installation		
Cable laying vessel	18	16 (18)
Crew transfer vessel	24	11 (22)
Cable terminations	20	20 (20)
Cable protection	15	6 (3)
Interconnection cable		
Cable laying vessel	10	10 (10)
Crew transfer vessel	28	28 (26)
Cable terminations	20	20 (2)
Cable protection	15	15 (3)
Wind turbine installation		
Installation vessel	58	28 (28)
Crew transfer vessel	430	215 (215)
Accommodation Vessel (if required)	18	10 (10)
Assumed number of journeys (in- and outbound) for CTVs and other vessels during the overall campaign	2150	1,075 (1,075)
Overall total	5,685	7636 (3,852 + (3,784))

269. The anticipated number of vessel movements for Phase 2 would be approximately the same as that required for Phase 1 (3,949) as presented *Table 5.31*. Therefore, the estimated number of trips undertaken by vessels involved in the construction of Phase 1 and Phase 2 would be approximately 8,000.
270. Any accommodation platform installed during Phase 1 would remain in position to accommodate personnel onsite during Phase 2.

5.5.15.9 Constraints and Buffers

271. Some restrictions on vessel movements within the East Anglia THREE site may be required to protect the health and safety of all users of the sea. It is anticipated that

vessels would navigate to give each windfarm asset as large a clearance as possible. However, to reduce the possibility of vessel collisions, it may be considered necessary to apply for safety zones. The safety zones that could be applied for as part of the East Anglia THREE submission are presented in *Table 5.32* below. These would be determined on the basis of a detailed safety case. For further discussion see Chapter 15 Shipping and Navigation.

Table 5.32 Potential Safety Zones during Construction, Operation and Decommissioning

Type of Safety zone	Area Covered
Construction ¹	Up to 500m around each foundation or renewable energy installation whilst under construction
Commissioning ²	Up to 50m around each renewable energy installation where construction has finished but some work is ongoing, e.g. wind turbine incomplete or in the process of being tested before commissioning.
Operations ²	50m around each renewable energy installation during operation.
Major Maintenance ¹	Up to 500m when major maintenance is in progress (use of jack-up vessel or similar).
Decommissioning	Up to 500m at the end of the working life of a renewable energy installation when it is being removed from site
¹ The Construction, Major Maintenance and Decommissioning safety zones are required to ensure a safe distance is maintained from vessels engaged in high risk activities such as jacking operations and heavy lifts.	
² The Commissioning and Operations safety zones are required to ensure small vessels are not adversely affected by propeller or thruster wash from vessels used for transfer whilst also ensuring no additional risk is created for personnel during access and egress. This zone also reduces risk of injury to third parties from items dropped from aloft.	

5.5.15.10 Vessel Profiles

272. This section provides an overview of the types of vessel that would be used in the construction, operation and decommissioning of the proposed East Anglia THREE project.

5.5.15.10.1 Jack-up vessels

273. Jack-up vessels are considered an option for installation of jacket foundations (along with floating vessels) and the most suitable means of installing wind turbines.

274. An envelope of dimensions for jack-up vessels likely to be considered for the proposed East Anglia THREE project is illustrated in *Table 5.33* below. Floating vessels are under consideration for some operations although the techniques are not always proven so jack-up vessels are still likely to be used.

Table 5.33 Envelope of Dimensions for Jack-up Vessels

Dimensions Jack-up Vessel	
Length	110 – 200m
Breadth	42 – 80m
Draught (max.)	6.0 – 10m
Number of legs	3 – 6
Deck area	2,500 - 5000m ²
Spud can area per leg	50-300m ²
Types of leg	Cylindrical, triangular, truss leg, lattice
Max. allowable leg penetration	Site specific, typically 0.5 – 20m

5.5.15.10.2 Dynamic Positioning Heavy Lift Vessel

275. If used at the East Anglia THREE site a heavy lift vessel would need to be capable of lifting heavy loads such as transition pieces and nacelles into place.

276. DP is a computer-controlled system which is used to automatically maintain a vessel's position and heading by using its own propellers and thrusters. Position reference sensors, combined with wind sensors, motion sensors and gyro compasses, provide information to the computer pertaining to the vessel's position and the magnitude and direction of environmental forces affecting its position.

277. DP vessels often make use of azimuth thrusters whereby the propeller is placed within a pod or a duct to allow rapid repositioning of the thruster in response to changes in vessels position. This enables the vessel to stay in a precise location.

5.5.15.10.3 Accommodation Vessel:

278. One or more accommodation vessels could be used as a temporary home to the workers who install and commission the wind turbines and electrical infrastructure at the windfarm. These types of vessels are sometimes known as “flotels”.

5.5.15.10.4 Windfarm Service Vessel:

279. Windfarm service vessels (also known as CTVs) are typically much smaller than the jack-up, heavy lift and accommodations vessels and are usually no greater than 30m in length. These vessels are often multi-hulled which makes them more stable and moveable especially in rough sea conditions.

280. Service vessels would vary in design and dimensions as they would be required to carry out a variety of different services and operations.

5.5.15.10.5 Cable Laying Vessel:

281. There may be up to two separate vessels involved in laying the inter-array and export cables. In one scenario, the first vessel would lay the cable on the sea bed and the second would bury the cable. Alternatively, one vessel would lay and bury the cable at the same time, or one vessel would pre-trench and another one lay (the first one, or other, could be required to backfill or to install protection).

282. Cable laying vessels are typically very large (70m or more) with sufficient deck area to accommodate the hundreds of kilometres of cable needed on an offshore wind farm.

5.5.16 Windfarm Construction Programme

283. As previously stated EATL are considering constructing the proposed East Anglia THREE project either in a single phase or over two phases.

5.5.16.1 Single Phase

284. If the project was constructed in a single phase it is anticipated that the build programme for the offshore elements would take up to 41 months. An illustration of this programme is displayed in *Table 5.34* below.

285. Under the Single Phase approach foundation installation would take up to 15 months to complete and would vary depending on the foundation type and the number of installation vessels. Other foundation types than those displayed in *Table 5.34* are being considered for the proposed East Anglia THREE project (see section 5.5.4) however these would be installed in less time than those presented in *Table 5.34*.

286. Installation of the different electrical cables would take place at different points of the programme (*Table 5.34*); however, work would start early on the offshore export cables as these would take up to 22 months to install.

The programme presented in *Table 5.34* also provides an indication of how the offshore programme would be coordinated with the onshore programme which is further discussed in sections 5.7.3.8 and 5.7.8.14.

Table 5.34 Indicative Offshore Project Construction Programme Under a Single Phase Approach

Installation activity	Duration (months)	Months																																																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41								
Piling	15																																																	
(using two vessel)	8																																																	
Jacket installation	10																																																	
Inter- array cables	14																																																	
Wind turbines	18																																																	
Collector platform	3																																																	
Converter platform	2																																																	
Accommodation platform	1																																																	
Met mast	2																																																	
Platform link cables	11																																																	
Interconnector cable	13																																																	
Offshore export cable	22																																																	
Onshore substation and cable installation																																																		

5.5.16.2 Two Phased

287. Under a Two Phased approach the proposed East Anglia THREE project would be built in a staggered way, with the construction of Phase 2 commencing a maximum of 18 months after the start of onshore construction of Phase 1 (see *Table 5.37*).
288. Phase 1 would broadly consist of a self-contained 600MW offshore windfarm. Therefore, the infrastructure involved would be approximately half of the 1,200MW project described thus far. Many of the characteristics presented for in *Table 5.4* would not change under a Two Phased approach. However, *Table 5.35* provides a breakdown of the Phase 1 and Phase 2 elements.

Table 5.35 Project Characteristics Offshore for Under a Phased Construction Approach

Parameter	Phase 1	Phase 1 + Phase 2
General characteristics		
Capacity	600MW	1,200MW
Number of wind turbines	50 – 86 units	100 – 172 units
Total Inter-array cable length	80 – 275km	190 – 550km
Maximum offshore cable corridor length	166km	No change
HVAC collector station platform	1 – 2	2 – 4
HVDC converter station platform	0 – 1	0 – 2
Platform link cables	2 (total length of 30km) - 5 (total length of 75km)	Up to 16 (total length 240km)
Interconnector cables with East Anglia ONE	2 cables (total length 190km)	4 cables (total length of 380km)
Number of export cables	2 (total length of 332km)	4 (total length 664km)
Proposed turbine capacity	7 - 12MW	No change
Met masts	Up to 2	No change
Accommodation platform	1	No change
Maximum quantities of excavated material		
Maximum expected cable crossings including platform link, interconnector and export cable	92 (meaning a protected area of 30,912 m ²)	196 (meaning a protected area of 65,856 m ²)
Maximum amount of cable protection required due to unsuitable ground conditions	255,000m ²	537,000m ²
Scour protection footprint around	22,672m ² × 50 =	22,172m ² × 100 =

Parameter	Phase 1	Phase 1 + Phase 2
wind turbine foundations	1,133,600m ²	2,267,200m ²
Scour protection footprint around offshore platforms (electrical and accommodation)	4 × 8,789m ² = 35,156m ²	7 × 8789m ² =61,523m ²
Scour protection footprint for met masts	2 × 2,830 = 5,560m ²	2 × 2,830 = 5,560m ²

289. The time taken to install foundations would vary depending on the foundation type and installation method chosen. In a Two Phased approach, the need for two installation vessels working simultaneously in the same activity may not exist. Indicative foundation installation timescales are presented in *Table 5.36*.

Table 5.36 Indicative Foundation Installation Timings Under a Two Phased Construction (duration per phase)

Foundation Type	Time required to install 86 foundations ¹
Jackets	Approximately eight months for piling and an additional five months for jacket installation (including weather downtime), with one spread per activity.
Monopiles	Approximately five months
Gravity Base	Approximately seven working months (in summer seasons)
Suction Caisson	Approximately seven working months (in summer seasons)

¹ This does not take into account downtime of transit of installation vessels or ground preparation Time

290. Inter-array cabling is anticipated to last a maximum of seven months and wind turbine installation 11 months for construction of Phase 1.
291. The assumption has been made that Phase 2 would overlap with the construction of Phase 1 as shown in *Table 5.37*.
292. The key characteristics of Phase 1 and Phase 2 are presented in *Table 5.35 above*. *Table 5.20* and *Diagrams 5.11* and *5.12* illustrate the maximum electrical infrastructure required for a Two Phased approach to construction using both the HVDC and LFAC electrical solutions.
293. The time taken to install Phase 1 and Phase 2 would be the result of the installation time of each phase, minus any overlap between the end of Phase 1 and the start of Phase 2. *Table 5.37* below presents an indicative programme for construction using

the Two Phased approach, with construction estimated to take 45 months to complete.

Table 5.37 Indicative Offshore Two Phased Construction Programme.

Installation activity	No months	Month																																																		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45						
Phase 1	Piles	8																																																		
	Jackets	5																																																		
	Inter array cables (using two vessel)	14																																																		
	Wind turbines	10																																																		
	Collector platform	2																																																		
	Converter platform	1																																																		
	Accommodation platform	1																																																		
	Met mast	1																																																		
	Platform link cables	5																																																		
	Interconnectors	13																																																		
	Offshore export cable	11																																																		
	Onshore substation and cable installation	13																																																		
	Phase 2	Piles	8																																																	
Jackets		5																																																		
Inter array cables (using two vessel)		14																																																		
Wind turbines		10																																																		
Collector platform		2																																																		
Converter platform		1																																																		
Accommodation platform		1																																																		
Met mast		1																																																		
Platform link cables		5																																																		
Interconnectors		13																																																		
Offshore export cable		11																																																		
Onshore substation and cable installation		13																																																		

5.5.17 Operational Offshore Maintenance

5.5.17.1 Maintenance Activities

294. Once commissioned, the windfarm would operate for up to 25 years. All offshore infrastructure including wind turbines, foundations, cables and offshore substations would be monitored and maintained during this period in order to maximise operational efficiency and safety for other sea users.
295. The operation and control of the windfarm would be managed by a Supervisory Control and Data Acquisition (SCADA) system, connecting each turbine to the onshore control room. The SCADA system would enable the remote control of individual turbines, the windfarm in general, as well as remote interrogation, information transfer, storage and the shutdown or restart of any wind turbine if required.
296. There are a number of potential maintenance strategies for the windfarm. The windfarm could be maintained from shore using a number of varying O&M vessels (e.g. CTVs, supply vessels) and/or helicopters – the onshore option. Alternatively, the windfarm could be maintained primarily from an offshore base, for example a accommodation vessel (a large offshore service vessel (possibly of the jack-up type) or a fixed offshore platform (possibly shared with other infrastructure e.g. a converter station platform or a standalone accommodation and O&M platform within the project boundary) with transfer vessels or helicopters used to transfer personnel to or from turbines and platforms – the offshore option.
297. Alternatively, a combination of the onshore and offshore O&M options described above may be employed depending upon the nature of the maintenance tasks scheduled.
298. Given the design life of the offshore components some refurbishment or replacement would be required during this time. Relevant consents or licences required would be applied for if required.
299. Typical maintenance activities would include -general wind turbine service; oil sampling / change; UPS (uninterruptible power supply)-battery change; service and inspections of wind turbine safety equipment, nacelle crane, service lift, high voltage (HV) system, blades; major overhauls (years 5, 7, 10), wind turbine repairs and restarts.
300. During the life of the project, there should be no need for scheduled repair or replacement the sub-sea cables, however, reactive repairs may be required and periodic inspection may be required (see section 5.5.17.3). Periodic surveys would

also be required to ensure the cables remain buried and if they do become exposed, re-burial works would be undertaken.

5.5.17.2 Vessel and Helicopter Operations

301. A number of vessel and / or helicopter visits to each turbine would be required each year to allow for scheduled and unscheduled maintenance. The predicted worst case is 365 two-way helicopter visits to the East Anglia THREE site per year and an average of approximately 4,000 two-way windfarm support vessel trips which includes all scheduled and unscheduled maintenance. If the onshore operation option is chosen, this would mean small crew vessels sailing to and from the windfarm on a daily basis from shore, possibly supported by helicopters. If the offshore operation option is preferred, the majority of small crew vessels would be operated on a daily basis from the offshore accommodation vessel or platform, although further support vessels are also still likely to transit to and from shore each day and helicopter operations may still be utilised. Offshore electrical platforms would require one visit a week maximum.
302. It is anticipated that up to two service vessels (with accommodation) would be on site at any one time and that a service vessel may alter its location within the windfarm site once per day.
303. Although it is not anticipated that large components (e.g. wind turbine blades or substation transformers) would frequently require replacement during the operational phase, the failure of one of these components is possible. Should this be required, large jack-up vessels may need to operate continuously for significant periods to carry out these major maintenance activities.
304. During O&M activities EATL would seek to agree appropriate safety zones around wind turbines and work areas to be applied. Safety zones are described above in *Table 5.23*.

5.5.17.3 Cable Operations and Maintenance of Cables

305. During the life of the project, cable repairs may be required and periodic inspection would be undertaken. Periodic surveys would also be required to ensure the cables remain buried and if they do become exposed, re-burial works would be undertaken.
306. EATL have carried out statistical analysis based on experience at other existing windfarms of cable failure and estimate the rate of cable failure would be approximately:

2.86 failure / 1000km / year.

307. This figure is based on existing and previous technology and does not allow for advances in cable technology in the future which may reduce failure rates.
308. Using the calculated failure rate and taking account of the maximum length of cables calculated (1,800km, which would occur under the Two Phased HDVC approach) it is estimated that there would be 4.5 cable failures per year across the entire project. A breakdown of the failure rate per type of cable is presented in *Table 5.38*.

Table 5.38 Indicative Cables Failure Rates

Cable type	Failures/ year	No. reparations / year	Affected length (km)
Inter –array	1.57	2	2
Export cable	1.90	2	0.5
Platform link cables	0.68	1	0.5
Interconnector	0.54	1	0.5
Total	4.5	6	3.5

309. It should be noted that the figures provided in *Table 5.38* are based on the maximum possible cable lengths installed under any of the possible construction options discussed in section 5.5.13 and therefore would be greatly reduced for the LFAC electrical solution and in one phase of the Two Phased approach or slightly reduced under the Single Phase approach.
310. In most cases a failure would lead to the following operation:
- Pre-recovery survey to determine nature of fault and affected length of cable;
 - Exposure of the damaged part of the cable by jetting (or removal of mattress/rock protection);
 - Retrieval of the affected section to surface using buoys, jetting or an air-lift tool (method used would depend on the burial depth and composition of substrate which would be determined by a pre-recovery survey);
 - Cutting the cable, inserting a joint;
 - Bringing a new segment of cable and jointing the new segment with the old cable;

- Reinstalling the mattress, rock dumping, jetting or other methods of cable burial or protection; and
 - Any defective cable would be removed to a vessel for onshore disposal at a registered disposal site.
311. If the cable fault was in close proximity to the substation or wind turbine and if there was sufficient slack it could be directly pulled in to the substation of wind turbine and the damaged cable removed or repaired.
312. However, in some situations a whole section of the cable a length of 1 to 2km would be replaced rather than risk a repair to a damaged section.
313. An indicative timetable for the works is as follows:
- Onshore mobilisation: one month;
 - Execution of repair work : one month; and
 - Cable reburial and survey: one month.
314. Cables could also become exposed due to moving sand waves or erosion of other soft/mobile sediment (not just sand waves). During the life of the project, periodic surveys would be required to ensure the cables remain buried and if they do become exposed, re-burial works would be undertaken.
315. The need for post construction surveys would form part of the DCO through the deemed Marine Licence (dML). These surveys are outlined in the Outline Offshore Operation and Management Plan (OOOMP) however, the exact scope of these would be determined pre-construction in agreement with the Marine Management Organisation (MMO) and their advisors.
316. Other methods to detect the exposure of cables are available. Some operators have been testing the use of Distributed Temperature Sensing (DTS), which uses the fibre optic cables as a measure of cable temperature. An exposed cable is cooler since the water conducts the heat away more efficiently than when buried. The use of this system is common for export cables but not for inter-array cables.
317. EATL have used existing data to calculate that the expected reburial figure for the proposed East Anglia THREE project would be a maximum of one reburial every five years. This is based on the maximum amount of cables (1,800km) being installed.

5.5.17.4 O&M Port

318. The O&M facility is to be located in a service port (yet to be chosen). It is envisaged that O&M needs, in terms of laydown areas and facilities would be minimal compared to requirements during the construction phase.
319. In the event of major intervention where large components are needed (blades, gearboxes, generators) EATL would aim to minimise the amount of spares it keeps, and to supply such components directly to site from the supplier's works.
320. An office, storage or warehouse facility and quayside loading area would be needed. During the first operational years of the project, operations might be coordinated and implemented from the onshore facility. As more wind turbines are installed it is the expectation that the majority of accommodation needs are to be offshore.
321. It is expected that an O&M strategy would be based on a concept of large service vessels operating for long durations at the offshore site, however, this would not be confirmed until a wind turbine provider is selected. After more wind turbines are installed, these may be supplemented with offshore flotels or fixed accommodation platforms, with helicopter support.

5.5.18 Offshore Decommissioning

322. At the end of the operation phase the project would be decommissioned. As an alternative to decommissioning, EATL may wish to consider re-powering the windfarm. Should EATL choose to pursue this option, this would be subject to a new application for consent.
323. The scope of the decommissioning works would be determined by the relevant legislation and guidance at the time of decommissioning and would most likely involve the accessible installed components. Offshore this is likely to include: all of the wind turbine components, part of the foundations (those above sea bed level) and the sections of the inter-array cables close to the offshore structures, as well as sections of the export cables.
324. Details for decommissioning of offshore foundations are discussed in section 5.5.4 above.
325. At the time of decommissioning EATL would comply with best practice and current guidance with regard to removal of scour protection. The methods for decommissioning would be agreed with the relevant authorities at that time.
326. With regards to offshore cabling, it is likely that general UK practice would be followed, i.e. buried cables would simply be cut at the ends and left in situ, with the

exception of the inter-tidal zone and across the beach where the cables would be at risk of being exposed over time. It is considered that full removal of the buried cables would be a more damaging environmental impact than is the case when leaving them in situ. However, if agreed with the regulator at the time of decommissioning, it may be of economic value to remove the cables. Excavation or jetting may be necessary to remove the cables.

327. Based on previous estimates and experience it is anticipated that decommissioning of the proposed East Anglia THREE project would take approximately 1 year.

5.6 Onshore

328. *Table 5.39* provides a list of parameters and their associated characteristics for the proposed East Anglia THREE project.

Table 5.39 Project Characteristics Onshore

Parameter	Characteristic
Landfall	Bawdsey
Grid connection location	Bramford substation
Export cable route length	37km
Substation compound area (hectares (ha))	3.04
Number of substations within compound	Up to two
Number of onshore cables	Up to 12 (4 x single core for HVDC, or 4 x 3-core i.e. 12 for LFAC)
Number of ducts	Up to four (installed by EAOL)
Fibre Optic cables	Up to two

329. The descriptions in section 5.6 present the worst case scenario for any parameter taken from either of the electrical solutions or phasing approaches unless it is stated otherwise.
330. Section 5.6 is structured so that the landfall, the onshore cable route and then the onshore substation are described using the following structure for each:
- Site description;
 - Description of infrastructure;
 - Construction methods;
 - Construction Programmes;

- Operation; and Maintenance; and
- Decommissioning.

331. As ducts will be installed during the construction of East Anglia ONE techniques for installing the ducts are not described here. For information on how the ducts will be installed please refer to the East Anglia ONE Environmental Statement (ES) (EAOL, 2012) and associated documents available on the Planning Inspectorate website.⁴

5.6.1 Landfall Site and Project Description

332. It is proposed that up to four offshore export cables from the proposed East Anglia THREE project would make landfall at Bawdsey in Suffolk. This site was chosen as part of the site selection process for East Anglia ONE export cable route but with the intention of accommodating cable requirements for up to three projects amounting to up to 3.6GW in total to connect to the National Grid.

333. Construction activities at the landfall location for the proposed East Anglia THREE project would consist of pulling the up to four export cables through ducts which will have already been installed.

334. The East Anglia THREE landfall site is characterised by exposed London clay with an eroding shingle terrace at the base of low lying cliffs (approximately 10m above ordnance datum) which are partially vegetated by grasses, gorse and other small shrubs. There are no formal coastal defences associated with flood prevention or coastal stability at the landfall location.

5.6.2 Landfall Construction Methods

335. EAOL is currently considering either a long or short duct method to install cables (and ducts for the proposed East Anglia THREE project) at landfall, as part of the installation of the East Anglia ONE project. EAOL anticipates that the cable ducts would be installed from the transition bay which would be set back a distance of up to 180m from the cliff top to allow for natural coastal erosion, with duct ends buried in the sea bed up to 1,100m from the base of the cliff for the long duct, and closer inshore for the short duct. Cables installed within the ducts would either be connected to the offshore export cables immediately, or ducts would be left within the sea bed until the cables are installed within them and connected to offshore export cables.

⁴ <http://infrastructure.planningportal.gov.uk/projects/eastern/east-anglia-one-offshore-windfarm/>

336. For long ducts, a trench would be excavated using a barge based excavator or suction dredger from the duct end towards deeper water and softer sediments whereby a plough or jetting tool could be used to install the export cable further offshore.
337. For short ducts, the duct exit point would require temporary access from the cliff top to the beach area so that the end of the pre-installed duct could be excavated. This would be located in order to minimise disturbance to the Site of Special Scientific Interest (SSSI) at Bawdsey Cliffs and to avoid vegetated shingle at landfall. Access would most likely comprise a temporary ramp constructed to enable safe vehicular access down the cliff. The temporary access would be required for a tracked excavator, which would be used to prepare the exit point and make the connection with the duct. The excavator and site personnel must have a safe exit from the beach at all times.
338. The beach access would remain in position for the duration of the cable landing, but actual access to the beach would only be required for a few hours to excavate and rebury the exit pit each time a cable is pulled into each duct. During cable pulling operations, access to the beach may need to be restricted or sections of beach may need to be temporarily closed for the day to protect members of the public from construction hazards. At all other times the beach would remain open and no plant or equipment would be present.
339. Once the export cable is ready for jointing to the cables within the cable ducts at the landfall, the following steps would be required:
- On arrival of the export cable installation vessel, the duct exit would require de-burial. This would most likely be achieved using a mass flow excavator.
 - The export cable installation vessel would be positioned by anchors prior to undertaking the cable pull in operations, facilitated by a pre-installed messenger wire within the duct and a pre-mobilised pull-in winch located in the onshore transition bay.
 - Following completion of the pull-in operation (and subsequent termination and cable testing) the export cable installation vessel would commence cable lay operations. If the cable is installed as bundled pairs, then trenching is the most likely means of cable burial in this area, whilst for single cables, ploughing would be the preferable means of burial due to the nature of the sea bed in this area (out-cropping London Clay).

- Subsequent to the cable lay operations, the cable in the transition zone between the duct and full depth of cable trench would be lowered utilising diver based jet lancing and dredging operations, most likely supported from a small anchored or spudded barge.

5.6.2.1 Transition Bay

340. Up to two transition bays would be required at an appropriate distance (approximately 180m) from the top of the cliff to contain the offshore to onshore cable joints. Each transition bay would comprise a buried concrete-lined structure. The purpose of the transition bay at the landfall would be to contain the joint between the heavily armoured offshore cables and the onshore cables.
341. The transition bays would most likely be installed prior to offshore cable landing operations, but within the East Anglia THREE construction phase, to minimise delay and reduce the length of time for offshore cable pulling operations in the inter-tidal zone.
342. The installation of the transition bays would involve:
- Securing the area around the transition bay with fencing to prevent access by members of the public during construction activity.
 - Removal of the topsoil.
 - Mechanical excavation of the transition bay chamber (excavation would be slightly larger than the jointing bay dimensions). Excavated material may either be used as backfill or removed from the site and suitably disposed of.
 - Construction of a concrete chamber. This would involve the installation of shuttered walls, reinforcement and poured concrete (which would be transported to the site). Shuttering would be removed once the concrete is suitably cured).
 - Addition of pre-cast slab to form the roof structure
 - Temporary backfill (sand or similar) of the transition bay chamber until the cables are installed.
343. Each transition bay could be up to 15m long by 10m wide by 3m deep.
344. Access to the cables for maintenance would be via one of two options; either a manhole or other suitable access cover, or alternatively via kiosks. Kiosks would comprise a box measuring 1m x 0.75m by 1m high. There would be one kiosk per

joint per cable therefore a maximum of four kiosks at the transition bays. These would be installed once the transition bays had been constructed.

5.6.2.2 Construction Traffic and Plant

345. Access for the onshore elements at the landfall would be via the public highway at Ferry Road. Details of vehicle movements for construction at the landfall are provided in Chapter 27 Traffic and Transport.

346. For the transition bay installation the following plant would be required:

- Telehandler (a machine used for construction which is similar in appearance and function to a forklift but also functions as a crane);
- 30 tonne excavator;
- Loader;
- Tractor; and
- Trailer.

347. For the short duct method the further following plant would also be required:

- 30 tonne excavator; and
- 9 tonne dumper.

348. It should also be noted that a shallow water cable laying vessel (vessel movements included in *Table 5.31*) would also be required for laying cables in shallow water. Cable would be passed from this vessel into the ducts to be pulled onshore from the transition bay compound(s).

5.6.2.3 Lighting

349. It has been assumed that the works at the landfall would not require 24 hour lighting.

5.6.2.4 Workforce

350. The total number of construction employees required has been predicted at approximately nine at the landfall. This figure is based on manpower figures from previous projects.

5.6.2.5 Programme

351. It has been estimated that construction at the landfall would be up to ten weeks.

5.6.2.6 Reinstatement

352. The construction compound would be reinstated to its former condition. If necessary, the subsoil would be ripped prior to topsoil placement if compaction has occurred. Topsoil would be spread in such a way as to ensure that it does not become compacted.

5.6.3 Landfall Operation and Maintenance

353. Routine maintenance is anticipated to consist of one annual visit to each transition bay to carry out integrity testing, which would be accessed by digging down to man-hole covers, and most likely, non-intrusive checking of the cable with, for instance, ground penetrating radar.

354. Appropriate off-road vehicles would be used to access each transition bay. Kiosks could be used as an alternative maintenance access point to transition bay.

355. Non-scheduled maintenance to address faults as and when these may arise would also be necessary, and this maintenance could be required in between transition bay or kiosk locations. Appropriate off-road vehicles would be used for access.

5.6.4 Landfall Decommissioning

356. With regards to offshore cabling, within the near shore and intertidal zone it is anticipated that cables would be removed due to the increased risk of being exposed over time. However, if agreed with the regulator at the time of decommissioning it may be cause less impact to leave the cables in situ. Excavation or jetting may be necessary to remove the cables.

357. The transition bays would also be left in situ.

5.6.5 Onshore Cable Route Site Description

358. The onshore cable route is approximately 37km long and is shown in *Figure 5.2*. The route was determined during the development of the onshore electricity transmission works for East Anglia ONE. From the outset (during the East Anglia ONE planning process) careful routeing of the onshore electrical transmission works has set out to avoid key areas of sensitivity wherever possible, as listed below:

- Burying of the cable(s) throughout its length to minimise visual impact;
- Careful routeing of the cable route to minimise distance within the Suffolk Coast and Heaths Areas of Outstanding Natural Beauty (AONB);
- Careful routeing and site selection to avoid key sensitive land uses such as development land, urban land and residential land;

- Micro-routeing of the onshore cable route as close to field boundaries as possible, so as not to create 'orphan' fields;
 - Careful routeing to minimise length of cabling within floodplains;
 - Careful routeing to avoid large areas of woodland;
 - High level routeing to avoid Sutton Hoo and other known designated archaeological sites; and
 - East Anglia ONE will install ducts under the following sensitive features (rather than trench):
 - Bawdsey cliffs;
 - Deben Estuary (Special Protection Area (SPA), Ramsar and SSSI);
 - Kirton Creek;
 - Martlesham Creek and railway crossing at Kingston;
 - A12 crossing north of Martlesham;
 - A14 crossing at Little Blakenham;
 - River Gipping and railway line crossing;
 - The B1113 Bramford road;
 - Millers Wood;
 - Lodge Road; and
 - Sandy Lane.
359. A full description of the onshore cable route is provided below.
360. Commencing at a landfall location the onshore cable route runs in a north-westerly direction, crossing a local road and ditch before travelling approximately 2km through agricultural land (comprising small irregular shaped fields) parallel and set back from the River Deben.
361. Approximately 3.5km from the landfall, the onshore cable route turns in a south-westerly direction and crosses the River Deben perpendicularly, through pre-installed ducts. After crossing the river, the route runs in a westerly direction for approximately 1.25km, across more agricultural land. Directly north of the

- settlement of Falkenham the route bears north and travels in a north-westerly direction for approximately 1.25km.
362. The onshore cable route continues in a northerly direction northeast of the settlement of Kirton, for approximately 6.23km, travelling parallel to the River Deben. It passes east of the settlement of Newbourne and west of Waldringfield. This section passes across agricultural land, over Ipswich Road and then bears east around the northern boundary on Waldringfield to avoid the Waldringfield Golf Course.
363. The route then continues in a northerly direction crossing Waldringfield Road and passing Martlesham to the west, before crossing Martlesham Creek and the railway line south of Woodbridge. Immediately after crossing the railway line the onshore cable route turns west.
364. Further west the onshore cable route crosses the A12 south-west of the roundabout. Approximately 1.5km after crossing the A12 the route passes between the settlements of Great Bealings and Little Bealings.
365. After passing between Great Bealings and Little Bealings the route continues in a westerly direction, travelling north of Ipswich and the railway, passed the settlement of Playford. Along this section the route passes through agricultural land with dispersed rural settlements. The route, while continuing in a general westerly direction, arches north around the village of Tuddenham St. Martin.
366. West of Tuddenham St. Martin the onshore cable route turns in a northwesterly direction for approximately 1.25km passing under two overhead lines before turning southwesterly to cross the border, from Suffolk Coastal District into Mid Suffolk District. The route then travels adjacent to the overhead lines for approximately 1.25km. From here the route continues in a westerly direction for 3km and then crosses the A14 south of the settlement of Claydon. Within the next 1.5km, while continuing to travel in westerly direction, the route crosses a road, a watercourse, a railway line and the B1113 and passes north of the Suffolk Water Park.
367. The onshore cable route turns to travel in a south-westerly direction for approximately 3km before reaching the substation location adjacent to an existing substation near Bramford. During this final section the route travels across agricultural land.

5.6.6 Onshore Cable Construction Methods

368. The following works would be required to construct the onshore elements of the proposed East Anglia THREE project:

- Creation of Construction Consolidation Sites (CCSs). Up to seven sites equating to 3.2ha mostly located on brownfield sites.
- Creation of access points to the cable route. This would mainly be via existing roads and tracks (therefore minimal haul road required except for where joints are placed in remote areas). A maximum of 18.05km of 5.5m width haul road is required. Temporary track matting may be required if ground conditions are poor.
- Creation of jointing bays. Under a Single Phase approach two jointing bays each containing two HVDC cables or six LFAC cables would be created side by side (as illustrated in *Diagram 5.20*) during the same construction period. This would occur at up to 62 locations therefore creating 124 jointing bays along the cable route (within 62 pits). Under a Two Phased approach a single jointing bay containing two or six cables would be constructed at each location during each phase also resulting in 124 jointing bays (within 124 pits).
- Transport to site, cable pulling and jointing at up to 124 jointing bays.
- Reinstatement of land.

5.6.6.1 Creation of Construction Consolidation sites

369. The locations of CCS's are displayed in *Figure 5.2*. The process for installing the CCS would be as follows:

370. CCS Construction Methodology:

- Mark out the extent of CCS with use of Global Positioning Systems (GPS) (Real Time Kinematic (RTK) equipment);
- Set out and install drainage features as required;
- Erect security fencing around the perimeter of CCS;
- Remove and locally store topsoil material over CCS area;
- Excavate to formation level and store any excess material;
- Place imported stone in accordance with the design CCS base structure; and

- Following completion of construction works the CCS would be removed and topsoil reinstated.

371. The predicted construction periods for each CCS are presented in *Table 5.40* below.

Table 5.40 Construction Consolidation Sites

CCS location (Number)	CCS Type	Construction duration weeks
Park Lane	Secondary CCS	8
North of Newbourne	Secondary CCS	9
Top Street	Primary PCCS	17
Playford	Secondary CCS	8
B1077 Witnesham Road	Secondary CCS	11
Paper Mill Lane	Primary PCCS	17
Bramford	Secondary CCS	3

372. The dimensions of a PCCS would be approximately 90m long by 40m wide covering a surface area of 3,600m² and a SCCS would be 60m long by 20m wide covering an area of 1,200m².

5.6.6.2 Creation of Access Points to Cable Route

373. The creation of access points would generally involve one or all of the following three activities:

- The modification of existing road network;
- Upgrading of existing farm tracks; and
- Installation of haul road.

5.6.6.2.1 Modification of Existing Road Network

374. In order to facilitate construction traffic and / or construction-related deliveries, temporary modifications may be required at locations on the existing public road network. The purpose of the temporary modifications would be to allow larger vehicles than normal to access certain parts of the public road network. It is anticipated that the works would be concentrated at junctions.

375. It is anticipated that the temporary modifications would be completed prior to construction starting within relevant sections of the cable corridor route.

376. The temporary modifications could potentially comprise:
- Localised widening / creation of overrun areas;
 - Temporary moving or socketing of street signs; and
 - Temporary moving of street furniture etc.
377. Any temporary modifications to roads would be undertaken in accordance with the requirements of the local Highways Authority.
378. Where possible the accesses make use of existing tracks to link between the public road network and the cable route. There may be a requirement to upgrade some existing tracks to make them suitable for the transportation of large vehicles. Where this is required it would be completed using a method which is both suitable for EATL and is agreed by the Landowner.

5.6.6.2.2 *Installation of Haul Road*

379. During the construction of East Anglia ONE a haul road will be built along the entire length of the onshore cable route. In the DCO for East Anglia ONE it is stated that following construction the haul road must be removed and the disturbed land be returned to pre-construction state. Therefore, within this ES it is necessary to consider the installation of haul road as a worst case scenario.
380. During the construction of the proposed East Anglia THREE project it would only be necessary to access the jointing bay locations to construct the bays themselves and pull through the cables. Therefore, accesses for the proposed East Anglia THREE project are not the same as those required for East Anglia ONE. This has also provided EATL with the opportunity to reduce the amount of haul road required for the construction process. However, up to 18.05km of haul road could be installed during construction of the proposed East Anglia THREE project.
381. EATL would look at any opportunities to leave haul road in place between projects or phases to further minimise impacts. It has been (and will continue to be) EATL's aim to reduce the requirement for haul road for two reasons. Firstly, the bulk of the materials delivered to and taken off site would be for the creation of haul road itself. Any reduction in haul road requirement would reduce overall material volumes and therefore vehicle movements. Secondly, if existing tracks could be upgraded to access remote jointing bay locations this would reduce disruption to arable fields (and hedgerows and other sensitive habitats) and provide an upgrade to the local infrastructure.

382. As noted above this ES considers the current consented position for East Anglia ONE in which haul road and CCS are reinstated upon completion of construction of East Anglia ONE. In the case that haul road and CCS are able to be retained between projects there is potential that some of the impacts assessed within the ES would be different. The key differences would be with regard to terrestrial ecology and landscape and visual impacts, therefore, *Appendices 23.7* and *29.5* consider this.
383. Use of existing tracks has been the subject of consultation with landowners (see The East Anglia THREE Consultation Report which forms part of this application), the general public and local planning authorities. The final accesses are displayed in *Figure 5.2*.
384. By using these access points it has been possible to limit the amount of haul that would be required to install the East Anglia THREE onshore export cables.
385. The eventual length of temporary haul road required would be dependent on the detailed design and the final location of the jointing bays. However, using the indicative jointing bay locations presented in *Figure 5.2* the total length of temporary haul road would be up to 18.05km in length and 5.5m in width.
386. Temporary haul road construction requires the placement of suitable graded imported material onto a suitable subgrade, potentially with a reinforcing geogrid and / or a geotextile separator; *Diagram 5.18* shows a typical haul road design and details of the design parameter.

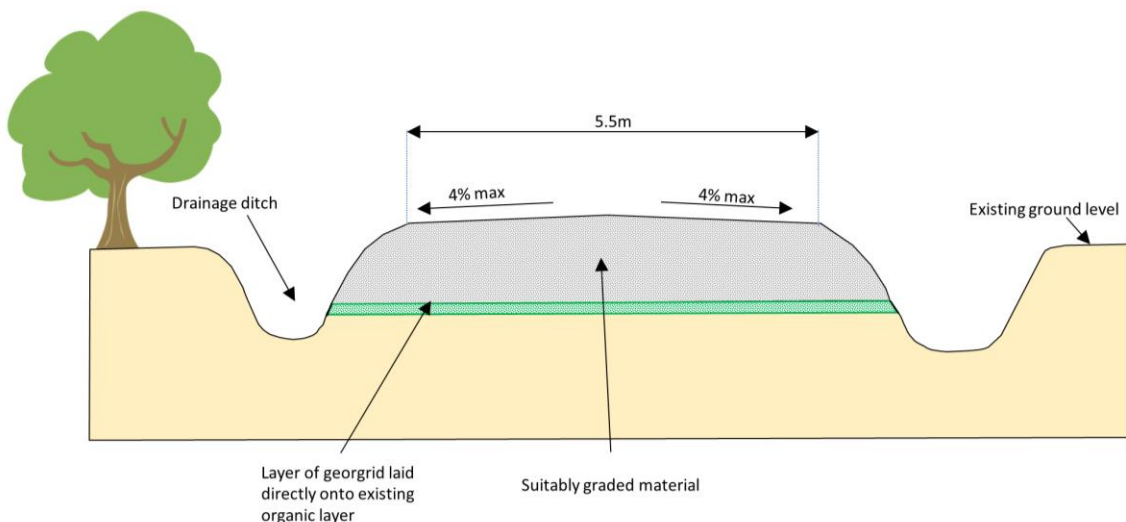


Diagram 5.18 Cross Section of Installed Haul Road

387. The construction methodologies associated with temporary roads are as follows:

- Set out the site tracks with the use of GPS (Real Time Kinematic (RTK)) equipment;
- Erect and maintain suitable signage and goal posts where the temporary road runs under overhead lines;
- Set out and install drainage features the length of track to be constructed (approximately 100m);
- Remove and locally store topsoil material over the working width;
- Excavate to formation level and store any excess material;
- Under-track drainage would be installed where necessary and in accordance with the drainage requirements;
- Place imported stone in accordance with the design to form the track structure;
- Where site tracks cross existing watercourses it would be necessary to install temporary watercourse crossings to maintain flows within the existing watercourse; and
- In the vicinity of private water supplies it may be necessary to monitor the water quality and consider further protection measures (e.g. bunding).

5.6.6.3 Creation of Jointing Bays

388. The methodology that would be used for creating a jointing bay is as follows:

- Set out the joint bay locations with the use of GPS (RTK) equipment and mark up the area according to cable jointing requirements to be excavated;
- Perimeter security fence erected;
- Remove and store the topsoil layer within of the joint bay construction area;
- Installation of hardstanding areas as shown in *Diagram 5.20*;
- Excavate subsoil materials up to 2.5m depth with adequate slope batter or shoring on all sides of the excavation to prevent the soil from collapse. Remove and store the subsoil separately to the topsoil;
- Uncover the duct and cut a suitable length to allow construction of the slab;

- Installation of a concrete blinding layer beneath the slab location;
- Installation of reinforced concrete slab at for the foundation of each concrete box;
- Excavate additional sump pit at a lower level to facilitate drainage and dewatering;
- Install and joint cables;
- Install concrete blocks which would be constructed to a height of 1.3m and doweled into the excavate ground level;
- Install pre-cast slabs to form the roof;
- Surround concrete boxes with sand and then selected backfill with subsoil;
- Lay tiles and/or warning tape on top of the surround layer;
- Restoration any land drains affected by the operation;
- Off-site disposal of any excess subsoil; and
- Reinstatement of surface with stored topsoil and re-planting.

389. *Diagram 5.19 and 5.20* below illustrates the indicative layout of a jointing bay compound.

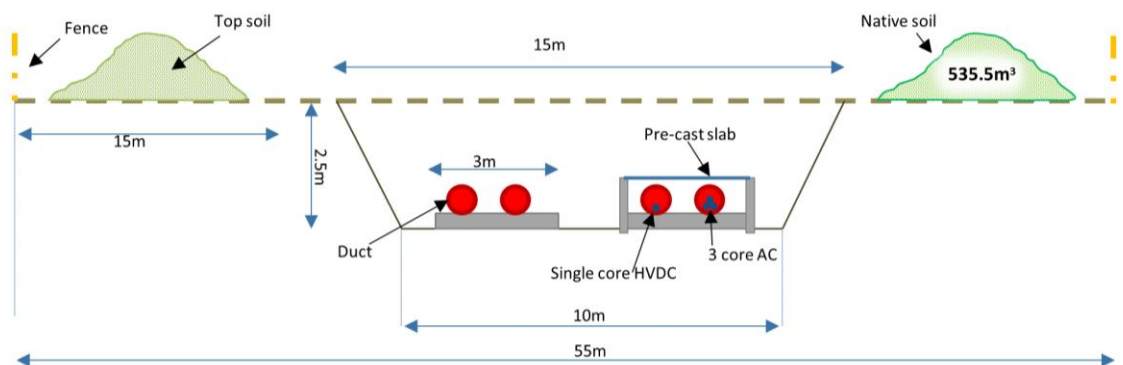


Diagram 5.19 Side View of a Jointing Bays. It should be noted that although a 3 core AC cable and a single core HVDC cable are both shown this is for illustrative purposes; only one type of cable (i.e. AC or DC cables) would be installed

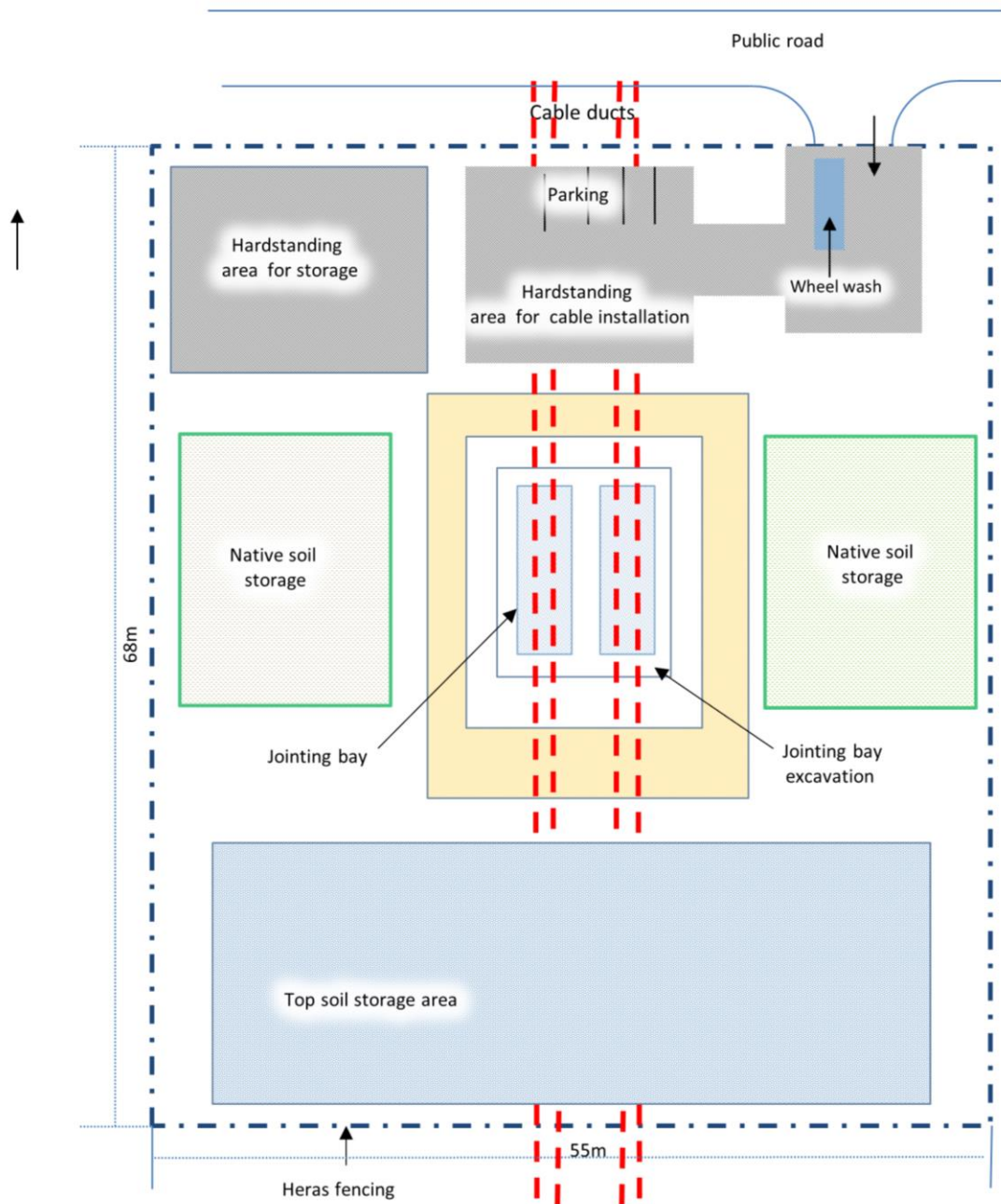


Diagram 5.20 Plan of jointing bay construction compound showing two jointing bays being constructed simultaneously, which would occur under a single phased construction and not during a Two Phased construction.

390. A jointing bay construction compound would contain hardstanding areas of up to 775m² within the jointing bay compound which would measure 3,740m² (see *Diagram 5.20*).
391. The quantity of excavated material is calculated to be 1,420m³ of topsoil and 536m³ of subsoil. Half of this material is likely to be reused as backfill materials with the excess disposed of offsite. The jointing bays would also contain bedding sand.

392. Under a Two Phased programme a single jointing bay would be constructed in each phase of the build at each of the jointing bay locations. Although the dimensions of the actual jointing bay would not differ between a Single and Two Phased approach, the dimensions of the pit in which they sit and therefore the excavated materials would differ. *Table 5.41* illustrates these differences.

Table 5.41 Jointing Bay Parameters

Parameter	Single phased	Phase 1	Phase 2	Total Two Phased ¹
Number of jointing bays constructed	124	62	62	124
Number of jointing bay compounds	62	62	62	124
Jointing bay compound dimensions (area)	68m × 55m (3,740m ²)	68m × 50m (3,400m ²)	68m × 50m (3,400m ²)	
Hard standing areas within compound	775m ²	775m ²	775m ²	1550 m ²
Jointing bays constructed at each jointing bay location	2	1	1	2
Dimensions of pit in which jointing bay(s) would be constructed	17m long × 15m wide × 2.5m deep	17m long × 10m wide × 2.5m deep	17m long × 10m wide × 2.5m deep	
Excavated Top soil volume (pit in which jointing bay(s) would be constructed)	1,420m ³	1,360m ³	1,360m ³	2,720 m ³
Excavated Native soil volume(pit in which jointing bay(s) would be constructed)	535.5m ³	378.6m ³	378.6m ³	757.2 m ³
Total soil disposed of off-site (all 62 pits in which jointing bay(s) and 4 transition bays would be constructed)	4,404m ³	2,202m ³	2,202m ³	4,404 m ³

¹ Figures are provided for the total values expected over the two phases of a Two Phased construction programme; these would be constructed in temporal isolation and Phase 1 would have reinstated the land by the time Phase 2 construction could begin.

393. It should be noted once Phase 1 works are completed the pit would be back filled and the land made good, so during Phase 2 all works would be repeated.

394. It is anticipated that the equipment required to construct a jointing bay would include:
- Generator with lighting;
 - De-watering pump;
 - Excavator;
 - Temporary Heras security fencing around the site to prevent unauthorised access;
 - Loader;
 - Tractor; and
 - Trailer.
395. The predicted duration of the works is three to four weeks per jointing bay with simultaneous operations along the route.
396. It is expected that jointing operations would take approximately ten days spread over a four to six working week period, with approximately five workers for each jointing bay.

5.6.6.4 Transport to Site, Cable Pulling and Jointing

397. This section describes how the electrical cables would be installed.

5.6.6.4.1 Cable Drum Transport

398. The electrical transmission cables would be delivered either direct to the jointing bay construction compounds or to a CCS where they would transferred onto a tractor and trailer unit. The cables would be on cable drums with an approximate weight of 30 tonnes each.
399. The cable lengths would be dependent on jointing bay spacing but are likely to be between 500m and 1,000m in length. The maximum anticipated dimensions of the cable drum are 2.8m wide and 5.0m in diameter.
400. Photos of typical drum transport low loaders and cable trailers are provided in *Plate 5.4*.
401. No abnormal loads to the sites are considered to be necessary in the cable installation process, and therefore no temporary works are required along the public highway for abnormal loads.



Plate 5.4: Typical Tractor and Trailer Set-up for Cable Drum Transportation⁵

402. Once the cables have been delivered to the jointing bay construction compounds they would be temporarily stored in a hardstanding area adjacent to the jointing bay prior to installation into pre-installed cable ducts.

5.6.6.4.2 Installation of Cables Into Ducts

403. The cable drum would be delivered to one of the jointing bays and a cable pulling system would be installed into the bay. This may comprise a steel bond and winching system with free spinning cable rollers placed along the bottom of the bay.
404. Once on site, the cable drum would be raised off the ground on hydraulic jacks to enable it to spin freely when pulled. The cable would then be pulled from the drum into the trench using the pre-installed rollers, with sufficient cable pulled through to the far jointing bay to allow for jointing onto the next section.
405. The winch would be used to pull in cable using a pulling rope via an appropriate swivel eye. The winch would be fitted with a suitable dynamometer which would ensure the maximum pulling tension is not exceeded at any time. To reduce the tension on the cable a biodegradable water based lubricant would be used during the pulling process.
406. The process would be repeated for the second cable to be installed in the duct.
407. *Plate 5.5* illustrates a typical cable pull. The example shows that the sides of the excavation have been softened from vertical sides back to a safe angle to reduce the

Source: Photo courtesy of Prysmian Group.

This photo is representative of works that would be undertaken for the proposed East Anglia THREE project.

risk of collapse. This approach is likely to be used for the majority of the East Anglia THREE excavations and is what the calculations for soil removal presented in *Table 5.42* are based on. The cable is shown being guided into the previously installed duct with the aid of rollers weighted down with sand bags. Also shown is the concrete slab which is required for the base of the jointing bay to provide a level working area prior to jointing.



Plate 5.5: Jointing bay Layout and Cable Pulling⁶

408. It is likely access provision would be made at some of the joint locations for routine integrity testing. Access would take the form of a small kiosk as described previously.

5.6.6.5 Construction Traffic and Plant

409. Access to the onshore cable route would be made from the public highway and then onto existing tracks, up-graded tracks or directly onto the haul road (where present). The accesses have been defined based on a number of factors including but not limited to:

- Residential amenity (i.e. minimising disruption);
- Road safety;
- Ecology sensitivity; and

Source: Photo courtesy of Prysmian Group.

This photo is representative of works that would be undertaken for the proposed East Anglia THREE project.

- Engineering suitability.
410. Accesses predominantly seek to make use of existing tracks (which may be upgraded) and have been identified at the following locations from east to west (see *Figure 5.2*) and are shown in *Table 5.42*. Note that these are the final accesses selected, for details of the selection process see Chapter 4 Site Selection and Alternatives.

Table 5.42 Onshore Access Locations

Access ID	Description
A	Access to the East from Ferry road at Bawdsey follows haul road to transition bay location
B	From Ferry Road Bawdsey this access follows existing track north-east crossing the Queens Fleet before heading west across Alderton Marshes, a short section of new haul road would then be placed to access the cable route
C	Access follows existing track (Duke's Lane) connecting with onshore cable route at two points also via existing tracks
D	Access from Lower Falkenham Road north along existing track Access then splits west to join the onshore cable route and then east to cross the cable route on an existing track before heading south to re-join the cable route
E	Access the cable route directly from the south side of Park Lane
F	Access from Park Lane heading south on existing tacks past Corporation Farm cottages.
G	Access splits to access the cable route to the east of Lodge farm along existing track and also to the north past Sluice farm and then to the thicket, where new haul road would be laid on a short section to access the cable route to the east.
H	Access to the east from Woodbridge Road along existing track to onshore cable route
I	Access to the east from Newbourne Road along existing track to onshore cable route
K	Access to the north from Ipswich Road
L	Access to the east from Woodbridge road.
M	Access to the east along existing track from Woodbridge road to Rudd's barn
N	Access to the east from Waldringfield Road opposite Howe's Farm Cottages along existing track to onshore cable route.
O	Access south from Waldringfield Road along new haul road
P	Access to the north from Waldringfield Road following existing track, turning 90 degrees to connect to the onshore cable route from the west
Q	Access to the south east from sandy lane along new haul road
R	Access to the west from Sandy lane along new haul road
S	Access to the north from Top Street along small section of existing track
T	Access to the west from Top Street along existing tack (Brock Lane)
U	Access south along existing track from the minor road which runs past Seckford hall
V	Access to the south from Lodge road along existing track
W	Access to the north-east from Holly Lane

Access ID	Description
X	Access to the south from Playford corner
Y	Access to the south from Grundisburgh Road (east of Culpho Hall) along existing track to onshore cable route
Z	Access to the south from Grundisburgh Road (east of Hillside Cottages) along existing track to onshore cable route
AA	Access to the north from Grundisburgh Road (west of Hillside Cottages) along existing track, past Tuddenham Hall farm buildings, turning 90 degrees to connect to the onshore cable route from the east along new haul road
AB	Access to the east from Clopton Road
AC	Access from Winesham Road north of Pine lodge
AD	Access to the east of Henley Road.
AE	Access to the east from Old Ipswich Road.
AF	Access to CCS and cable route east from Paper Mill Lane
AG	Access to cable route west from Paper Mill Lane
AH	Access to the east from Bramford Road along new haul road
AI	Access to the cable route directly west of Bramford Road
AJ	Access to the cable route south from Somersham Road along existing track past Copenhagen Cottage.
AK	Access to the cable route west from Somersham road via Plamer House
AL	Access to the cable route to the north from Bullen Lane

411. Details of vehicle movements for construction along the onshore cable route are provided in Chapter 27 Traffic and Transport.
412. Plant required for the different activities along the onshore cable route are shown in *Table 5.43*.

Table 5.43 Indicative plant requirements for construction activities on the onshore cable route

Activity	Plant required	
CCSs	Loader D8 Dozer Grader Road Roller 9T Dumper	10T Excavator Tractor Trailer Bowser Sweeper
Jointing bays	Telehandler 30T Excavator Loader	Tractor Trailer
Haul Road	Loader D8 Dozer Grader Road Roller 9T Dumper	10T Excavator Tractor Trailer Bowser Sweeper

5.6.6.6 Lighting

413. Temporary lighting may be required within construction areas dependent on the season and activities being undertaken. Twenty-four hour lighting is also likely to be required at the CCSs.

5.6.6.7 Workforce

414. The construction programme assumes that the onshore cable route would be subdivided into 11 sections of up to 4km in length each, separated by the presence of CCS. The 11 sections are presented in *Figure 5.5* and a breakdown of the total work force required for construction of the onshore cable elements of the proposed East Anglia THREE project under either a Single Phase or a Two Phased approach is presented in Chapter 27 Traffic and Transport.

415. Working hours along the cable route would be restricted to the hours between 7:00 and 19:00. Therefore workers should arrive onsite prior to peak traffic hours of (8am – 9am) and leave after peak hours (5pm -6pm).

416. The numbers of personnel on any one section at any one time would vary dependent upon the works being undertaken. Under a Single Phase build the total number of construction employees required at peak periods of activity in any one section of the onshore cable installation has been predicted at up to 50. The overall maximum number of personnel required along the entire onshore cable route in any one month is calculated as 160 with an average of 94 per month.

417. Under a Two Phased construction the total number of construction employees at peak periods of activity installing the onshore cable in any one section has been predicted at up to 30. The overall maximum number of personnel required along the entire cable route in any one month is calculated as 110 in Phase 1 and 119 in Phase 2 with an average of 66 per month in Phase 1 and 64 per month in Phase 2.

5.6.7 Onshore Cable Route Infrastructure

418. This section describes the infrastructure that would be installed during the construction of proposed East Anglia THREE project under either the HVDC or the LFAC electrical solution.

5.6.7.1 Construction Consolidation Sites (CCS)

419. EATL would require seven temporary construction compounds to aid in the construction of the proposed East Anglia THREE project. These are termed CCS. These have been designated as 'Primary' (PCCS) and 'Secondary' (SCCS). EATL would install up to two PCCS and five SCCS, which would all be temporary and would be removed once construction is complete.

420. A CCS would be used for a number of functions including access to the cable corridor, to allow storage of bulk materials and construction plant and to accommodate site offices. Bulk materials, such as crushed stone aggregate, can be delivered to a CCS where the load is stored and then delivered to the work front/point of use as and when required in smaller vehicles more appropriate for the road conditions.

421. It is anticipated that each CCS would include the following temporary facilities:

- Offices for the management of construction;
- Messing facilities;
- Changing, washroom and drying room facilities;
- Car parking;
- Vehicle marshalling facilities (e.g. wheelwash, weighbridge); and
- Storage for tools, plant, equipment and materials.

422. Hardstandings are required within the CCSs for access by vehicles and storage of heavier plant, equipment and materials.

423. It is the intention that these PCCSs would:

- Form the main point(s) of access onto the linear construction site;
- Provide the main areas for the storage of materials and equipment;
- House site administration and welfare facilities for the labour resources; and
- Form an interchange hub for deliveries of material, equipment and resources.

424. In addition to the two primary sites, a further five SCCSs are proposed along the cable route. Their purpose would be to act as hubs for the delivery of materials, equipment and resources along the route and to enable access to the cable route for construction. The secondary CCS would be of sufficient size to accommodate limited storage of materials, equipment and labour welfare facilities.

5.6.7.2 Onshore Export Cables

425. A summary of the onshore electrical cables options is provided in *Table 5.44*.

Table 5.44 Indicative Onshore Cable Lengths

Electrical infrastructure	Minimum Case		Maximum case	
	Number	Total Length	Number	Total Length
HVDC cable	2 x 36.2km	72.4km	4 x 36.2km	144.8km
FO cable	1 x 36.2km	36.2km	2 x 36.2km	72.4km
AC cables	2 x 36.2km	72.4km	12 (single core) x 36.2km	434.40 km

426. The East Anglia THREE cables would follow the East Anglia ONE onshore cable route from the landfall to the substation at Bramford. Cables would be installed to a maximum of 2.5m below ground level where other methods like HDD or similar have not been implemented by East Anglia ONE. Under either the HVDC or LFAC electrical solutions up to four cables (12 single core cables in the LFAC solution) would be installed into four sets of ducts.

5.6.7.2.1 Land Cables

427. Under the HDVC electrical solution cross-linked polyethylene (XLPE) or Mass Impregnated HVDC cables of typically ± 300 -600 kV would transport the electrical power from the offshore platform via the transition bays to the onshore substations. An image of an XLPE HVDC land cable is shown in *Diagram 5.21* with details provided in *Table 5.45*.

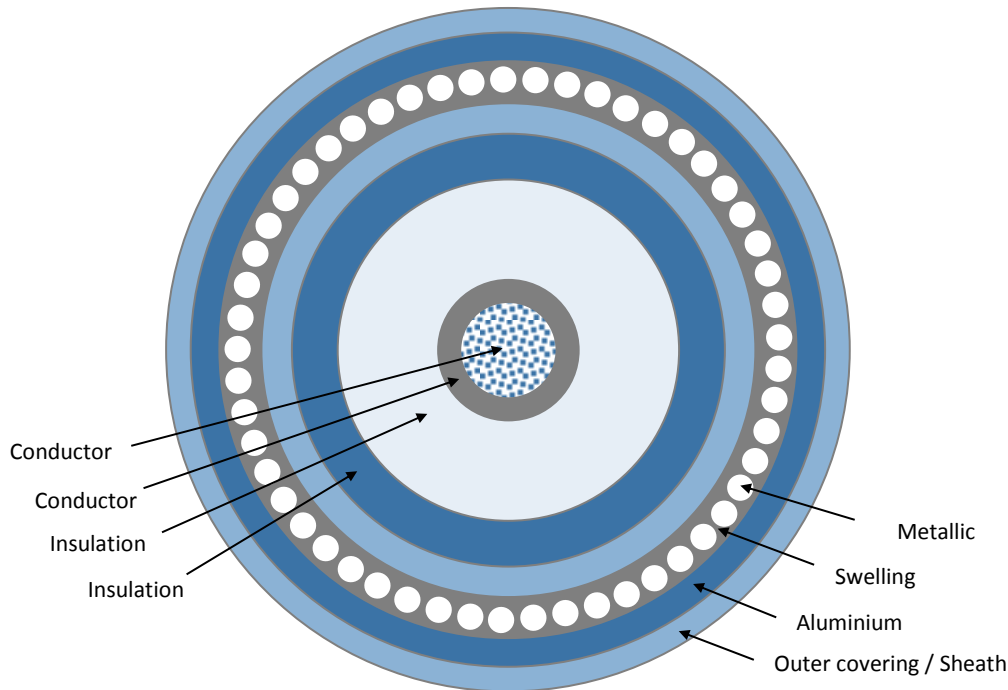


Diagram 5.21 General Cutaway of a XLPE HVDC Land cable⁷

Table 5.45 Typical HVDC XLPE ± 320 kV Aluminium Land Cable Details

Details	1,000 mm ²	1,200 mm ²	1,600 mm ²	2,000 mm ²	2,400 mm ²
Overall diameter (mm)	101	105	112	118	123
Weight (kg/m)	9	10	12	14	16

428. Heat loss per metre for a typical 2,400mm² DC land cable at full load is 90W/m

5.6.7.3 Jointing Bays and Kiosks

429. As the onshore cabling is typically supplied on drums of up to 1,000m in length, jointing bays would be required along the cable route to join each section of the cable together. Each jointing bay would comprise a concrete box 10m long by 3m wide by 1.3m high buried so that the base is 2.5m below ground level.

430. The precise location of the jointing bays would be determined during post-consent detailed design; however indicative locations for jointing bays are displayed in *Figure 5.2*. These have been located, wherever practical to do so, at the edge of field boundaries or roads to allow future access.

⁷ Source: ABB

“[http://www05.abb.com/global/scot/scot221.nsf/veritydisplay/fb4d15b402dc68c7c12577210040f853/\\$file/pow0038%20r6%20lr.pdf](http://www05.abb.com/global/scot/scot221.nsf/veritydisplay/fb4d15b402dc68c7c12577210040f853/$file/pow0038%20r6%20lr.pdf)”

431. In the vicinity of the jointing bay each joint would have a kiosk to provide access for testing and maintenance. These could be required at each jointing bay location (i.e. at the 62 locations presented in *Figure 5.2*) therefore there would be a maximum of 248 kiosks along the onshore cable route. Each kiosk would be 1m x 0.75m x 1m high.

5.6.8 Onshore Cable Route Construction Programmes

432. The construction programme for a Single Phase build and a Two Phased approach would differ. An indicative programme for a HVDC Single Phased approach is displayed in *Table 5.46* and an inactive programme for a HVDC Two Phased approach is displayed in *Table 5.47*. Both *Table 5.46* and *5.47* show when work would be undertaken in the 11 different sections of the cable route described above and displayed in *Figure 5.5*. If the LFAC solution is taken forward, the construction programmes would be almost identical.

433. Under either a Single Phase or Two Phased approach CCSs would facilitate concurrent working within the 11 sections along the onshore cable route (*Figure 5.5*). Each section of work would be supplied and supported by a CCS. The extent of each of the eleven sections has been defined by the constraints afforded by existing natural or man-made obstructions.

434. Within each of the sections, work would be undertaken in a practical, logical and sequential manner. Wherever practical, the works would commence from one CCS and terminate at the next.

435. The sequence of construction activity within each section along the onshore cable route would be:

- Establish accesses;
- Establish and prepare temporary haul road where required;
- Establish temporary jointing bay compounds;
- Excavate pits to locate ducts;
- Construct jointing bay;
- Pull cables through ducts;
- Topsoil replacement and seeding;
- Remove temporary compounds; and

- Reinstatement permanent fences and hedges.

5.6.8.1 Single Phase

436. Given the above assumptions regarding 11 separate construction sections, all working concurrently, each up to 4km long, the programmed estimate for the duration of works is 29 weeks. This estimate includes the excavation, jointing bay construction, cable pulling and backfilling of the pits along the onshore cable route and takes into account the commencement and reinstatement works assuming the phases are constructed concurrently. *Table 5.46* shows the indicative schedule for sections of the onshore cable route; these have been used to inform Chapter 27 Traffic and Transport (further detail regarding implication for traffic movements can be found in that chapter and its appendices).

437. Works would be staggered along the onshore cable route, for example (on indicative scheduling) works in section 1 (including the landfall) would be concluded by week 22, and works in section 11 (up to the substations) would only commence in week 19 (see *Table 5.46*).

5.6.8.2 Two Phased

438. Under a Two Phased approach it is estimated that Phase 1 would last for 29 weeks. There would be less material to transport in and out of the construction sites than under the Single Phase approach, and therefore the work in each section of the route would be less intensive, however, due to the order in which consecutive tasks must be completed the time from start to finish of the construction period is the same.

439. Following the completion and reinstatement of some of the elements of Phase 1 there would be a period where no works were carried out. Phase 2 work would commence a maximum of 18 months after Phase 1 commences, therefore the maximum gap between phases is 5 months. The total period over which onshore works would take place is therefore 31 months (see *Table 5.47*).

Table 5.46 Indicative Scheduling for Onshore Cable Route Under a Single Phase Approach (this would be subject to change dependent upon the construction contractor chosen and any changes in technology when East Anglia THREE is constructed) See *Figure 5.5* for location of sections

Section	Week																																																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44														
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Note: the sections run east to west from the landfall to up to the substations location. The time for section 1 includes 10 weeks of construction operations at the landfall

5.6.8.3 Reinstatement

440. As stated previously, for the purposes of this ES it has been assumed that there would be complete reinstatement of the land back to the preconstruction environment following the construction of East Anglia ONE and therefore no haul road would be left in place for the proposed East Anglia THREE project.
441. Under the Two Phased approach the haul road put in place for Phase 1 would be removed and reinstated for Phase 2.
442. Following either construction approach the onshore cable route, CCSs and all temporary work areas and access roads would be reinstated with the stored topsoil and subsoil following trenching. If necessary, the subsoil would be 'ripped' prior to placement if compaction had occurred. Topsoil would be spread in such a way as to ensure that it did not become compacted.
443. Following reinstatement of soil and subsoil, final restoration would commence where possible. Pasture and arable land would be reseeded, fences would be reinstated and suitable hedgerow species replanted. Hedges and any replacement planting would be carried out during the first appropriate planting season following site restoration. In ecologically sensitive areas special restoration may be necessary.
444. The location of cables would be marked with marker posts at field boundaries. These would be visible from the ground and all marker posts would be located to minimise interference with agricultural activities. The final stage in the cable construction process once reinstatement was established would be the removal of the temporary fencing. *Plates 5.6 and 5.7* show images of reinstated cable routes.



Plate 5.6 A Buried Cable One to Two Years After Construction⁸



Plate 5.7 A buried cable road crossing One to Two years After Construction.⁹

Source: Photo courtesy of Royal HaskoningDHV.

This photo is representative of works that would be undertaken for the proposed East Anglia THREE project.

5.6.9 Onshore Cable Route Operation and Maintenance

445. The operation and maintenance procedures would be largely identical regardless of whether the HVDC or LFAC solution was adopted.
446. A permanent easement would be sought by EATL directly over the cables. The easement would seek to restrict activities which would penetrate the ground by more than 0.5m. As such, it is expected that normal agricultural activities would be able to continue.
447. Routine maintenance is anticipated as consisting of one annual visit to jointing bay to carry out routine integrity tests, which would be accessed by kiosks or man-hole covers and possible non-intrusive checking of the cable in between jointing bays with, for instance, ground penetrating radar.
448. Appropriate off-road vehicles would be used to access each jointing bay. Jointing bays would therefore be located adjacent to field boundaries or roads as far as possible.
449. Non-scheduled maintenance to address faults as and when these may arise would also be necessary, and this maintenance could be required in between jointing bays or kiosk locations.

5.6.10 Onshore Cable Route Decommissioning

450. It is anticipated that the onshore cables would be decommissioned (de-energised) and cables left in situ. It has also been assumed that the jointing bays and ducts would be left in situ.

5.6.11 Onshore Substation(s): Site Description

451. Under either of the HVDC and LFAC solutions the maximum case for the proposed East Anglia THREE project is for two adjacent onshore substations within the same compound.
452. The proposed site for the onshore substation(s) is adjacent to the north of the existing National Grid Bramford Substation, and east of the East Anglia ONE converter station (see *Figure 5.2a – i*). Onshore substation refers to either the onshore converter(s) contained within one or more converter halls under the HVDC solution, or the LFAC substation and a compound containing electrical and other associated equipment.
453. The purpose of the substation(s) is to change the electrical current from HVDC to HVAC, to be compatible with the National Grid in the electrical transmission network.

454. From the outset, careful siting of the substations has set out to avoid key areas of sensitivity wherever possible. Embedded mitigation has included:

- Careful siting of the substation(s) to the north of the existing National Grid Bramford Substation to gain maximum benefit from existing screening; and
- Siting the substation(s) in an area of low flood risk (Flood Zone 1).

5.6.12 Onshore Substation(s) Infrastructure

5.6.12.1 Infrastructure

455. The onshore HVDC converter station(s) (if chosen) would be located within a single compound that would have maximum dimension of 150m (width) x 190m (length) with the building up to 25m high. The substation for the LFAC solution (if chosen) would be 160m (width) x 190m (length) with the building up to 25m high.

456. Up to two substations would be built under the Single Phase approach and one substation would be built during each phase under a Two Phased approach.

457. In the HVDC electrical solution, in addition to the main converter halls, the onshore substation compound would contain electrical equipment including power transformers, switchgear, reactive compensation equipment, harmonic filters, cables, lightning protection masts, control buildings, communications masts, backup generators, access, fencing and other associated equipment, structures or buildings. The station would have a compact layout, with the majority of equipment contained in typical agricultural style buildings.

458. The substation(s) would be enclosed by a fence surrounding the external equipment outlined above. Other infrastructure and equipment would be included within the compound such as interconnecting cables, access tracks, hard standing, car parking, water tanks, communications mast, diesel generators and welfare facilities.

459. The proposed substation would be connected to the existing National Grid substation at Bramford.

460. The final routing of cables connecting into the substation is not known at the current time. Therefore, the pre-installed ducts will end just beyond the western boundary of the screening trees and bunding installed by East Anglia ONE to the east of the East Anglia THREE substation. The final stretch of cables will be open trenched from the end of the ducts to the substation. This will be a maximum distance of 300m. Likewise, National Grid will install ducts to connect into the existing Bramford substation but these will end at the boundary of the National Grid

land, therefore EATL will need to open trench up to the end of these ducts, a distance of up to 235m. In both cases the cables would be laid directly into trenches.

461. Space would also be required for the HVAC equipment to link the substation to the existing National Grid equipment.
462. *Table 5.48* outlines key design parameters for the substation. These represent the maximum dimensions. *Diagram 5.22* shows an example of a HVDC onshore converter station. In a Two Phased approach one of the buildings could be built in Phase 1 and the second added during Phase 2.

Table 5.48 Substation Design Parameters

Parameter	Specification
Colour	Olive green facades and grey roof
Substation Hall height (m)	25
Substation Hall dimensions (m)	85 x 116
Substation compound dimensions (ha)	3.04
Maximum height of external electrical equipment (m) ¹⁾	15
Ground levels	Finished floor levels of substation halls approximately 54m Above Ordnance Datum (AOD). Rest of the compound slightly lower.
Quantities of earth mounding	Approximately 50,000m ³
Height of proposed mounds	Approximately 5m above ground level
Heights of tree growth	Approximately 300mm per year following planting
Orientation of buildings	The electrical conversion process and its relationship to the National Grid substation define orientation of the buildings.

¹⁾ Excluding compound perimeter lightning protection and support gantries (of approx. 25m.)



Diagram 5.22 Typical Layout of a 1000MW HVDC Converter Station

5.6.13 Onshore Substation (s) construction methods

5.6.13.1 Site Establishment and Laydown Area

463. During construction of the substation(s), site establishment and laydown areas would be required. The following would be required during the construction works:

- Temporary construction management offices;
- Canteen;

- Washroom facilities;
- Car parking;
- Wheel washing facility; and
- Workshops.

5.6.13.2 Pre-Construction Activities

464. Prior to the commencement of the substation works, a number of pre-construction surveys and studies would be undertaken to inform the design teams when developing the final design including:

- Topographic surveys;
- Ecological pre-construction surveys;
- potentially intrusive archaeological surveys;
- Geotechnical investigations; and
- Drainage study.

5.6.13.3 Temporary Fencing

465. Temporary fences would be erected along the boundaries of the substation site for the duration of the construction period.

5.6.13.4 Grading and Earthworks

466. The enabling works that are typically required to facilitate the construction of a substation facility can vary greatly. The main factors to consider are the overall topography of the site and the previous use of the land in question.

467. The site for the substation for the proposed East Anglia THREE project is greenfield agricultural land.

468. The entire area would be stripped of all organic matter and loose rocks. Any waste material encountered would be removed as required by the environmental and geotechnical investigations. Once the surface had been cleared, the grading operations would begin.

469. Materials would be retained on site for use as engineering fill or landscaping depending on the material properties.

470. If it were to prove impossible or impractical to balance the earthwork quantities, it would be necessary to either export excess soil or import new fill soil. Any soil

exported would be disposed of at a licensed disposal site. Excavations of foundations and trenches would commence following the completion of grading.

5.6.13.5 Surface Water Drainage

471. At the substation, the proposed surface water drainage scheme would be designed to meet the requirements of the National Planning Policy Framework (NPPF) by limiting the post development off site run-off to the existing greenfield rate and providing sufficient on site attenuation for rainfall events up to the 1 in 100 year rainfall event, plus a 30% allowance for climate change over the lifetime of the development.
472. Sustainable Drainage System (SuDS) is a departure from the traditional approach to draining sites. There are some key principles that influence the planning and design process enabling SuDS to mimic natural drainage by:
- Storing runoff and releasing it slowly (attenuation);
 - Allowing water to soak into the ground (infiltration);
 - Slowly transporting (conveying) water on the surface;
 - Filtering out pollutants; and
 - Allowing sediments to settle out by controlling the flow of the water.
473. Run-off from the substation location would be limited, where feasible, through the use of infiltration techniques which can be accommodated within the area of works. Where the proposed run-off rate from the site exceeds the current rate, the additional run-off would be attenuated using SuDS storage techniques. The SuDS principles would be implemented so as to mimic the existing environment at the substation site and would take into account the principles and provisions of the OLEMS which is being submitted as part of this application, considering synergies where possible.

5.6.13.6 Foul Drainage

474. Foul drainage would be collected in either of the following ways:
- Mains connection discharged to local authority sewer system, if available; or
 - Septic tank located within the substation boundary.

475. The preferred method for controlling foul waste would be determined during detailed design and would depend upon the availability and cost of a mains connection and the number of visiting hours' staff would attend site.

5.6.13.7 Construction: Foundations

476. Under either the HVDC or LFAC solution the foundations would either be ground-bearing or piled based on the prevailing ground conditions.

477. The construction of the foundations in either case would take place in the following general sequence:

- Excavation as appropriate;
- Installation of blinding (concrete);
- Construction and installation of timber formwork and supports;
- Installation of steel cages for structural support (rebar);
- Placement of structural concrete around rebar; and
- Curing of concrete and finishing.

478. It should be noted that prior to undertaking detailed ground investigations, it is not yet possible to determine whether piling is required in order to support the foundations and limit settlement to acceptable levels.

5.6.13.8 Construction: Buildings

479. Under either HVDC or HVAC solutions the building substructures would typically be composed of steel and cladding materials. The structural steelwork would be fabricated and prepared off site and delivered to site for erection activities. The steelwork would be erected with the use of cranes.

480. Cladding panels (typically composite) would also be delivered to site ready to erect and be fixed to the steelwork. A variety of means would be used to install the cladding, depending on the particular area being accessed. The control building would include the construction of brick or blockwork partitions and would include a number of follow on trades for plumbing, plastering, and low voltage mechanical and electrical installations.

5.6.13.9 Construction: Installation Works

481. For the installation and commissioning of the HVDC substation a variety of specialist activities would be required. The main aspect of installation within the building

would be the valves themselves. These are typically installed with the use of specifically designed beams that are part of the structural fabric of the building.

482. Another main part of the installation would be the transformers. These items of plant would be delivered sealed and would be particularly bulky, heavy items. Due to their size and weight they would be delivered via specialist means and offloaded with the use of a mobile gantry crane.
483. The majority of the remaining HVDC equipment, HVAC equipment and cooling towers would be erected with the use of small mobile plant and lifting apparatus.
484. As the LFAC solution would require relatively new and novel techniques it is not yet possible to describe in detail the installation works.

5.6.13.10 Construction Traffic and Plant

485. Access to the substation location would be via Bullen Lane. The following is an indicative plant list for construction:

- 30T Excavator;
- Dozer;
- 9T Dumper;
- Backactor Excavator;
- Road Roller;
- Telehandler;
- Mobile Crane;
- Static Crane;
- 3T Dumper;
- Scissor Lift; and
- Concrete Pump.

5.6.13.11 Lighting

486. As a worst case scenario, it has been assumed that some periods of 24 hour construction may be required, for which task related flood lighting may be necessary. Operational lighting requirements at the substation site may entail:

- Security lighting around perimeter fence of compound, to allow CCTV coverage;
- Car park lighting – as per standard car park lighting, possibly motion sensitive; and
- Repair and maintenance – task related flood lighting may be necessary.

487. No additional lighting is proposed along Bullen Road or along the additional access roads within the substation site boundary.

5.6.13.12 Onshore Substation Construction under a Two Phased Approach

488. The activities described above would all be undertaken during both a Single Phase and Two Phased approach. However, under the Two Phased approach a number of activities would be completed during Phase 1 to accommodate and aid construction of Phase 2, these include the following:

- Fenced compound (suitable security fencing surround);
- Valves and reactors buildings containing electrical plant (assumed two buildings);
- Control room building; and

- MV Interface building and spares storage building.

489. Details of vehicle movements for both a Single Phase and Two Phased approach to construction of the onshore substation(s) are provided in Chapter 27 Traffic and Transport.

5.6.13.13 Workforce

490. Under a Single Phase approach up to 75 workers could be on site during months of peak activity and an average number of workers onsite would be 44.

491. Under a Two Phased approach up to 75 workers would be on site during months of peak activity in Phase 1 and an average number of workers onsite would be 44. During Phase 2 the maximum number would be approximately 40 with an average of 20.

5.6.14 Onshore Substation Construction programme

492. Outline programmes for construction of substation(s) under both the Single Phase and Two Phased approach are presented in *Tables 5.49* and *Table 5.50*.

493. Under the Single Phase approach the build out time is estimated to be approximately 55 weeks, this would consist of 43 weeks of construction and mechanical and electrical fitting followed by 12 weeks of testing and commission.

494. If a Two Phased approach to construction is taken the build out time is estimated to span approximately 123 weeks; this would consist of 76 weeks of construction and mechanical and electrical fitting split between two periods over a total of 112 weeks. At the end of each construction phase 12 weeks of testing and commission would follow.

Table 5.50 Indicative Scheduling for Substation Construction Under the Two Phased Approach

Activity	Week																																																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48							
Site preparation	█	█	█																																																				
Substation building construction				█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█			
Control room construction								█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█		
Storage & MV interface building construction																																																							
External blast walls & plinths construction																																																							
Hardstanding & access road construction																																																							
Car parking construction																																																							
Mechanical & Electrical fit out																																																							
Commissioning																																																							
Demobilise																																																							

5.6.15 Onshore Substation(s) Operation

495. The maintenance regime for the substation(s) would depend on the final design of the electrical system, but would be largely identical regardless of whether the HVDC or LFAC solution was adopted. The design would incorporate extensive redundancies for cooling systems, duplicated control systems and power. This would allow most of the maintenance work to be done with no interruption to operation.
496. It is anticipated that the substation(s) would be staffed 24 hours a day by a minimal workforce. In addition to the operational staff there would be the occasional maintenance visits. Within the onshore substation site, there would be an area for storage of key components. Storage for cable repairs may be at the O&M port or strategic location near the onshore cable route.

5.6.16 Onshore Substation(s) Decommissioning

497. No decision has been made regarding the final decommissioning policy for the proposed substation(s), as it is recognised that industry best practice, rules and legislation change over time.
498. The substation(s) and equipment could be removed and the components reused or recycled. The foundations would be removed to below ground level and the ground covered in topsoil and re-vegetated to return the site to its initial state or reused for other future developments.
499. The decommissioning methodology cannot be finalised until immediately prior to decommissioning, but would be in line with relevant policy at that time.

5.7 References

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