Appendix B2 – Offshore Connections and Infrastructure Options Note

The Connections and Infrastructure Options Note is available as an Excel Spreadsheet.

Offshore Connections and Infrastructure Options Note

User	East Anglia Offshore Wind Limited		
Site Name	East Anglia Offshore Wind Farm		
NETS Reference Number			
Application Steering Group Members (Delete As Applicable)	**NETSO**	NGET	**Lead details** Name: Contact No: Email:
	Affected TO 1	NGET	**Lead details** Name: Contact No: Email:
	Other Affected TO	EAOW	**Lead details** Name: Contact No: Email:
Application Type	Offshore Wind Generator Modification Application		

Overview of the application (Short description of the application)	East Anglia TWO Wind Farm was a 1200MW offshore wind farm connection. A Modification Application was submitted in [redacted] to relocate the offshore platforms. East Anglia TWO is located within the East Anglia Offshore Wind Farm zone, which has a total Transmission Entry Capacity of 7200MW (including East Anglia TWO). The East Anglia zone was originally assessed for the total capacity of 7200MW; however, following the Modification Application submitted in [redacted] to define six specific project locations, each project is assessed in a separate CION and has a separate connection agreement. The User has indicated it wishes to receive an SQSS compliant offer and standard ownership boundary connection as set out in CUSC.

Revision Number	Date of Revision	Reason for Revision	Revised by
[redacted]			

Notes for Completion:

1. *Please complete the table above when the document is first used for a scheme and when any subsequent revisions are made to any of the information in the live document.*

2. *Please insert the scheme number into the header, and the revision number and date of revision into the footer.*

3. *This page should be retained throughout the life of the document and remain with the final version.*

East Anglia zone overview

East Anglia Offshore Wind Limited (EAOW) submitted an application for 7200MW of offshore wind generation in the Crown Estate Round 3 Zone 5 in May 2010 and signed the connection agreement in (which National Grid offered as three separate agreements) [redacted]. EAOW subsequently transitioned the agreement to the Generator Build arrangements in [redacted] and is therefore the Offshore Transmission System Development User Works (OTSDUW) party responsible for the delivery of the offshore transmission assets.

EAOW submitted a Modification Application in [redacted] to modify the Completion Dates for the projects within the East Anglia zone (Zone 5) and to redefine the locations of the offshore platforms within the zone. National Grid used this opportunity to create a discrete contract in respect to each project. The zone is divided into six projects:

- EA ONE 1200MW (two 600MW offshore AC collector platforms)
- EA TWO 800MW (two 400MW offshore AC collector platforms)
- EA THREE 1200MW (two 600MW offshore AC collector platforms)
- EA FOUR 1200MW (two 600MW offshore AC collector platforms)
- EA FIVE 1000MW (two 500MW offshore AC collector platforms)
- EA SIX 1800MW (three 600MW offshore AC collector platforms)

The locations of the platforms are provided in Figure 1 below and each platform will be an Offshore Connection Point, i.e. the ownership boundary between the generator and the selected OFTO party at the low voltage (33kV) terminals of the transformers.

Following the first Government announcement on subsidy levels through the Contract for Difference (CfD) in 2014, EAOW undertook a strategic review of the zonal development plan for the East Anglia zone; this included a review of project sizes and locations as well as connection technology with the aim of identifying projects within the zone which provide the lowest cost of energy, and of a suitable size to bring them in line with likely subsidies.

The East Anglia Zone will now be reflected as:

- EA ONE 680MW
- EA ONE North 520MW
- EA TWO 1200MW
- EA THREE 1200MW
- EA Vanguard (also known as Tranche1) 1800MW
- EA Boreas (also known as Tranche2) 1800MW

Based on the geography of the projects within the East Anglia zone the following Onshore Interface Points (IPs) as defined in the National Electricity Transmission System Security and Quality of Supply Standard, Version 2.2, March 5 2012 (NETS SQSS) for the connections have been assessed:

[redacted]

Interface Points located north of [redacted] and south of [redacted] were discounted as they provide no benefit over closer Interface Points due to the technical issues and much higher cost involved with longer offshore HVDC routes.

The locations of the Interface Points are provided in Figure 2 below.

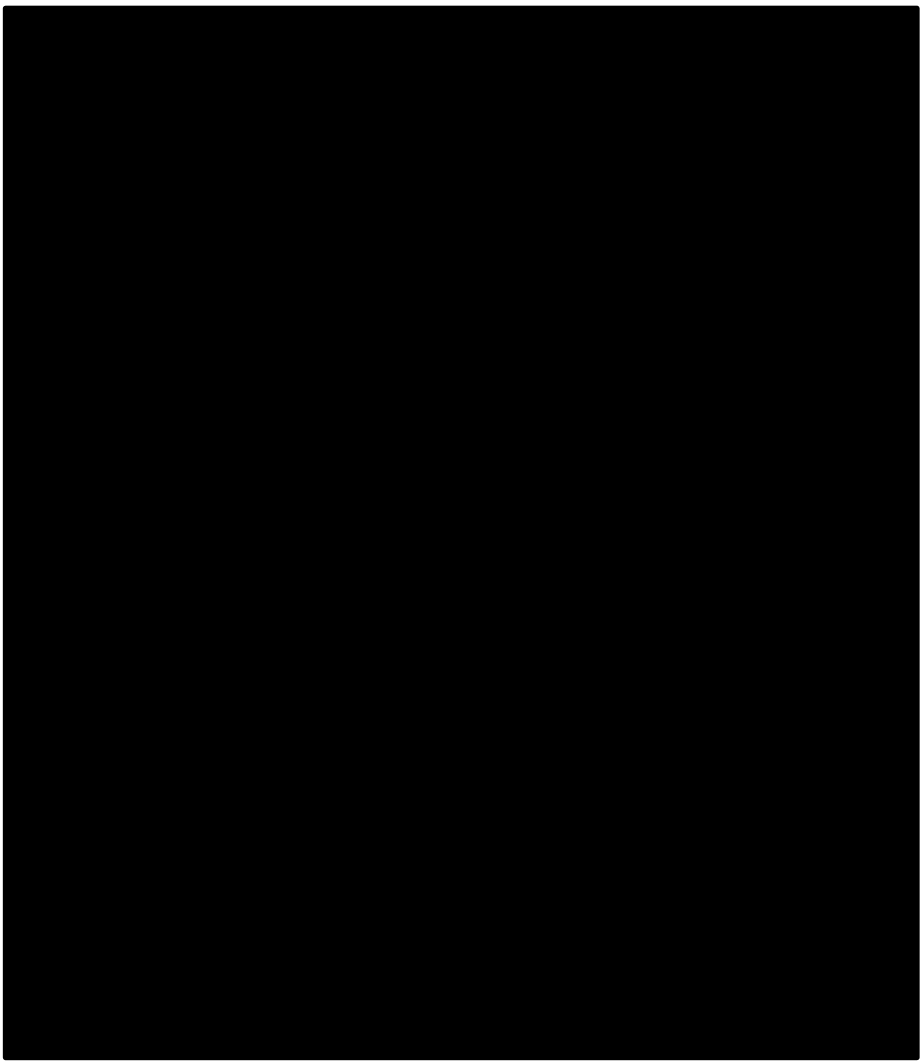


Figure 1: East Anglia zone platform locations

Figure 2: East Anglia zone potential onshore Interface Points

EA TWO

The EA TWO project is located in the east of the zone. The project has a capacity of 1200MW divided into two 600MW offshore platforms (Offshore Connection Sites). The Modification Application states a Completion Date of 1st April 2022.

The development of the EA TWO wind farm and OTSDUW assets is in progress and EAOW, as the OTSDUW party, has already started the works required to deliver a connection from EA TWO to Bramford substation. The EA ONE cable route from the landfall at Bawdsey to Bramford substation will also be used by EA TWO (and EA THREE) and the draft Development Consent Order for EA ONE contains ducting for the cables required. A section of the offshore cable route for EA ONE will also be used for EA TWO (and EA THREE). The application for Development Consent Order for EA ONE was submitted in November 2012.

The Environmental Impact Assessment and associated surveys for EA TWO OTSDUW assets is underway. The geophysical survey for the offshore export cables, which is a significant survey, is complete. A scoping opinion has been received for EA TWO (based on connection to Bramford. The current programme is to submit Preliminary Environmental Information during 2014 followed by the Development Consent Order submission in 2015.

Onshore Interface Points

The Onshore Interface Point constitutes the ownership boundary between NGET and the OTSDUW party. The Interface Point constitutes the First Onshore Substation, it marks the transition from connection criteria as required by Chapter 2 of the NETS SQSS "Generation Connection Criteria Applicable to the Onshore Transmission System" to connection criteria as required by Chapter 7 of the NETS SQSS "Generation Connection Criteria Applicable to the Offshore Transmission System".

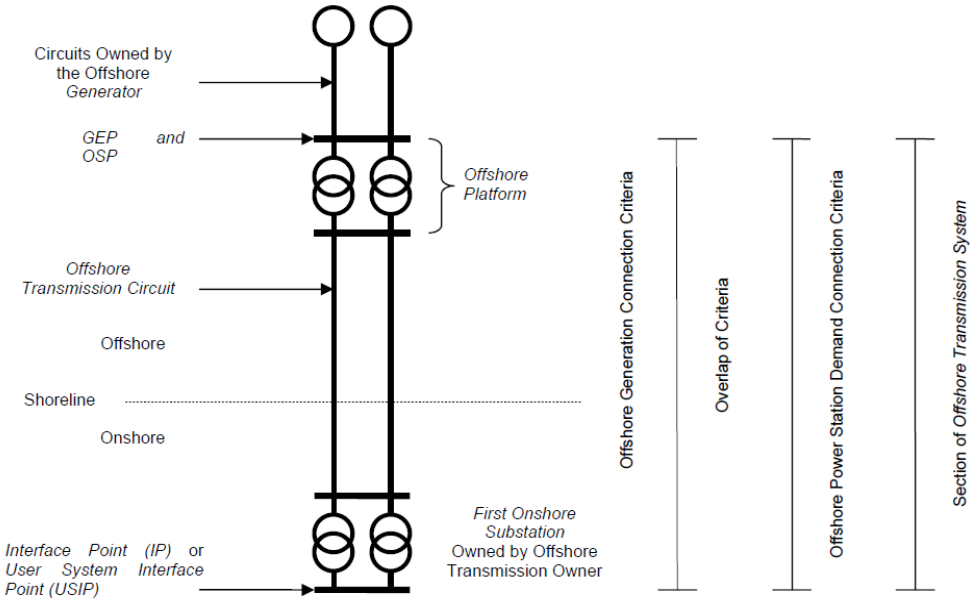


Figure 3: An example of an offshore transmission system with a directly connected power station and First Onshore Substation owned by the offshore transmission owner**.**

Potential Onshore Interface Points included a number of existing NGET substations as well as those that would require new NGET 400kV substations, requiring an extension of the existing 400kV network.

The onshore Interface Points that have been considered can be seen in the diagram in Figure 2 and are described below:

Technology Options

The projects within the East Anglia zone range in capacity from 800MW to 1800MW [redacted]. The power can be transmitted from the platforms to the onshore Interface Points using different transmission technologies, such as different voltages of AC or HVDC, and the output from multiple platforms can be collected for bulk transmission. Due to the number of Interface Points, the different transmission technologies available, the different options for interconnecting platforms offshore and the potential technological advances over the timescales of the projects, a number of assumptions have been made in order to limit the number of scenarios considered for this initial comparative assessment.

[redacted]

The inherent capacitive nature of AC cable requires reactive compensation equipment in the form of shunt reactors to be installed at one or both ends of the cable and/ or intermediate point(s). As the cable length increases, so the amount of capacitive charging current increases and the amount of active power that can be transmitted decreases. HVDC links should be considered when factors such as rated power, system design, Grid Code compliance, land availability, circuit corridor width, ground conditions lead to an AC connection being impractical or uneconomic. These factors are assessed on a project specific basis to identify the most suitable connection technology.

Specific project details have been considered for each of the IPs assessed in this document to define whether a connection can be provided via AC or whether HVDC must be utilised.

For the connection of EA TWO, via the possible interface points, the OTSDUW party has confirmed that utilisation of HVDC is the preferred technology for the connection of EA TWO.

The requirement for utilisation of HVDC having been established, the incremental cost of deploying HVDC is comparable to the overhead AC technology equivalent. Therefore connection to an Interface Point with an existing AC substation maximising deployment of HVDC technology and minimising the use of AC equipment represents an economic and efficient method for the connection of EA TWO.

Initial Options Appraisal

The EAOW connection agreement is for a total of 7200MW of offshore wind generation, therefore total capacity requirement of the projects was considered as well as individual projects.

To comply with the statutory duties under Section 9 of the Electricity Act, the preferred connection design should be the most economic and efficient when considering both offshore and onshore works. Under the requirements of the Transmission Licence, the network design should be compliant with the minimum deterministic criteria of the NETSQSS.

Bramford was identified as the preferred IP for EA TWO in the original grid connection offer in 2010.

Following submission of the Modification Application to modify the Completion Date for EA TWO the contracted position of Bramford was reviewed and it was concluded that Bramford remains the preferred IP as the original rationale for the decision remains unchanged.

The initial options appraisal considered all of the IPs identified based on a high level assessment of programme, construction complexity, land availability, environmental / consenting issues and cost. IPs that were identified to have no benefit over other IPs were parked. This section provides a brief summary of the justification for parking the IPs or discounting technology options; further detail is available in the Options Appraisal Matrix in Appendix A.

[redacted] (new coastal substation)

The new circuit and new substation required to establish the Interface Point would mean that the IP would not be available for customer connection date. Due to the distance of EA TWO from the coast (>100km) it is necessary to employ HVDC for the connection regardless of the onshore IP. Therefore when considering the connection of the entire zone, the cost per kilometre is not as sensitive to connect EA TWO to an inshore IP.

The team has decided that these options are Discounted.

[redacted]
The new circuit and new substation needed to establish the Interface Point would require National Grid to seek a full consenting and consultation process as part of a Development Consent Order (DCO). Therefore the IP would not be available for the requested customer connection date hence it is decided that this option is Discounted.

[redacted]
These IPs are a greater distance from the EA TWO project meaning that longer HVDC cables would be required and alternative feasible options that offer a shorter connection distance are available. Therefore these locations have not been assessed further (Parked).

[redacted]
At Interface Point sites where there is no existing National Grid Substation, NGET works would be a new substation and minor OHL works. Sites identified in the vicinity with equivalent connection options (i.e. [redacted]) have different levels of impact and would need to be subject to further detailed siting to determine the optimum solution. [redacted] is preferred to [redacted] due to the potential impact on the local airfield therefore this option is parked.

[redacted]
The new circuit and new substation needed would require National Grid to undertake a full consenting and consultation process as part of a Development Consent Order (DCO). Therefore the IP would not be available for the requested customer connection date. The existing [redacted] substation is surrounded by the Suffolk Coast and Heaths AONB, which presents a significant land and environmental constraint to the extension of the existing substation. Therefore this potential Interface Point has been parked and not assessed further.

Detailed Options Appraisal

The IP options for the connection of EA TWO were assessed in greater detail by undertaking a desk-based constraint mapping exercise to identify potential substation locations and connection routes and assessing project specific costs.

Sections 1 and 2 of this document provide detail of the cost comparison and technical assumptions.

Interface Points that were identified to have no benefit over other IPs were parked. This section provides a brief summary of the justification for parking the IPs; further detail is available in the Options Appraisal Matrix in Appendix A.

[redacted]
The HVDC connection solution is the lowest capital cost option; however the marginal difference in cost for connecting to [redacted] does not outweigh the cost of abortive works or programme delay that would be incurred from modifying the Interface Point from Bramford at this stage of development or the additional development costs that would be required to identify a suitable connection route to [redacted]. The connection route to Bramford has been confirmed as it is the same route that will be used for EA ONE. The connection route to [redacted] is an indicative route identified from a desk-based study; it is likely that the cost of the [redacted] connection would increase once an actual connection route was identified in consultation with relevant stakeholders and on the basis of the necessary surveys.

[redacted]
The process concluded that a HVDC connection to Bramford is the preferred connection solution and the original rationale remains unchanged. Furthermore a change to the Interface Point at this time would have a significant impact on the OTSDUW party including abortive works and programme impacts. The EA ONE cable route from the landfall at Bawdsey to Bramford substation will also be used by EA TWO (and EA THREE) and the draft Development Consent Order for EA ONE contains ducting for the cables required. A section of the offshore cable route for EA ONE will also be used for

EA TWO (and EA THREE). The application for Development Consent Order for EA ONE was submitted in November 2012.

The Environmental Impact Assessment and associated surveys for EA TWO OTSDUW assets is underway. The landowner agreements for the route corridor for EA ONE, EA THREE and EA TWO are well advanced. The geophysical survey for the offshore export cables, which is a significant survey, is complete.

The assessment process identified no reasons for the need to change the Interface Point for EA TWO and it remains as Bramford.

Tables 2provide the cost summary of the options considered in the detailed assessment.

	Interface Point	Offshore Distance (km)	Onshore Distance (km)	Total (km)	OFTO Cost (£m)
1					
2					

Note: Distances may vary compared to AC solution due to assumed locations of HVDC platforms

Table 2: Cost to connect EA TWO to IP using HVDC

Wider Considerations

Not applicable.

Conclusions

The work completed for the options appraisal and in development of the CION document has identified Bramford 400kV substation as the preferred onshore Interface Point for the connection of 1200MW of wind generation from EA TWO. The connection from the HVDC converter station to Bramford will be delivered by an HVDC offshore transmission system operating at ±320kV with a new onshore converter station constructed adjacent to Bramford substation.

The onshore transmission system works required to connect EA TWO at Bramford are limited to construction of a new 400kV bay at the existing Bramford substation.

Further Work and Next Steps

Work is progressing in the development of the connection and there is a joint process between NGET and the OTSDUW party to define parameters at the interface at Bramford, such as cable routes within the Bramford substation site, agreement of detailed design parameters, protection settings, harmonic filter requirements etc.

SECTION 1 – Preferred Option Assessment

	Summary (Short overview description of each option)	**Major Risks**	**Onshore TO Cost £m**	**Offshore TO Cost £m**	**Overall Total Cost £m**
Option 1	Connecting to Bramford 400kV substation via one 1200MW ±320kV symmetrical monopole HVDC link		[redacted]		
Option 2	Connecting to [redacted] 400kV substation via one 1200MW ±320kV symmetrical monopole HVDC link	Significant risk that it would not be possible to identify a suitable connection route to [redacted] in the timescales required. Significant programme delays to OTSDUW works and abortive costs of the development works (e.g. environmental and geophysical surveys, landowner agreements) completed to date.			

SECTION 2 - Preferred option

Option - The preferred option is Option 1 where the 1200MW of wind generation in EA TWO is connected to the onshore IP at Bramford. [redacted]. The two collector platforms will be connected to a 1200MW ±320kV HVDC converter station. An onshore 1200MW ±320kV HVDC converter station will be constructed adjacent to Bramford. Two ±320kV HVDC cables (subsea and underground) will be installed between the converter stations and the link will be configured as a symmetrical monopole. 400kV underground cables will connect the converter station to Bramford.

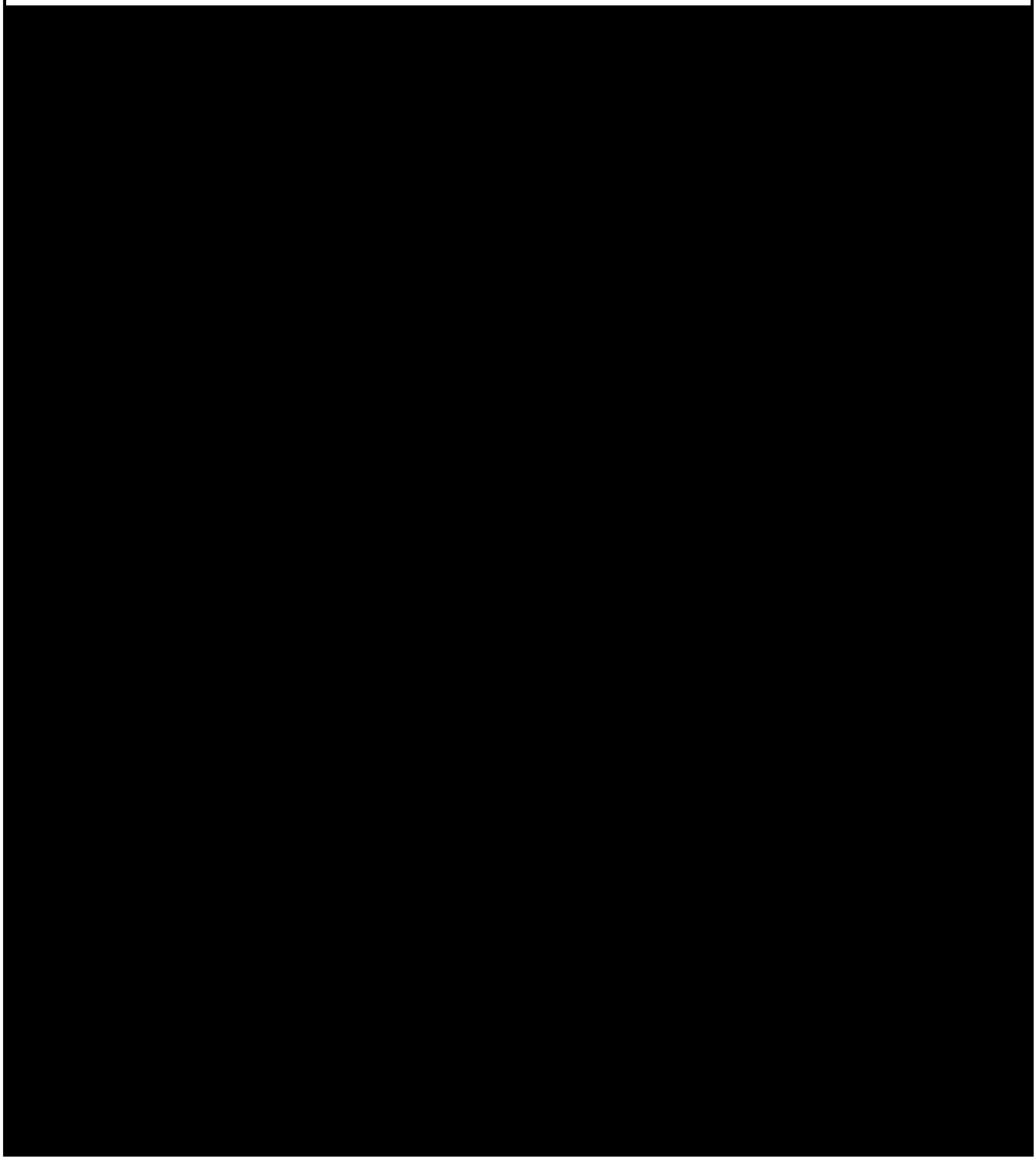
Details of Option 1 – Connecting to Bramford 400kV substation via one 1200MW ±320kV symmetrical monopole HVDC link		
Offshore Works	**Description of Works** (Detailed description of the works)	[redacted]
	Cost	
	Completion Date	
	Issues, Risks & Comments	
	Outage Requirements	
Onshore Works	**Description of Works** (Detailed description of the works)	
	Cost	
	Completion Date	
	Issues, Risks & Comments	
	Outage Requirements	

Details of Option 1 – Connecting to Bramford 400kV substation via one 1200MW ±320kV symmetrical monopole HVDC link
Single Line Diagram
[redacted]

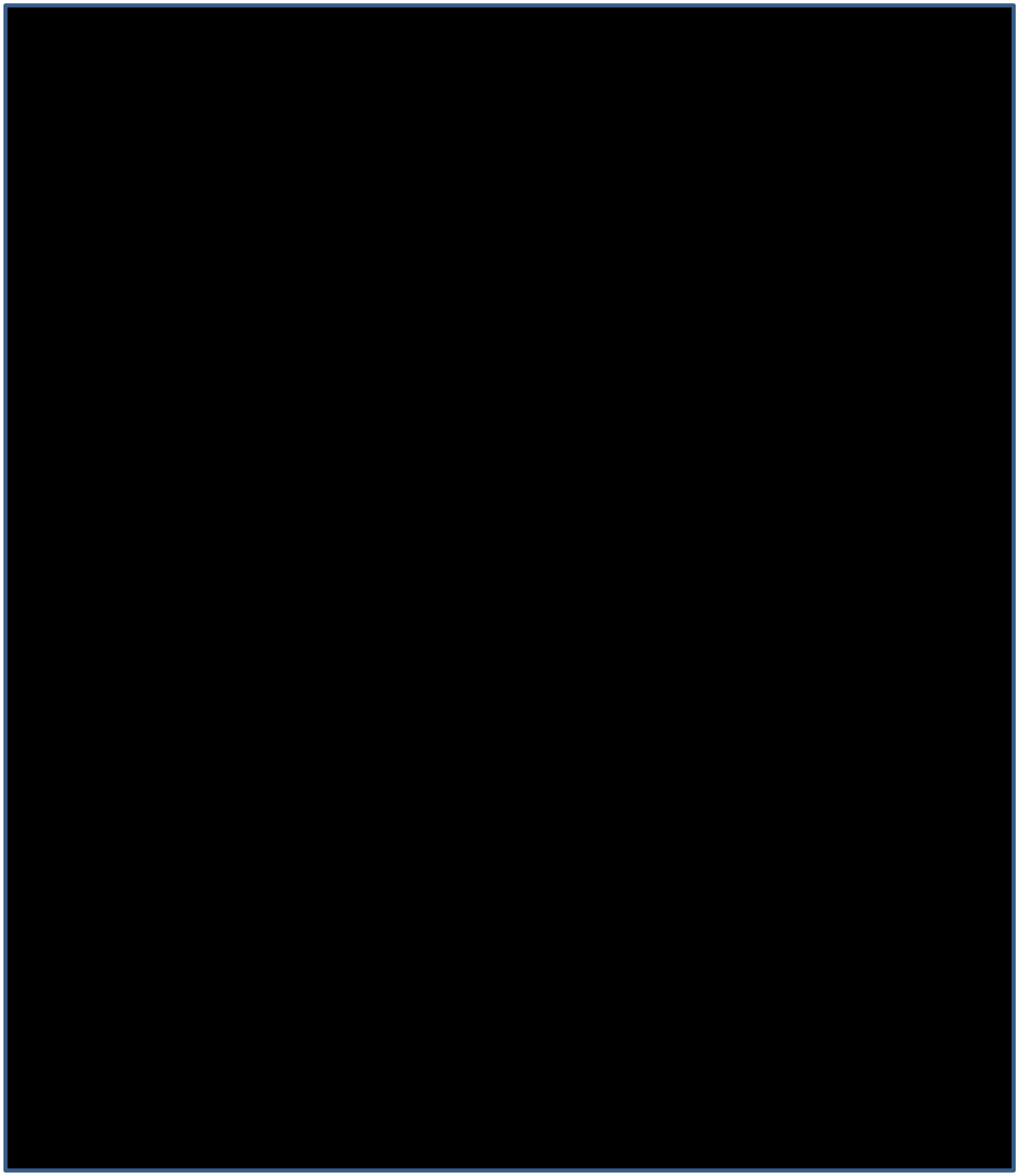
Details of Option 2– Connecting to Norwich 400kV Substation via one 1200MW ±320kV symmetrical monopole HVDC links		
Offshore Works	**Description of Works** (Detailed description of the works)	[redacted]
	Cost	
	Completion Date	
	Issues, Risks & Comments	
	Outage Requirements	
Onshore Works	**Description of Works** (Detailed description of the works)	
	Cost	
	Completion Date	
	Issues, Risks & Comments	
	Outage Requirements	

Details of Option 2– Connecting to Norwich 400kV Substation via one 1200MW ±320kV symmetrical monopole HVDC link

Single Line Diagram



SECTION 3 – Offshore Transmission Owner Cost Assumptions



SECTION 4 – Onshore Transmission Owner Cost Assumptions

An indicative capital cost estimate for the overall scope of works for each of the Onshore Interface Points has been prepared. All estimates were made based on high level project specific design information and based on assumptions about the scope of works required. National Grid's capital cost estimates include costs for the transmission equipment and also for the installation of that equipment and are based on generalised unit costs for the key elements of the option. The generalised unit cost information reflects recent contract values and/or budget estimates from equipment manufacturers/suppliers or specialist consultants and provides a consistent basis for preparing capital cost estimates. The IET, PB/CCI Report[1] presents cost information in size of transmission circuit capacity categories for each circuit design that was considered as part of the independent study.

[1] "Electricity Transmission Costing Study – An Independent Report Endorsed by the Institution of Engineering & Technology" by Parsons Brinckerhoff in association with Cable Consulting International. Page 10 refers to Double circuit capacities.
http://www.theiet.org/factfiles/transmission-report.cfm

APPENDIX A – Options Appraisal Matrix