EAST ANGLIA TRANSMISSION NETWORK REINFORCEMENTS

Hiorns Smart Energy Networks

Abstract

Review of National Grid Energy Transmission (NGET) proposals for East Anglia Network reinforcement with a focus on the need and timing of the proposed 400 kilovolt (kV) line from Norwich to Bramford to Tilbury 400 kV substations

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Contents	Page

Acronyms

Term	Definition
ASTI	Accelerated Strategic Transmission Investment
BESS	Battery Energy Storage System
CPA	Construction Planning Assumptions
CCGT	Combined Cycle Gas Turbine
CFD	Contract for Difference
CMIS	Constraint Management Intertrip Service
DNO	Distribution Network
EC5	East Coast 5 boundary export
ESO	Electricity System Operator
EYTS	Electricity Ten Year Statement
FES	Future Energy Scenarios
GIL	Gas Insulated Line
GSP	Grid Supply Point
GW	Giga Watts
HND	Holistic Network Design
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
IA	Interconnector Allowance
kV	Kilo Volt
MITs	Main Interconnected Transmission System
MW	Mega Watts
EC5N	Necton & Norwich Export Group
NGET	National Grid Electricity Transmission
NOA	Network Option Assessment
OHL	Overhead Line
OTNR	Offshore Transmission Network Review
PFC	Power Flow Control
SIEX	Sizewell Export Group
SSE	Scottish and Southern Electricity
SQSS	Security and Quality of Supply Standards
TEC	Transmission Entry Capacity
TOs’	Transmission Owners

1. Executive Summary

1.1 Growth in offshore Wind Generation, along with potential new Interconnectors to Europe and Nuclear Generation development in East Anglia region will make a significant contribution in reaching the Net Zero Targets. The generation in this region could potentially meet some 25% - 50% of UK demand at any given time depending on the prevailing wind conditions.

1.2 In seeking to ensure there is adequate transmission capacity to accommodate this volume of generation, several major network reinforcements have been proposed. The proposed reinforcements include a new 400kv line between Bramford to Twinstead Tee, a new 400kv between Norwich – Bramford – Tilbury along with a high voltage direct current (HVDC) link between Sizewell to Richborough. NGET is seeking to complete all these reinforcements by 2031 in line with the contracted connection dates for the generation being developed in this area.

1.2 This report reviews:

a. The need and timing for additional capacity out of the East Anglia region against the Electricity System Operators (ESO) Contracted Generation.
b. The need against a range of credible Generation Scenarios to assess the robustness of the need case.

1.3 The analysis undertaken in this report concurs with National Grid Electricity Transmission conclusion that if all the Generation which is presently contracted proceeds in accordance with its contracted dates, then there is a requirement for additional transmission capacity identified above. The proposed solutions provide the most economical solution in meeting these needs.

1.4 However, the need for Norwich to Bramford to Tilbury OHL has been demonstrated against the Contracted Generation. The ESO have noted that 70% of Generation projects listed in the Generation Contracted may never be built and it should also be noted that many of the projects which are eventually built come online later than their contracted dates. In looking at a range of more credible scenarios there is significant uncertainty with regard both the required volume of additional transmission capacity and timing when all this additional transmission capacity will be required.

1.5 The proposed development of the Bramford - Twinstead Tee and the Sizewell to to Richborough HVDC link, with some minor incremental investment provides additional transmission capacity across a number of key boundaries and would accommodate circa 12 gigawatts (GW) of additional offshore Windfarm Generation in the East Anglia Region.

1.6 The analysis undertaken in this report concludes that the need for the Norwich-Bramford-Tilbury overhead line can be deferred by 5 years. Whilst the proposed new overhead lines (OHL) may ultimately be the optimum solution to meet the future needs, given the level of uncertainty associated with the Contracted Generation background it too early to conclude it represents the best overall solution in meeting future system needs.

1.7 Given the uncertainty with respect to both volume and timing of future generation along with the timely development of the Bramford - Twinstead Tee and the Sizewell to to Richborough HVDC link it provides the opportunity to pause development of the Norwich to Bramford to Tilbury until future Generation requirements crystallized and for the need case to be reviewed against the proposals outlined in Great Britain (GB) connection reform.

1.8 This approach would not impact on the development of the offshore wind Generation projects which are required to meet the Net Zero challenge given the additional capacity provided by the development of the Bramford – Twinstead Tee and the HVDC link between Sizewell and Richborough along with ESO Connection reform which would ensure equitable release of available transmission capacity.

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2. Introduction

2.1 Existing Transmission Network Capacity

2.1.1 The transmission network in the East Anglia region was built to serve demand in the region and has remained largely unaltered since being constructed in the 1960's. The last major network upgrade in this area was undertaken to accommodate Sizewell B nuclear generation.

2.1.2 Peak demand In the East Anglia area is circa 1.5GW and anticipated to grow to circa 2GW by 2035/36. Demand is supplied to the East Anglia area predominately from Walpole, Norwich Main, Bramford Grid Supply Points (GSP). A map of the transmission system in East Anglia is shown in Figure 2.1[1].

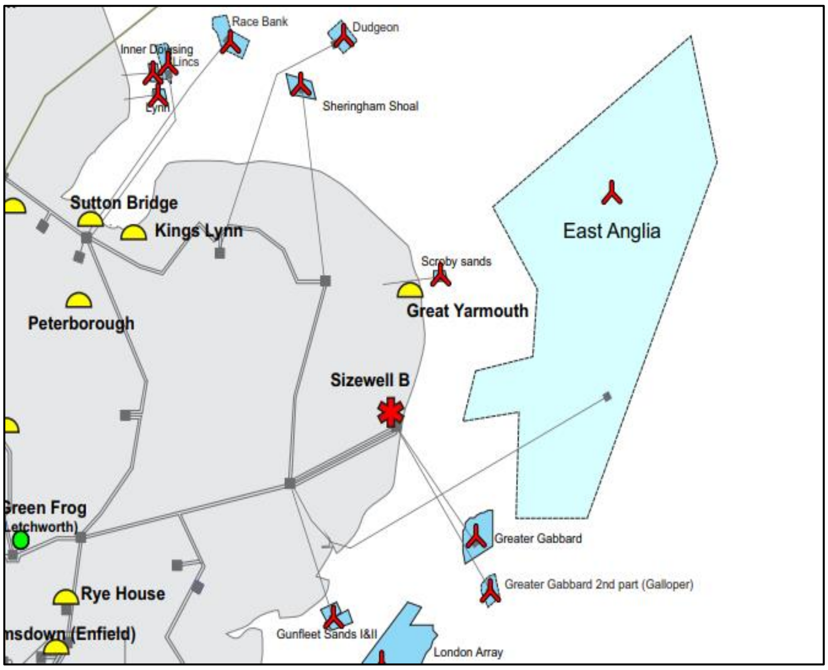

Figure 2.1 - Map showing the electricity transmission system in East Anglia

2.1.3 There is a 400kV double circuits between Walpole 400kV substation to Twinstead Tee point, shown in Fig 2.2 below, which connects the four 400kV GSP (Necton, Norwich, Bramford & Sizewell) to the Main Interconnected Transmission System (MITs). There are two 400kV double circuits between Sizewell and Bramford 400kV substation to connect the generation at Sizewell to the Main MITs.

[1] Figure 2.1 & 2.2 have been extracted from ESO 2022 Electricity Ten Year Statement (ETYS).

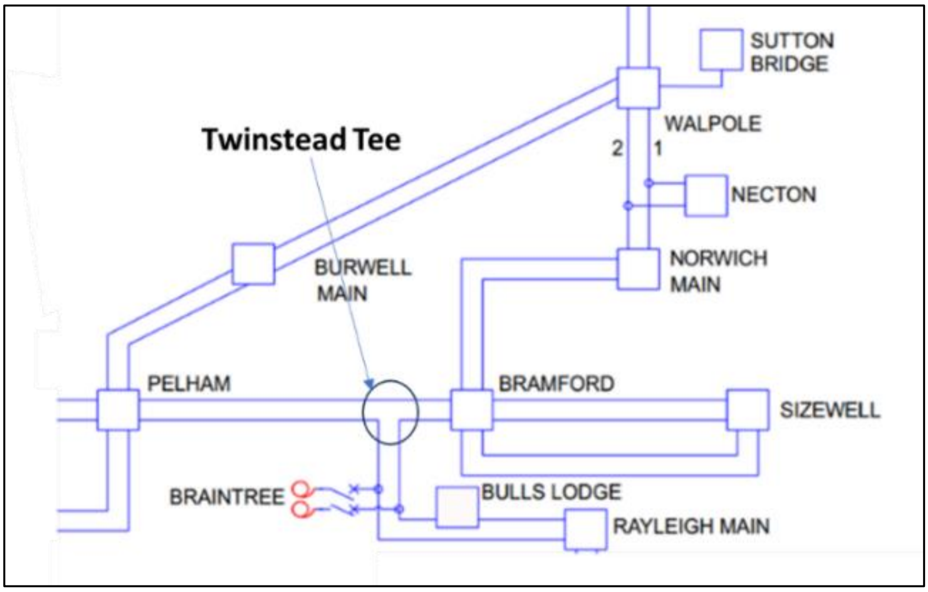

Figure 2.2 – Diagram showing the electricity transmission system in East Anglia

2.2 Network Boundaries

2.2.1 In considering network transmission capacity it is convenient to consider the transmission network as a series of ‘boundaries.’ The concept of ‘boundaries’ is to notionally split the system into two parts, the boundary crossing critical paths that carry power between the areas where power flow limitations may be encountered.

2.2.2 The transmission system is planned in accordance with the Security and Quality of Supply Standards[2] (SQSS) such that no boundary under consideration unduly restricts the ability of the generation to meet the GB consumer demand.

2.2.3 Where the required transfer exceeds the boundary capacity then National Grid Electricity Transmission plc (NGET) have a licence obligation to provide additional transmission network capacity to ensure the required transfers can be accommodated.

2.2.4 Three boundaries have been developed for the East Anglian area to evaluate the adequacy of the transmission network capacity as shown in Figure 2.3 below, these are: -

a. EC5N; Generation export from the Necton and Norwich Main GSP’s
b. EC5 Boundary; Generation export from the Necton, Norwich Main, Bramford and Sizewell C GSP’s
c. SIEX; Generation export boundary from Sizewell & Leiston[3].

2.2.5 When a shortfall of transmission capacity is identified across a boundary, NGET will identify a range of viable solutions to address this shortfall in transmission capacity. The Electricity System Operator (ESO) reviews these options and makes recommendations of which of the identified solutions should be taken

[2] https://www.nationalgrideso.com/document/266526/download
[3] A second GSP at Leiston is being established which will connect into the existing Bramford to Sizewell circuits and will form part of the SIEX group.

forward. NGET will then progress the reinforcement which the ESO have recommended.

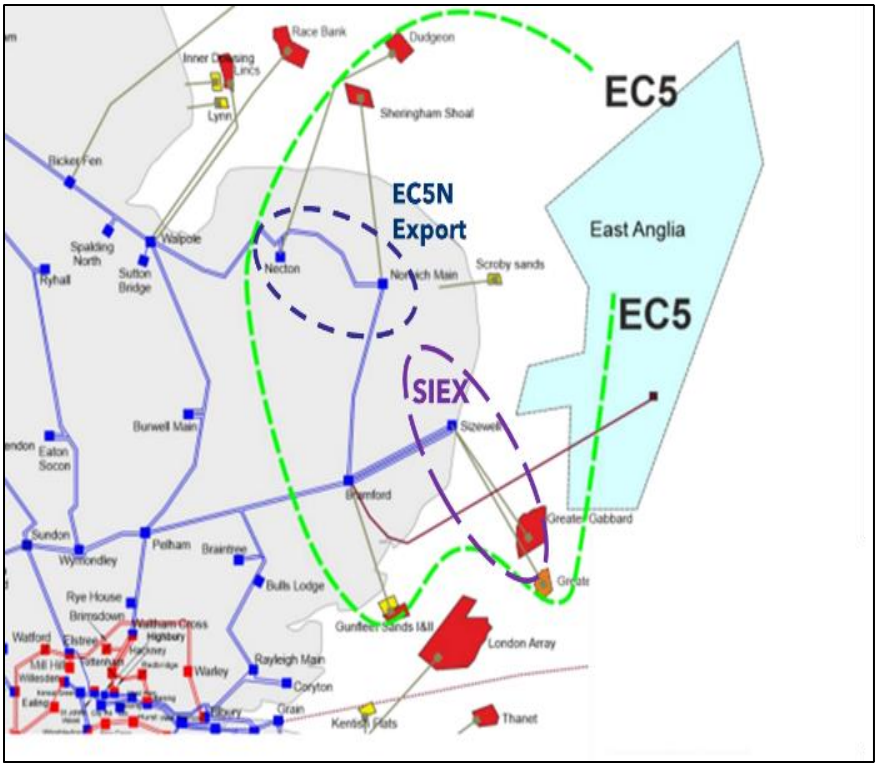

Figure 2.3 - Map showing the electricity transmission boundaries in East Anglia.

2.3 EC5N Boundary

2.3.1 The EC5N boundary consists of Necton and Norwich Main 400kV Substation. For the outage of the double circuit between Bramford and Norwich Main the generation will be left connected to MITs via the Necton to Walpole 400kV double circuits. The capacity of this group under this outage is shown in Table 2.1 below.

Table 2.1 – EC5N electricity transmission boundary		
Circuit Name	Winter Rating[4] (MVA)	Winter Rating (MVA)
Norwich Main – Necton- Walpole 1	3326	Contingency
Norwich Main – Necton- Walpole 2	3326	Contingency
Necton – Walpole 1	3326	3326
Necton – Walpole 2	3326	3326
Total	**13304**	**6652**

Table 2.1 – Table showing the electricity transmission capacity of ECN5 Boundary

[4] The ratings are extracted from Appendix B of the 2022 Electricity Ten Year Statement (ETYS)

2.3.2 The capacity shown in Table 2.1 is higher than quoted in the 'Norwich to Tilbury Strategic options Backcheck and Review' document recently issued by NGET. However, following discussions with NGET they have advised they will update their boundary capacity in the next update of the Backcheck and Review Report[5].

2.4 EC5 Boundary

2.4.1 EC5 crosses two 400kV double circuits and encloses four 400kV GSP. The theoretical maximum thermal export capacity of this group under outage condition is circa 6200MW as shown in the Table 2.2 below.

2.4.2 Due to unbalanced circuit loading the net export capacity is presently declared as 3850MW[6]. NGET have identified a series of incremental reinforcements, which have been endorsed by ESO via the Network Option Assessment (NOA) process, which will increase the export capacity to 6200 megawatt (MW).

Table 2.2 – EC5 Boundary export capacity		
Circuit Name	Winter Rating (MVA)	**Winter Rating (MVA)**
Norwich Main – Necton-Walpole 1	3326	Contingency
Norwich Main – Necton-Walpole 2	3326	Contingency
Bramford - Pelham	3102	3102
Bramford –Braintree	3102	3102
Total	**12856**	**6204**

Table 2.2 – Table showing the electricity transmission capacity at EC5 Boundary

2.4.3 Given the volume of additional Generation seeking to connect within the EC5 boundary, NGET are actively progress the 'Bramford – Twinstead Tee' project. Given the status of this project, this report assumes that this projects will be completed in evaluating the need for further additional transmission capacity.

2.4.4 Following establishment of the Bramford – Twinstead Tee project the transmission network will be as shown in Figure 2.4 below. The completion of this project provides a third 400kV double circuit across the EC5 boundary which significantly increases the network capacity across this boundary.

2.4.5 The critical double circuit outage for this boundary now becomes the Walpole to Burwell Mail 400kV double circuit. For this critical outage, power will flow into the group at Walpole, transiting through the East Anglia and exiting at Bramford. These power flows will then be supplemented by the generation export from the East Anglia area as shown in Figure 2.5. These through flows from Walpole to Bramford have the potential to reduce boundary transfers across EC5.

[5] The Backcheck and Review Report is a live document with NGET updating as latest information becomes available.
[6] The 2022 Electricity Ten Year Statement quotes the boundary capability of key boundaries.

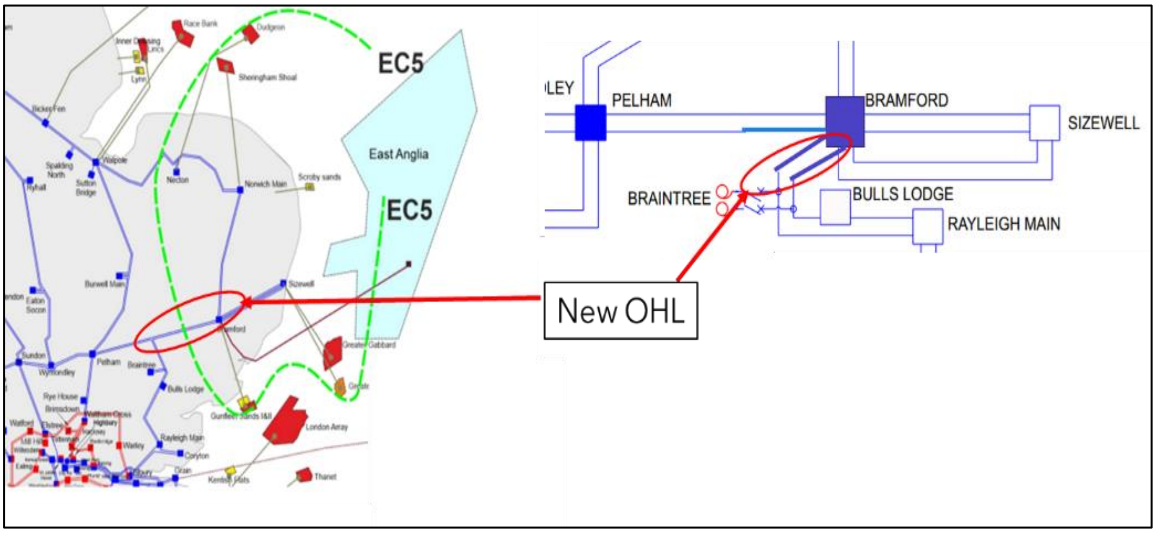

Figure 2.4 - Map and diagram showing the East Anglia Transmission Network incorporating Bramford – Twinstead Tee OHL

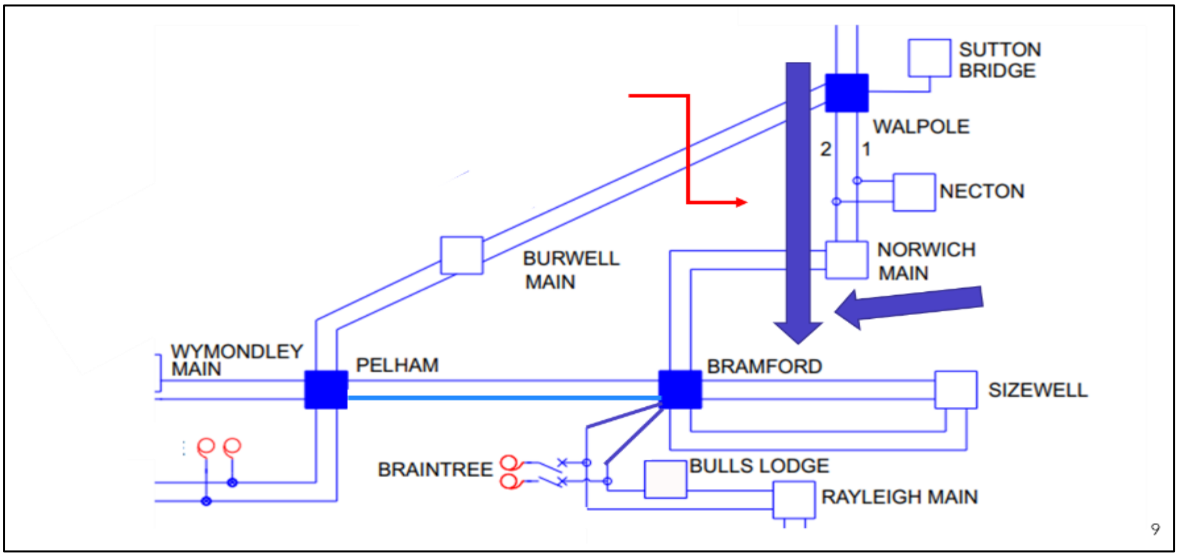

Figure 2.5 - Map and diagram showing electricity transfer following establishment of Bramford – Twinstead Tee

2.4.6 The maximum thermal capability of this group, assuming all lines could be fully utilised would be 14292 MW as shown in Table 2.3 below. NGET have confirmed that the usable export capacity out of this group is 12580MW. This represents 88% network utilisation, which is higher than typical norms and reflects that National Grid have sought to maximise existing and future network capability prior seeking transmission expansion.

Table 2.3 – Maximum EC5 export capacity following establishment Bramford – Twinstead Tee OHL		
Circuit Name	**Planned Winter Rating (MVA[7])**	**Planned Winter Rating (MVA)**

[7] Data extracted from Appendix B of 2022 Electricity Ten Year Statement (ETYS)

Norwich Main – Necton-Walpole 1	3326	Contingency
Norwich Main – Necton-Walpole 2	3326	Contingency
Bramford – Pelham 1	3326	3326
Bramford – Pelham 2	3326	3326
Bramford – Braintree-Rayleigh	3820	3820
Bramford –Braintree-Bulls Lodge	3820	3820
Total	**20944**	**14292**

Figure 2.3 – Table showing the maximum export capacity in the EC5 Boundary following the establishment of the Bramford – Twinstead Tee OHL.

2.5 SIEX Group

2.5.1 SIEX consists of a single GSP with generation connected to Sizewell with local demand being supplied. A second GSP at Leiston is being established which will connect into the existing Bramford to Sizewell circuits and will form part of the SIEX Group. For the loss of either of the double circuit between Bramford and Sizewell the generation export will be left connected to the MITs via the other Bramford to Sizewell double circuit. The capacity of this group under outage contingency is shown in Table 2.4 below.

Table 2.4 – Export capacity of SIEX electricity transmission capacity group		
Circuit Name	**Winter Rating (MVA)**	**Winter Rating (MVA)**
Bramford – Sizewell 1 400kV	2779	Contingency
Bramford – Sizewell 2 400kV	2779	Contingency
Bramford – Sizewell 3 400kV	2779	2779
Bramford – Sizewell 4 400kV	2779	2779
Total	**11116**	**5558**

Figure 2.4 – Table showing the export capacity in the SIEX Group under outage contingency.

3. Roles & Responsibilities

3.1 The 1989 Electricity Act defines transmission of electricity within GB and its offshore waters as a prohibited activity which cannot be conducted without transmission license. These license holders are known as Transmission Owners (TOs), with responsibility for owning and maintaining transmission assets. Through the transmission license the TOs' are responsible for ensuring compliance with the SQSS which seeks to establish the minimum level of transmission capacity which the TOs are obliged to provide. A single transmission license has been granted to the ESO that permits operation of the Transmission Network within Great Britain and its offshore waters.

3.2 The ESO provides the contractual interface with the Generators and Interconnectors which are either connected, or seeking to connect, to the transmission network. Potential Generator and Interconnectors apply to the ESO for a Connections Agreement to connect the GB transmission Network. The ESO works closely with the TOs to confirm what, if any additional transmission capacity is required to accommodate proposed connection of future generation and agrees with the TOs when any necessary reinforcements can be completed. The conclusion of this assessment forms the basis of the Connection Agreement which the ESO offers to the Generator seeking to connect to the Transmission System.

3.3 The ESO are also responsible for several other additional activities which they undertake on behalf of the electricity industry, including the publication each year of:

a. Future Energy Scenarios (FES) which takes a range of energy industry views and develops a set of energy growth scenarios which is used as the basis for determining future MITs requirements.

b. Electricity Ten Year Statement (ETYS) which sets out the system development requirements of the MITs over the next 10 years.

c. Network Options Assessment (NOA), which provides an economic assessment of the TOs potential options for reinforcing the MITs.

3.4 In Summer 2022 the ESO published its Holistic Network Design (HND)[8] in response to the Governments Offshore Transmission Network Review (OTNR). The HND sets out a single integrated transmission network design to ensure that the transmission connections for offshore wind connections are delivered in the most appropriate way considering the increased ambition for offshore wind. In making its recommendations the report considered environmental, social and economic costs. The HND recommended the development of a new 400kV line between Norwich Main to Tilbury 400kV substations.

3.5 Following the publication of the HND and 2022 NOA Refresh, Ofgem published the Accelerated Strategic Transmission Investment (ASTI) decision[9], which is seeking to facilitate achieving the government targets by streamlining the regulatory approval process and to ensure adequate regulatory funding in place to support development and delivery of the ASTI projects. The schedule of projects which Ofgem gave funding to proceed included the new 400kV double circuit going North and South of East Anglia

3.6 The TOs are obliged to provide the capacity required by the ESO, which includes the reinforcements identified in the HND and which regulatory approval has been provided in the ASTI decision. Furthermore, the TO's are incentivised

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[8] https://www.nationalgrideso.com/document/262676/download
[9] Decision on accelerating onshore electricity transmission investment (ofgem.gov.uk)

to deliver these projects in accordance with schedule included in the ASTI decision report.

4. Drivers for Transmission Expansion

4.1 The electricity industry is undergoing an unprecedented change in transitioning from a reliance on fossil fuels towards low carbon Generation. Closure of fossil fuel Generation and end of life of existing nuclear power stations will require significant investment in new Generation and Interconnection[10] capacity to ensure security of supply is maintained.

4.2 The UK Government published the British Energy Security Strategy in April 2022 setting out a strategy for secure, clean and affordable energy. This strategy sets out the UK's energy ambitions, which included:

a. Up to 50GW of offshore wind connected by 2030.
b. Up to eight new nuclear reactors reaching up to 24GW to be achieved by 2050:

4.3 Crown Estate has produced a map showing potential sites for offshore windfarm projects. Figure 4.1 provides an extract showing potential offshore projects which may connect to the East Anglia Area.

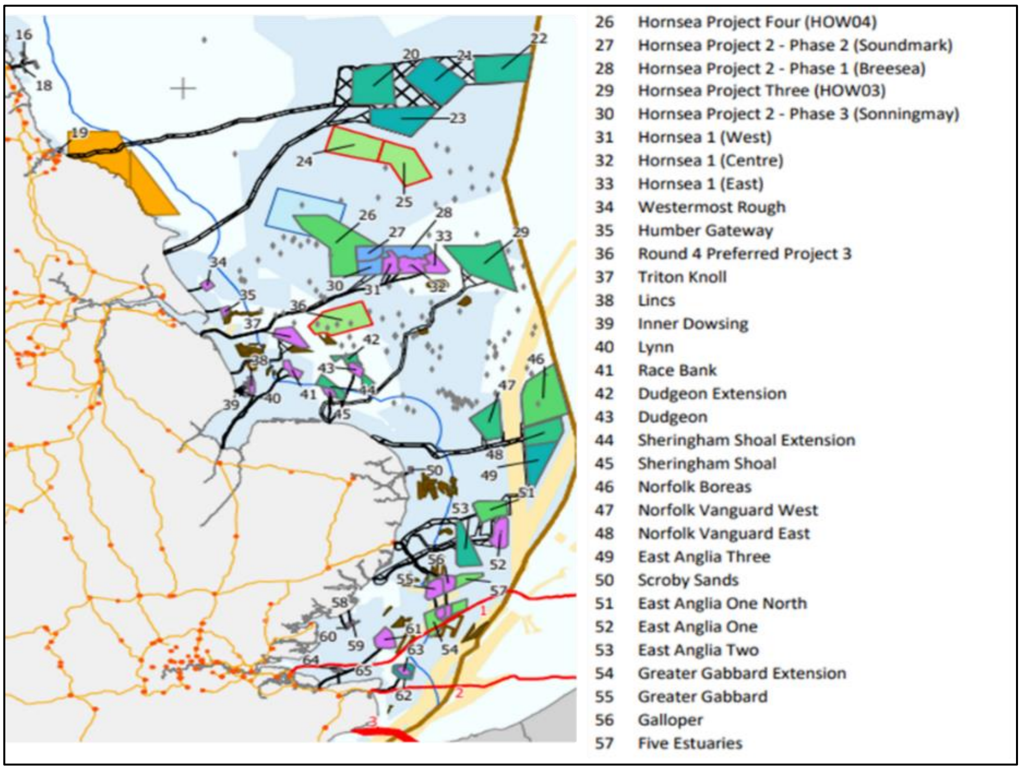

Figure 4.1 – Map showing the Crown Estate and potential offshore wind projects in the East Anglia region.

5. Contracted Generation

[10] Interconnectors between different countries will play a critical role in allowing access renewable generation to be traded between countries.

5.1 All existing Generators and Interconnectors who are either connected to, or use the Transmission Network, have a Connection Agreement with ESO. These Connection Agreement identify the point of connection and define the total MW output which can be injected onto the transmission system (defined as the Transmission Entry Capacity (TEC)).

5.2 When a new Generator or Interconnector is developing a project which will either connect to the transmission system, or seek to utilise the transmission network, they will make an application to the ESO for a Connection Agreement.

5.3 For an onshore generator, ESO consult with the appropriate to determine the most efficient way to accommodate this connection request. For offshore Generator and Interconnectors, the ESO will look to determine the optimum onshore connection point by evaluation of all parties cost. The Generator or Interconnector will then be offered a Connection Agreement which will define his connection point, along with the allowable TEC and year of connection.

5.4 The ESO publishes all schedule of all Generation with Connection Agreements via its TEC register[11]. There is presently 75.5GW (of which 12.6GW is offshore Wind) of Generation either connected to, or as contracts to use, the transmission network. There is a further 275GW of potential new generation projects (of which there is circa 110GW offshore Wind) which have Connection Agreements to connect to, or to use, the Transmission system.

5.5 The ESO also publishes the Interconnector TEC register. This shows that presently there is 9.5GW of Interconnector capacity connected to the GB Transmission system with a further 24.7GW of potential new Interconnectors having a contract for connection.

5.6 The combined Generation and Interconnector TEC register is referred to as the 'Contracted Generation' within this report.

5.7 The ESO has recognised that lead time to connect renewable project is too long and this is hindering progress to deliver Net Zero. ESO are taking forward a range of actions to address this issue, referred to as the 5-point plan. ESO have stated that the changes to in way they design the network and how and when they provide access to the network can bring forward connection dates. ESO anticipate 70% of the pipeline of connecting projects, which currently have a connection date after 2026, will be able to connect some 2 and 10 years earlier then presently envisaged following the adoption of the 5-point plan.

5.8 ESO proposed plan[12] consists of:

a. Allowing Generators to terminate their agreement without incurring penalties.

b. Change in background modelling assumptions - updating how project connection dates are determined. The ESO is working with TO's to review and update existing contracts with these new Construction Planning Assumptions (CPAs).

[11] https://www.nationalgrideso.com/industry-information/connections/reports-and-registers
[12] GB Connection Reform ESO End of Year Report May 2021 (nationalgrideso.com)

c. Batteries and other energy storage technologies soak up energy generation when connected to the grid as well as releasing it back onto the grid. As this technology has a dual purpose, the ESO have changed how it calculates its impact on the system.

d. Developing new contractual terms for connection contracts to manage the queue more efficiently, so those projects that are progressing can connect and those that are not can leave the queue.

e. Enabling energy storage projects to connect to the grid more quickly allowing their flexibility to support development of the Transmission network.

5.9 These reforms will allow existing transmission capacity to be released in a more equitable manner and allow some of the generation connection dates to be brought forward.

6. ESO Future Energy Scenarios

6.1 Each year the ESO undertake an in-depth consultation process in developing a range of Future Energy Scenarios (FES)[13] , in which Fintan Slye ESO CEO noted that:

'*This year's Future Energy Scenarios continue to set out credible ways that the UK can achieve net zero by 2050, as well as the UK Government's commitment to a decarbonised electricity system by 2035. Based on extensive stakeholder engagement, research and modelling, each scenario considers how much energy we might need, where it could come from and how we continue to maintain outstanding levels of system reliability'*

6.2 In considering a plausible range of future outcomes the FES 2023 considered 4 scenarios, only one of these scenarios is predicated to achieves the target of 50GW of offshore Wind by 2030, with target only being achieved by 2035 and 2040 other scenarios.

6.3 Of the 110GW of contracted offshore wind, 103GW as a connection date by 2033 with the remaining generation contracted to connect by 2037. Given there is already 12.6GW of offshore wind connected to the UK network, the ESO scenarios suggests a maximum of 36% of new projects which have contract connection dates prior to 2035 will connect by this date.

6.4 As noted by Julian Leslie, Head of Networks, National Grid Electricity System Operator

'*'Over 280 GW of generation projects are currently seeking to connect to the transmission network and an increasing number of those projects have connection dates into the mid to late 2030s. Renewable project developers are waiting too long to connect to the network, and this is hindering our progress to deliver Net Zero. The causes for these delays are clear. We have seen huge increases in the numbers and capacities of projects seeking to connect, yet our data shows that up to 70% of those projects may never be built. Those projects*

[13] Download our datasets | ESO (nationalgrideso.com)

are holding capacity that is significantly delaying the connection of other projects".

6.5 Lack of transmission capacity has been widely recognised as a major contributor to delays in the development of offshore wind generation projects. NGET along with the other GB TO's (i.e., Scottish Power and SSE) are under increasing pressure to increase network capacity more quickly to facilitate connection of generation in meeting UK renewable targets. The challenge the industry faces is to take forward the optimum investment in a timely manner. Investing against the Contracted Generation background will lead to unnecessary investment.

7. Contracted Generation - East Anglia Region

7.1 The existing generation contained in EC5 Boundary is shown in Table 7.1.

7.2 There is a significant volume of projects being developed in East Anglia area, Table 7.2 shows the potential offshore windfarms along with proposed connection point to the transmission network and connection dates which these projects have contracted with the ESO. It should also be noted that there are potential additional offshore windfarm projects being develop within this region which have not yet entered into a Connection Agreement with the ESO.

Table 7.1 - Generation in East Anglia (within the EC5 group)[14]

Project Name	Connection Site	Capacity (MW)	Plant Type
Dudgeon Offshore Wind Farm	Necton 400kV Substation	400	Wind Offshore
East Anglia One	Bramford 400kV Substation	680	Wind Offshore
Galloper Wind Farm	Sizewell 400kV Substation	348	Wind Offshore
Greater Gabbard Offshore Wind Farm	Sizewell 400kV Substation	500	Wind Offshore
Gunfleet Sands II Offshore Wind Farm	Bramford 400kV Substation	64	Wind Offshore
Gunfleet Sands Offshore Wind Farm	Bramford 400kV Substation	99.9	Wind Offshore
Great Yarmouth CCGT	Norwich Main 400kV Substation	420	CCGT
Scroby Sands	DNO Embedded	60	Wind Offshore
Sheringham Shoal Offshore Wind Farm	Norwich Main 400kV Substation	315	Wind Offshore
Sizewell B	Sizewell 400kV Substation	1230	Nuclear
Thetford	Bramford 400kV Substation	41	Biomass
Total		4158 MW	

[14] Data extracted from the ESO Transmission Entry Capacity (TEC) Register

Table 7.1 – Table showing existing electricity generation in the EC5 Boundary.

Table 7.2 - Future offshore Windfarm Projects in the EC5 group			
Project Name	Connection Site	Capacity (MW)	Effective From
East Anglia One North	Bramford 400kV substation	860	31/03/2026
East Anglia Three	Bramford 400kV substation	1200	31/12/2028
East Anglia Two	Bramford 400kV substation	860	31/12/2025
Norfolk Boreas	Necton 400kV Substation	1320	01/08/2026
North Falls Offshore Wind Farm[15]	Sizewell 400kV Substation	1000	31/10/2030
Scira-Dudgeon Extension	Norwich Main 400kV Substation	950	31/10/2031
Vanguard West	Necton 400kV Substation	1320	01/12/2025
Vanguard East	Necton 400kV Substation	960	01/03/2027
Vanguard East	Necton 400kV Substation	360	31/12/2028
Hornsea Three offshore Wind	Norwich Main 400kV Substation	3000	31/12/2028
Total		11830 MW	

Table 7.2 – Table showing future offshore windfarm projects with contracts to connect in EC5 Boundary.

7.3 In addition to these offshore windfarms there are further developments in both nuclear power stations, interconnectors and Energy Storage Systems which would also potentially drive the need for additional Transmission capacity. These are shown in Table 7.3 below. In total there is a potential 16GW of additional Generation contracted with the ESO to connect to the Transmission network in the East Anglia area.

Table 7.3 - Additional future new generation capacity in the EC5 group			
Project Name	Connection Site	Capacity (MW)	Effective From
Alcemi Bramford Battery Energy Storage	Bramford 400kV Substation	500	30/10/2030
Bramford (Tertiary) Energy Storage	Bramford 400kV Substation	49.9	01/11/2023
Brook Farm BESS Energy Storage	Bramford 400kV Substation	49.9	25/09/2022
Norwich CCGT	Norwich Main 400kV Substation	49.5	31/10/2023
Norwich 100MW BESS	Norwich Main 400kV Substation	100	31/10/2031
Sizewell C - Nuclear	Sizewell 400kV Substation	3340	31/10/2030
Total		4089 MW	

[15] This Generator could be potential connected to a new coastal node located south of the EC5 group.

Table 7.3 Table showing additional future electricity generation projects with contracts to connect in EC5 Boundary.

7.4 Growth in offshore wind generation, along with interconnectors to Europe and new nuclear generation in East Anglia will make a significant contribution in reaching the net Zero targets, if all the contracted generation in this area did proceed it would be potentially contributing in meeting over 25% - 50% of UK demand at any given time depending on the prevailing wind conditions.

7.5 The analysis undertaken by NGET is based on the Contracted Generation background with limited sensitivities been undertaken to assess the robustness of the need against range of potential credible outturns. Historic evidence as demonstrated that Generation Development vary significantly from the Contracted position.

7.6 The GB Connection reform introduces a revised methodology for calculating required network capacity based on an agreed set CPA to reflect current connection rates and reducing the assumption that most projects in the queue will connect. The ESO as also changed the methodology on how to calculate the impact of Batteries and other energy storage technologies in determining the required transmission network capacity given that this technology has a dual purpose. It is unclear how NGET have utilised this revised approach in determining future network capacity requirements.

7.7 It is therefore essential that in determining what future expansion is required the ESO/NGET provide more transparency on their assumptions on what future generation connections are likely to be in each area and not to restrict the justification on future network expansion solely on the ESO contracted position.

8. Need for Network Reinforcements

8.1 EC5N Boundary

8.1.1 With respect to EC5N Boundary, there is less than 1500MW demand within this group the generation connection criteria apply. This requires full export of all this generation from the group when considering a double circuit outage for all '*conditions on the onshore transmission which ought to be reasonably expected to arise in the course of a year of operation*[16]'

8.1.2 Table 8.1 considers the EC5N export requirements against the ESO contracted position. The required exports out of this group will exceed the group capability as the Generation volumes increase and to accommodate the contracted Generation additional transmission capacity will be required by 2028/29. However, it is noted that one project which did have Contract for Difference (CfD) and was being progressed as suspended work due to inflationary pressures making project not commercially viable and no further generation within this group obtained a CfD in this year's allocation which will delay buildup of generation in this group.

[16] Defined in section 2.8 of the SQSS.

Contracted Generation	Table 8.1 - Contracted Generation - EC5N Group									
	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32	2032/33	2033/34	2034/35
(A) Existing	*1195*	*1195*	*1195*	*1195*	*1195*	*1195*	*1195*	*1195*	*1195*	*1195*
(B) New[1]	2137.5	4645.5	5358	6270	6612	6612	7524	7524	7524	7524
(C) Embedded Gen	*664*	*664*	*664*	*664*	*664*	*664*	*664*	*664*	*664*	*664*
(D) Demand	*1138*	*1172*	*1207*	*1243*	*1280*	*1319*	*1358*	*1399*	*1441*	*1484*
(E) Net Export (A+B+C-D)	2859	5333	6010	6886	7191	7152	8025	7984	7942	7899
(F) Network Capacity	6652	6652	6652	6652	6652	6652	6652	6652	6652	6652
Surplus/Deficit (F-E)	3793	1319	642	-234	-539	-500	-1373	-1332	-1290	-1247

Table 8.1 - Table showing existing and new contracted electricity generation in the EC5N Group

8.1.3 The 'Norwich to Tilbury Strategic Option Backtrack and Review' report issued by National Grid it was noted that a higher deficit identified. On inspecting National Grid results it can be seen that the shortfall they identified was for a wider group and critical fault was for the Walpole – Burwell Main – Pelham double circuit which results in increased power flows flowing through East Anglia transmission network from Walpole to Bramford. However, there are additional reinforcement options which may be available to mitigate these power flows. NGET should be invited to present additional options which have not been presented in the Norwich to Tilbury Strategic Option Backtrack and Review which could mitigate these overloads.

8.2 EC5 Boundary

8.2.1 With respect to the EC5 boundary, the demand within this boundary will exceed 1500MW and as such the MITs planning criteria applies.

8.2.2 The EC5 boundary export requirements are considered in Table 8.2 below. Generation output has been reduced in accordance with the requirements of the SQSS (the planning standards do not assume the full output of all generation in each region). Against the contracted generation background this analysis identifies a need for additional transmission capacity from around 2028/29.

	Table 8.2 - Transmission Capacity required to accommodate contracted generation									
	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32	2032/33	2033/34	2034/35	2035/36
(A) Existing	2994	2994	2994	2994	2994	2994	2994	2994	2994	2994
(B) New	5467	5887	7949	9612	10312	10984	10984	10984	10984	10984
(C) Total (A+B)	8461	8881	10943	12606	13306	13978	13978	13978	13978	13978
(D) EC5 Demand	1595	1643	1693	1743	1796	1849	1905	1962	2021	2082
(E) Embedded Gen	840	840	840	840	840	840	840	840	840	840
(F) Interconnectors	0	1600	1600	3000	3000	3000	3000	3000	3000	3000
(G) NET Generation (C+E+F)	9301	11321	13383	16446	17146	17818	17818	17818	17818	17818
(H) Interconnector allowance	875	1112.5	1375	1400	1500	1625	1625	1625	1625	1625
(I) Required Transmission capacity	8580	12390	14665	19103	19850	20594	20538	20481	20422	20361
(J) Network Capacity	12580	12580	12580	12580	12580	12580	12580	12580	12580	12850
(K) Surplus/Deficit (J-I)	4000	190	-2085	-6523	-7270	-8014	-7958	-7901	-7842	-7511

Table 8.2 - Table showing existing and new transmission capacity required to accommodate contracted electricity generation with scaling factors applied.

8.3 SIEX Group

8.3.1 With respect to SIEX group, there is less than 1500MW of demand of this group, hence the Generation connection criteria apply.

8.3.2 Table 8.3 below considers the SIEX export requirements against the ESO contracted position. It can be seen that the required exports out of this group will exceed the group capability as generation volumes increase. To accommodate the contracted generation additional transmission capacity will be required by 2029/30.

Contracted Generation	Table 8.3 - Contracted Generation - SIEX Group							
	2028/29	2029/30	2030/31	2031/32	2032/33	2033/34	2034/35	2035/36
(A) Existing	*2078*	*2078*	*2078*	*2078*	*2078*	*2078*	*2078*	*2078*
(B) New	1000	1000	*2670*	*2670*	*4340*	*5340*	*5340*	*5340*
(C) Interconnectors	0	0	1600	3000	3000	3000	3000	3000
(D) Demand	*100*	*150*	*150*	*150*	*150*	*150*	*150*	*150*
(F) Net Export (A+B+C-D)	2978	2928	6198	7598	9268	10268	10268	10268
(H) Transmission Capacity	5558	5558	5558	5558	5558	5558	5558	5558
(G) Surplus/Deficit (F-H)	2580	2630	-640	-2040	-3710	-4710	-4710	-4710

Table 8.3 - Table showing existing and new contracted electricity generation in the SIEX Group.

8.4 Review of Need

8.1 The analysis as identified that there is need for additional transmission capacity for EC5N, EC5 and SIEX boundaries when considering the ESO Generation contracted position.

8.2 However as noted previously, it is extremely unlikely that all projects will proceed in line with their contracted position. In considering the Generation with connection agreements, further consideration need to be given to:

a. Sizewell C Nuclear power station as a connection date of 31 Oct 2029 & 31 Oct 2030 for Units 1 & 2, respectively. This project has not yet reached financial close and on completion after financial close it is anticipated to take a minimum of 9-12 years. Earliest connection date is unlikely before 2035.

b. Interconnectors – Two Interconnectors with a total capacity of 3GW are planned to connect at or close to Sizewell. In reviewing the ESO Interconnector register its noted that both projects are still at the Non-Statutory Consultation Stage. Given that the connection at this location is a major contributor to future investment requirement, the ESO should give further consideration to optimum connection points, with the potential to move further South (potentially Tilbury or Bradwell) thus freeing up capacity to accommodate offshore wind generation.

c. Offshore Wind – there is presently circa 12GW of offshore wind generation being developed which may connect into the East Anglian region. To meet the government targets a further 35GW of offshore wind will be required to connect by 2030. There is presently over 110 GW of offshore wind farm generation projects being developed. ESO have noted the majority of projects do not proceed in line with their contracted position. Whilst it's recognised that many of the East Anglian projects are actively being progressed, there is significant uncertainty if and when these Generations projects will connect.

8.3 Additional sensitivity studies have been undertaken in examining both the need and timing of future capacity out of the East Anglia Region. The sensitivity studies have been based on assumption that the Bramford – Twinstead Tee and Sizewell to Richborough HVDC link established with a commercial operational solution being applied. The results of this analysis are shown in Table 8.4 below.

8.4 Further analysis has been undertaken to assess how much additional offshore wind could be accommodated against a range of scenarios without the proposed Norwich to Bramford to Tilbury reinforcements. The results of this analysis are shown in table 8.5 below.

a. The capacity column shows volumes of offshore wind that could be accommodated in each group for the scenario being considered.
b. Generation accommodated shows the percentage of contracted generation which could be accommodated in in the three groups under consideration by 2030 and 2035.
c. The final column indicates the maximum volume of new generation which could be accommodated in the East Anglia region (within the EC5 boundary) without adoption of any operational solutions.
d. Thus, could be further enhanced by adopting operational solutions such as I/T and dynamic line ratings until additional transmission capacity was made available.

8.5 It should also be noted that given the GB Connection reform being progressed by the ESO it will be easier to re-allocate transmission capacity to projects which are ready to connect.

	Table 8.4 - Transmission Capacity required - delayed Sizewell C and only one interconnector in group.									
	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32	2032/33	2033/34	2034/35	2035/36
(A) Existing	2994	2994	2994	2994	2994	2994	2994	2994	2994	2994
(B) New	5467	5887	6559	6811	7511	8183	8183	8183	8183	8183
(C) Total (A+B)	8461	8881	9553	9805	10505	11177	11177	11177	11177	11177
(D) EC5 Demand	1595	1643	1693	1743	1796	1849	1905	1962	2021	2082
(E) Embedded Gen	840	840	840	840	840	840	840	840	840	840
(F) Interconnectors	0	0	0	1600	1600	1600	1600	1600	1600	1600
(G) NET Generation (C+E+F)	9301	9721	10393	12245	12945	13617	13617	13617	13617	13617
(H) Interconnector allowance	875	1112.5	1375	1400	1500	1625	1625	1625	1625	1625
(I) Required Transmission capacity	8580	9190	10075	13501	14249	14992	14937	14880	14821	14760
(J) Network Capacity	12580	12580	12580	12580	12580	14580	14580	14580	14580	14580
(k) Operational solutions	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400
(L) Surplus/Deficit (J-I-k)	5400	4790	3905	479	-269	988	1043	1100	1159	1220

Table 8.4 - Table showing electricity transmission capacity required with sensitivities applied relating to the delay of Sizewell C and including only one interconnector.

Table 8.5 -Volumes of additional Offshore Wind which can be accommodated without Norwich - Tilbury development						
Sensitivity studies	**EC5N**		**EC5**		**SIEX**	
	Available Capacity	**Generation accommodated**	**Available Capacity**	**Generation accommodated**	**Available Capacity**	**Generation accommodated**
(a) Contracted Generation	5.7GW	100% (72%)	0.6GW	8% (14%)	0	N/A
(b) As (a) but Sizewell C assumed to connected post 2035	5.7GW	100% (72%)	4.5GW	45% (48%)	0.5GW	N/A
(c) As (b) but with the Sizewell to Richborough HVDC link commissioned 2030	5.7GW	100% (72%)	5.9GW	68% (66%)	2.5GW	N/A
(d) As (c) but with Interconnectors moved out of group	5.7GW	100% (72%)	9GW	100% (100%)	5.5GW	N/A

Table 8.5 - Table showing electricity transmission capacity required with sensitivities applied relating to the delay of Sizewell C and including only one interconnector.

9. Description of Available Technical Solutions

9.1 Technology Overview

9.1.1 This section provides an overview of the technologies available to address the network capacity shortfalls. A high-level description of the relevant features of each technology and indicative cost for each of the technologies considered.

9.1.2 In providing this technology overview the consideration of available technology will be restricted to technologies which can provide adequate transmission capacity to address shortfalls which have been identified in the East Anglia region.

9.1.3 The estimated costs provided are based on a high-level assessment of requirements and do not consider the detailed requirements for any individual project. These can only be ascertained following a design review of individual projects.

9.2 High Voltage Overhead Lines

9.2.1 High Voltage AC Overhead lines (OHL) form most of the existing transmission systems in Great Britain and in transmission systems across the world. OHL are made up of three main component parts which are pylons (used to support the conductors) and insulators (used to safely connect the conductors to the pylon) and Conductors (used to transport the power).

9.2.2 In GB network, the pylons are typically designed to carry two circuits, one at each side of the pylon. Each circuit consists of three phases, and each phase needs to be installed on a separate arm on the Pylon.

9.2.3 The number of conductors per phase depends on the amount of power to be transmitted. For 400kV operation there will be either three or four conductors per phase, which will provide a total capacity of circa 3400MW per circuit (which gives a total capacity of a new OHL of circa 6800MW).

9.2.4 However, it should be noted that given the meshed nature of the GB transmission system and the need to ensure the network remains secure following critical outages, it will be difficult to fully utilise this capacity without utilisation of power flow technology.

9.3 Onshore Underground Cables

9.3.1 Underground cables at 275kV and 400kV make up approximately 10% of the existing transmission system in England and Wales. Most of the underground cables are installed in Urban areas where achieving an overhead route is not feasible. However, there is becoming an increasing recognition of the importance of protecting nationally designated landscapes areas and preserving important views where underground cable solutions have been adopted for existing and new OHL.

9.3.2 Underground cable systems are made up of two main components – the cable and connectors. Cables consist of an electrical conductor in the centre, which is usually copper or aluminum, surrounded by insulating material and sheaths of protective metal and plastics. Due to the weight of a HVAC cable, they are delivered to site in drums which limits the maximum total length of an individual section of cable. Cable joints are required which connect one cable to another cable or connect a cable to an OHL.

9.3.3 The rating of a HVAC Cable is a function of voltage, cross sectional area of cable and number of cables utilised per phase. In seeking to match the rating of an OHL it will require 3 cables per phase which results in 9 cables per circuit.

9.3.4 Due to the electrical characteristic of underground cable the ability of HVAC cables to transfer power is reduced for longer cables. To offset these phenomena, compensation equipment is required at the ends of the cable. For longer cables compensation equipment is required every 20km to main circuit rating. Subject to installation of appropriate level of compensation there is no restriction on the length of cables.

9.3.5 An alternative to Cables is Gas Insulated Lines (GIL). GIL has been developed from well-established technology of gas insulated switchgear, which has been installed on the transmission system. GIL uses a mixture of nitrogen and Sulphur hexafluoride (SF6) gas to provide the electrical installation. GIL is constructed from Welded or flanged metal tubes, approximately 500mm in diameter, with aluminum conductors in the centre. Three tubes are required per circuit, one tube for each phase. Six tubes are therefore required for two circuits. The analysis in this report has been restricted to cables given the cable system will have a marginally lower cost than a GIL system.

9.3.6 There are several environmental considerations to be made when considering OHL verses cable systems, such as trench required and restrictions on development which can be undertaken on the HVAC cable route, however this consideration is outside the scope of this report.

9.4 Superconductivity Cable Solutions

9.4.1 Consideration was given to the potential use of superconductivity as a solution to transfer higher power on a given route. However, the technology is still in its infancy and whilst there are some small-scale high voltage superconductivity solutions, these have been restricted to short lengths in urban setting. Superconductivity does not presently offer a technical or financially viable alternative to standard high voltage cable solution.

9.5 High Voltage Direct Current (HVDC)

9.5.1 HVDC technology can provide efficient solutions for high power transfers on transmission system and whilst previously been predominately utilised for connection between HVAC systems (for example transferring of power between France and England) it is becoming increasing utilised within AC system to increase boundary capacity when undertaking an economic and environmental appraisal of options. This report will focus on economic appraisal.

9.5.2 A HVDC system comprises of a two-converter station interconnected via HVDC cables. The converter station converts the HVAC to HVDC (and vice versa) and then the power is transferred from sending convertor to the receiving converter via a pair of HVDC cables.

9.5.3 HVDC systems can offer advantages over HVAC underground systems, such as:

a. A minimum of two cables per circuit is required for HVDC system, whereas a minimum of three cables per circuit is required for a HVAC system.

b. Cables with smaller cross-sectional areas can be utilised on the HVDC system in carrying equivalent power on the HVAC system.
c. HVDC cables can be more easily installed and require a much smaller corridor than equivalent HVAC system.

9.5.4 However, whilst the cable system is smaller and easier to install it should be noted that land take to accommodate converter stations is substantial.

9.6 Unit Cost

9.6.1 In undertaking their strategic optioneering NGET have based their high-level option cost on an independent report commissioned by the IET (Electricity Transmission Costing Study – An Independent Report Endorsed by the Institute of Engineering & Technology' by Parsons Brinckerhoff in association with Cable Consulting International). NGET have taken the unit cost from the independent report and then updated the costs in line with inflation and prevailing market conditions as shown in Table 9.1 below. These costs form a reasonable basis for strategic optioneering.

Table 9.1 – Strategic Optioneering, unit cost		
Equipment	Capital Cost (£m)	Description
400kv OHL (rating = 3190 MVA per circuit)	3.98	per km
400kv Cable (rating 3190 MVA per circuit)	39.89	per km
400kv GIL (rating 3190MVA per circuit)	43.25	per km
Cable compensation	27.14	per site
HVDC Converter Station	534	pair
HVDC cables - 2000NVA per circuit	3.09	per km

Table 9.1 - Table showing unit cost for each of the strategic options.

9.7 Economic Appraisal of Different Options

9.7.1 The cost of a 100km system is shown in table 9.2 below. The OHL provides the most economical solution for high power transfer over this distance, however: -

a. If a high percentage of the OHL is required to be via an underground system due to environmental considerations, then HVDC system can start to system becomes more economical attractive.
b. If lower ratings are required both cable and HVDC solutions start to look more economically attractive.
c. It can be technically challenging to fully utilise an OHL on a meshed network and consequentially it may not be possible to fully utilise capability

provided by the HVAC OHL system without further investment to manage power flows.

Table 9.2 - Capital costs for a 100kM 6GW system		
HVAC OHL System	HVAC Underground system	HVDC System
100km x £3.98M= £398M	100km x £39.89 M for cables 6 x £27.14M for compensation stations Total cost £4.2bn	3 x £534M for convertor stations 100km x £3.09M for HVDC cables Total cost £1.9bn

Table 9.2 - Table showing the capital costs for a 100-kilometre 6-gigawatt electricity system.

9.8 Incorporation of Offshore Cost

9.8.1 NGET have noted that incorporating the connection of offshore wind into a HVDC system could increase the cost of the HVDC circuit by circa £500M (cost of a HVDC converter on an offshore Platform). Whilst it true to note that the Transmission cost will increase if offshore wind generation is connected directly to a HVDC link, it is also probable that the total cost in accommodating offshore wind projects will fall as the cost of the offshore connections will fall given the offshore wind developer will no longer be required to build his own HVDC system to connect to the Transmission system and their connection to the grid will be shorter.

9.8.2 To determine the cost/benefits of connecting offshore wind directly to a HVDC transmission link needs a detailed cost appraisal of total costs. Given no justification has been provided for the additional cost it has not been included in the economic appraisal undertaken in this report.

9.9 Commercial Non-Build Solutions

9.9.1 Alongside network reinforcements the ESO has developed and procured a commercial non -build solution to address the shortfall in network capacity. An example of where this has been applied is across the B6 boundary (Anglo - Scottish border). The B6 Constraint Management Intertrip Service (CMIS) helps alleviate constraints which would occur due to lack of network capacity. The ESO has contracted with generators (totalling 2GW in capacity) in the region to provide a more economical method of managing constraints than actions through the balancing mechanism. After going live in April 2022, ESO as reported that this service has provided savings to the consumer of £80m in constraint costs during its first ten months of operation.

9.9.2 The 2003 ETYS notes that 'In order to manage the constraints across the East Coast boundaries, the ESO is also proactively developing a commercial non-build solution, the EC5 Constraint Management Intertrip Service (CMIS)'. The ESO intend to contract with generators in the region to provide a more economical method of managing constraints. This follows the success of the CMIS now in operation across the B6 boundary'.

9.9.3 Whilst the use of commercial non-build solutions does not provide additional transmission capacity it does provide an economic solution in meeting user requirements.

10. Potential Transmission Reinforcement Options

10.1 The following section considers potential reinforcement options to address the shortfall in Transmission Capacity previously identified. The options considered are at a conceptual stage and no environmental assessment has been undertaken with respect to the viability of any of the option under consideration.

10.2 EC5N Boundary

10.2.1 Against the Contracted Generation background additional transmission capacity is required. The limiting circuits have the highest rating which the existing Pylon and infrastructure can accommodate and therefore to provide more capacity out of this group either a new OHL or a HVDC circuit will be required. This could be achieved by connecting a new circuit directly to the existing 400kV substations at Necton or Norwich Main or by establishing a new 400kv substation between Necton and Norwich Main 400kv substations. For this high-level analysis it has been assumed that the new OHL or HVDC solution would be connected to the existing 400kv substation at Norwich.

10.3 EC5N Boundary – OHL solution

10.3.1 Four possible OHL solutions have been considered as shown in Figure 10.1 below. With a high-level assessment made on each potential option.

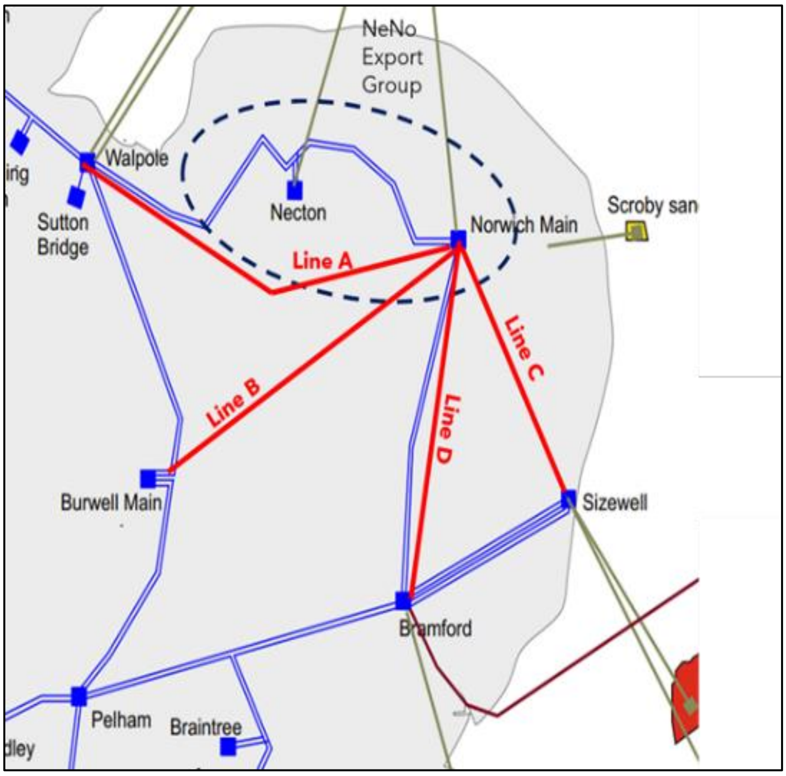

Figure 10.1 – Map and diagram showing potential overhead line solutions in EC5N Boundary.

Option Analysis for EC5N Boundary	
Line A	**OHL between Norwich Main to Walpole x (does not meet system requirements)**
	• Estimated total length 78kM (capital cost £352m)
	• Provides additional capacity to facilitate generation connection in EC5N boundary.
	• For loss/outage of circuits between Pelham – Walpole the Norwich Main to Bramford is potentially overloaded.
Line B	**OHL between Burwell Main to Norwich Main x (does not meet system requirements)**
	• Estimated total length circ 96kM (capital cost £424m)
	• Provides additional capacity to facilitate generation connection in EC5N boundary.
	• For loss of/outage of Burwell Main to Pelham the Norwich Main to Bramford is potential overloaded
Line C	**OHL between Sizewell to Norwich Main x (does not meet system requirements)**
	• Estimated total length circa 60kM (capital cost £280m)
	• Provides additional capacity to facilitate generation connection in EC5N boundary.
	• Would result in additional transfers into the SIEX group resulting in an accelerated need to reinforce this group.
Line D	**OHL between Bramford to Norwich Main √ (does meet system requirements)**

Option Analysis for EC5N Boundary	
	• Estimated total length 80kM (capital £350m)
	• Provides additional capacity to facilitate generation connection in EC5N boundary.
	• Provides additional capacity to accommodate loss/outage of circuits between Pelham -Walpole

Table 10.1 – Table containing bullet points related to the options analysis for EC5 Boundary

10.3.4 Of the four feasible options considered the OHL between Bramford to Norwich Main best meets the system requirements.

10.4 EC5N boundary – HVDC Solution

10.4.1 An alternative to an OHL solution would be the installation of HVDC solution. The shortfall of capacity out of this group is circa 1.25GW, thus requiring a single HVDC links with a total capacity of 2GW. One possible solution is shown in Fig 10.2 below.

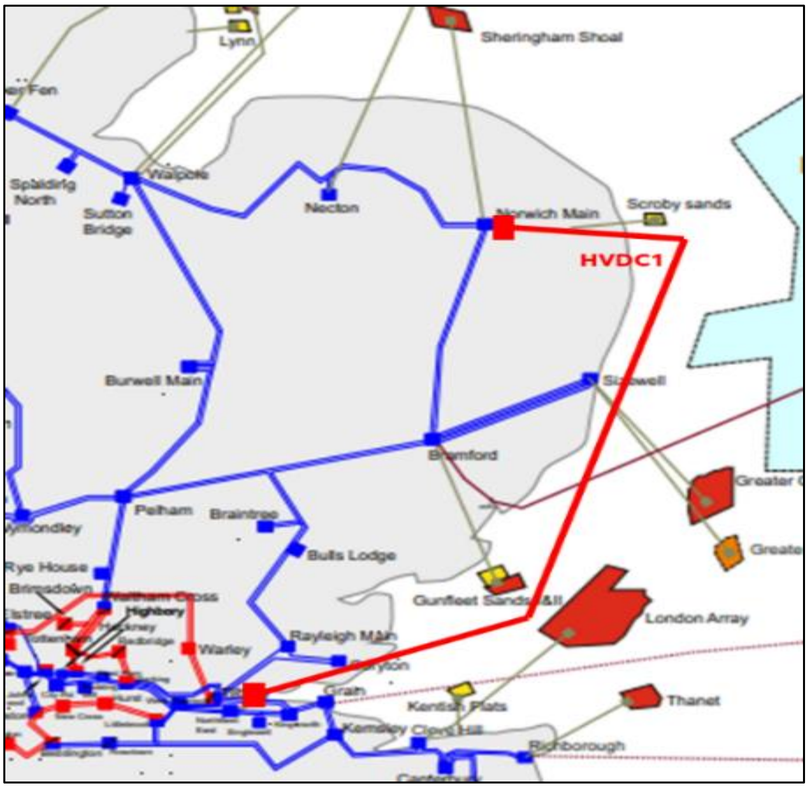

Figure 10.2 – Map and diagram of East Anglia showing potential high voltage direct current solutions in EC5N Boundary.

Option Analysis – HVDC Options	
HVDC1 – X 2GW link between Norwich Main to Tilbury, 400Kv	• Estimated Cost circa £1.3bn

Option Analysis – HVDC Options	
substation – approx. distance 220km.	• Provides 2GW of additional capacity across EC5N Boundary and EC5 Boundary.

Table 10.2 – Table containing bullet points related to the high voltage direct current options analysis for EC5N Boundary

10.5 EC5N boundary – Transfer Generation

10.5.1 The East Anglia network predominantly consists of a single double circuit between Walpole- Necton – Norwich Main – Bramford 400kv substations. The offshore connection is predominately via AC connection and to the nearest convenient point to the Transmission system. There is little opportunity to transfer to an alternative point on the transmission network without occurring significant delays and an increase in the offshore connection costs.

10.6 SIEX Group

10.6.1 Against the Contracted Generation background additional transmission capacity is required. There is the potential to increase the group export capability by installing higher rated conductors on the four circuits connecting Sizewell to Bramford, but this will only increase the export capability of this group to circa 6800MW.

10.6.2 To provide the required capacity out of this group either a new OHL or a HVDC circuit will be required. This could be achieved by connecting directly to the existing 400kV substations at Sizewell as shown in Fig 10.3 below.

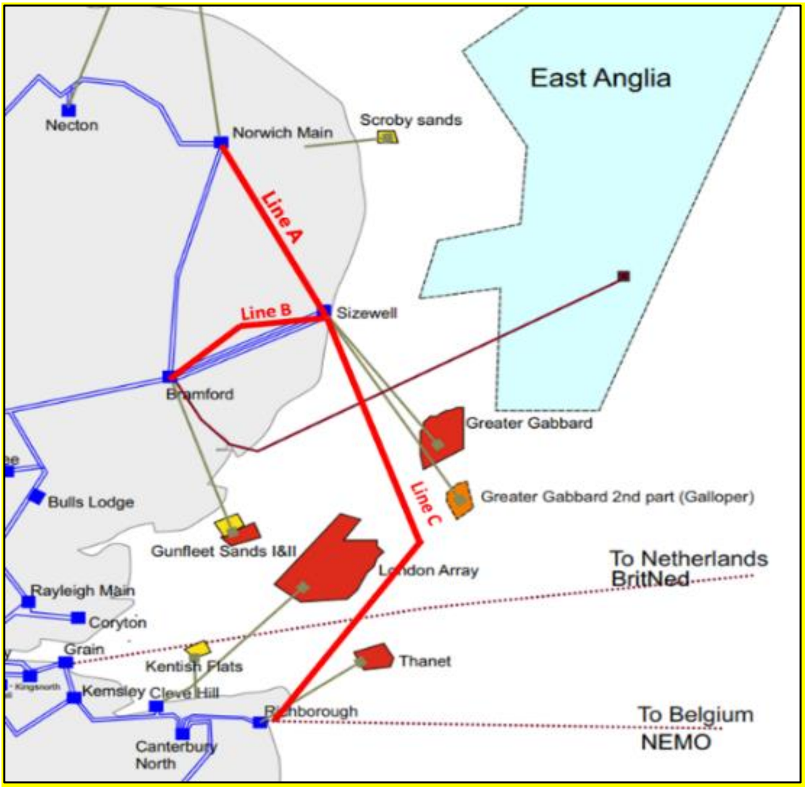

Figure 10.3 – Map and diagram of East Anglia showing reinforcement solutions in the SIEX Group

Option Analysis for SIEX Group	
A	**New OHL between Norwich Main to Sizewell x (does not meet system requirements)**
	• Estimated total length 60kM (£260M)
	• Provides little addition extra capacity[17] in facilitate generation connection in SIEX group.
	• Does not provide any additional capacity across EC5 boundary.
B	**New OHL between Bramford to Sizewell √ (does meet system requirements)**
	• Estimated total length circ 43kM (£212m)
	• Provides additional capacity to facilitate generation connection in SIEX group.
	• Does not provide any additional capacity across the EC5 boundary.
C	**New HVC Link between Sizewell to Richborough √ (does meet systems requirements)**
	• Estimated total length 120kM (£904M)
	• Provides additional capacity to SIEX group.
	• Provides 2GW of additional capacity across the EC5 boundary.
D	**Reconductor all circuits between Sizewell – Bramford √ (does meet systems requirements)**
	• Estimated cost £175M.
	• Provides circa 1GW of additional capacity to the SIEX group.

[17] The through Flows limit network utilisation.

Option Analysis for SIEX Group	
	• Does not provide any additional capacity across the EC5 boundary.

Table 10.3 – Table containing bullet points related to the options analysis for SIEX Group

10.6.3 Of the options consider, the Option A – new line between Bramford to Sizewell does provide significant additional capacity out of the SIEX group, increasing the transfer capability from 5550MW to 11100MW, but does not provide any additional capacity across EC5.

10.6.4 Combination of Option C - New HVDC Link between Sizewell to Richborough and option D - Reconductor all circuits between Sizewell – Bramford, does provide adequate additional capacity meet capacity requirements for SIEX group whist providing 2 GW of additional transmission capacity across EC5 boundary.

10.7 SIEX Group – Transfer Generation and/or Interconnectors

10.7.1 Consideration can be given to transferring the two Interconnectors presently planned to connect to Sizewell to location south of the EC5 boundary (possible Tilbury or Bradwell) to free up additional capacity to accommodate renewable generation which could potentially be connected via AC connection. Thus, would potentially reduce the overall cost to the consumer.

10.8 EC5 Boundary

10.8.1 Against the Contracted Generation background 7.5GW of additional transmission capacity is required. The limiting circuits have the highest rating which the existing Pylon and infrastructure can accommodate and therefore to provide more capacity out of this group either a new OHL’s or a HVDC circuits will be required. This could be achieved by connecting directly to the existing 400kV substations at either Bramford, Sizewell or Norwich as shown in Figure 10.4 below.

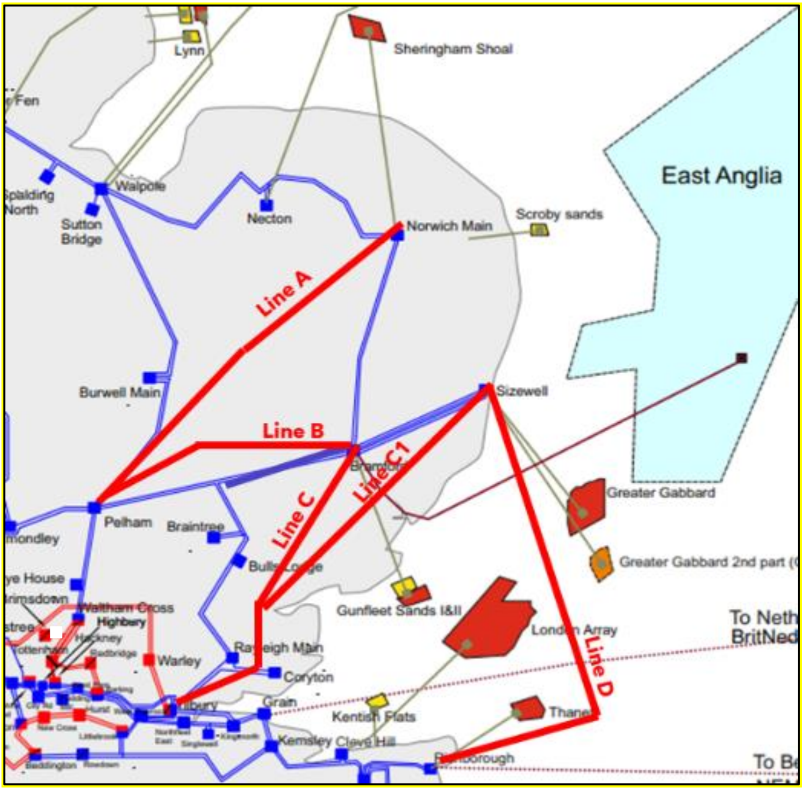

Figure 10.4 – Map and diagram of East Anglia showing potential overhead line and high voltage direct current solution in EC5 Boundary.

Option Analysis for EC5 Boundary	
Line A	**OHL between Norwich Main to Pelham x (does not meet system requirements)**
	• Estimated total length 140Km (£600M)
	• Provides additional capacity across the EC5 boundary.
	• However, in considering the of the outage of circuits between Pelham – Wymondly the Pelham to Waltham Cross would be overloaded.
Line B	**OHL between Bramford to Pelham x (does not meet system requirements)**
	• Estimated total length circ 70Km (£320m)
	• Provides additional capacity across the EC5 boundary.
	• However, for the outage of circuits between Pelham – Wymondly the Pelham to Waltham Cross would be overloaded.
Line C	**OHL between Bramford to Tilbury √ (does meet system requirements)**
	• Estimated total length circa 102 km (£448m)
	• Provides additional capacity across the EC5 boundary.
	• There is transmission capacity available at Tilbury to accommodate this line without triggering the need for further new OHL south of Tilbury.
	• Only provides a maximum of 6.8GW of additional capacity, further reinforcement required.

Option Analysis for EC5 Boundary	
Line C1	**OHL between Sizewell to Tilbury √ (does meet system requirements)**
	• Estimated total length circa 150Km (£640m)
	• Provides additional capacity across EC5 boundary & SEIX group.
	• Available transmission capacity at Tilbury to accommodate this line without triggering the need for further new OHL south of Tilbury.
	• Only provides a maximum of 6.8GW of additional capacity, further reinforcement required.
Line D	**2 x 2.2GW HVDC Link between Sizewell to Richborough √**
	• Estimated total length 120KM (£1.9bn)
	• Provides additional capacity across EC5 & SEIX
	• Provides additional capacity to accommodate loss/outage of circuits between Pelham -Walpole.

Table 10.4 – Table containing bullet points related to the options analysis for EC5 Boundary

10.8.2 To deliver the required additional capacity to meet the contracted position, no single reinforcement identified above provides sufficient capacity. Therefore, a combination of C), D) and E) would be required.

11. Potential Solution to Meet Overall Requirements.

11.1 Combination of OHL + HVDC

11.1 To meet the overall requirements to facilitate the connection of the contracted generation background a combination of OHL and HVDC could be adopted as shown in figure 10.5 below.

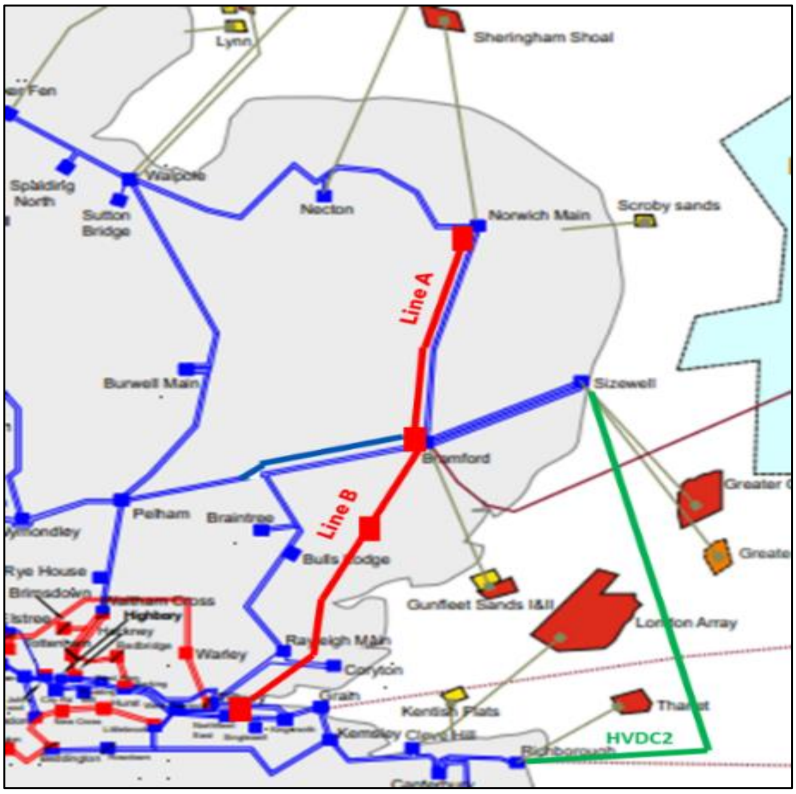

Figure 11.1 – Map and diagram of East Anglia showing a combined overhead line and high voltage direct current solution.

Utilising onshore and offshore solutions at cost of £1.5 bn
a) **Line A Line D - OHL between Bramford to Norwich Main**
• Estimated total length 61Km (£350m)
• Provides additional capacity to facilitate generation connection in EC5N group.
b) **Line B - OHL between Bramford to Tilbury**
• Estimated total length circa 102 km (£448)
• Provides additional capacity across EC5.
• Available transmission capacity at Tilbury to accommodate this line without triggering the need for further new OHL.
c) **HVDC 1 - 1 x 2 GW HVC Link between Sizewell and Richborough**
• total length 120kM (£985M)
d) **Reconductor all circuits between Sizewell – Bramford**
• Estimated cost £350M.
• C) + D) provides sufficient capacity to meet SIEX
This solution provides the following:
• 6.6 GW of additional capacity out of EC5N export
• 2.2 GW of additional capacity out of SEIX
• 8.8 GW of additional capacity out of EC5

Table 11.1 – Table containing bullet points detailing the utilisation of onshore and offshore solutions.

11.2 Offshore HVDC Solution

11.2 Alternatively, the capacity required to facilitate the contracted generation could be accommodated via a series of HVDC links as shown in Figure 10.6 below.

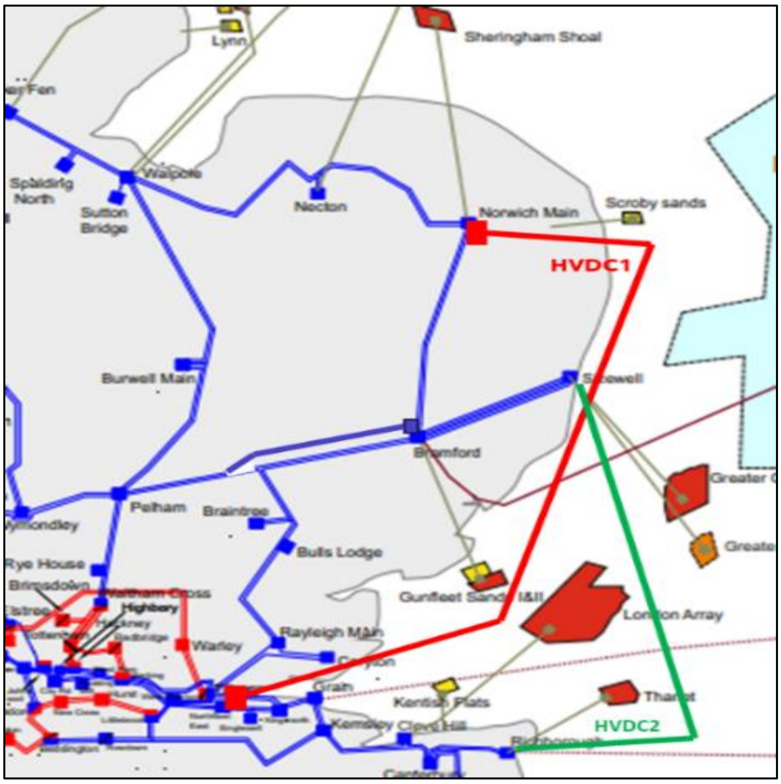

Figure 11.2 – Map and diagram of East Anglia showing a high voltage direct current solution.

Utilising offshore HVDC links at cost of £4.4bn
a) **HVDC 1: 2 x 2.2GW HVDC link between Norwich Main to Tilbury 400KV Substation**
• total length is 220Km.
• Estimated Cost circa £2.5bn
b) **HVDC 2 - 2 x 2.2GW HVC Link between Sizewell and Richborough**
• total length 120kM
• Estimated Cost circa £1,9bn for 2 x 2.2GW link.
This solution provides the following:
• 4.4GW of additional capacity across EC5N boundary
• 4.4GW of additional capacity out of SIEX
• 8.8GW of additional capacity across the EC5 boundary

Table 11.2 – Table containing bullet points detailing the utilisation of offshore high voltage direct current solutions.

11.3 Table 11.3 below provides a high-level summary of the potential solutions. It can be seen that the OHL solution does provide the most economical solution, but the cost of the onshore solution will increase if HVAC cables are required.

Table 11.1 - Cost Comparison of Viable Solutions										
Onshore Solution (OHL + HVDC link)			Onshore Solution (HVAC cables + HVDC link)				HVDC Solution			
Project	Capacity	Cost (£M)	Project	Capacity	Cost (£M)	Ratio	Project	capacity	Cost (£M)	Ratio
Norwich - Tilbury OHL	6.6GW	864	Norwich - Tilbury cabled	6.6GW	7674	8.9	2 X Norwich Main - Tilbury HVDC Link	4 GW	2508	2.9
Sizewell - Richborough HVDC Link	2GW	985	Sizewell - Richborough HVDC Link	2GW	985	1	2 X Sizewell - Richborough HVDC Link	4GW	1930	1.96
uprate Sizewell - Bramford circuits		175	uprate Sizewell - Bramford circuits		175					
Total	8.6GW	2024	**Total**	8.6GW	8834	4.4	**Total**	8.0 GW	4437	2.19

Table 11.3 – Table showing cost comparison of viable solutions.

12. Optimum Timing of Delivery of Required Reinforcements

12.1 In considering future capacity requirements for the EC5 group there is a clear requirement for the Bramford – Twinstead Tee proposal and this report as assumed they have proceeded.

12.2 In looking at subsequent reinforcement there is strong need for the Sizewell to Richborough HVDC link to provide additional capacity for both EC5 and SIEX exports, the timing being dictated by both the development of offshore wind and Sizewell C Nuclear Power Station. Whilst not considered in this report, this solution would provide additional transmission capacity across boundaries LE1 (London Import) and SC2 (South Coast import) (for more detail of these requirements see NGET report – Norwich to Tilbury Strategic Options Backcheck and review)

12.3 The Need for the Norwich to Bramford OHL is dictated by the development of offshore wind connected to Necton and Norwich Main Substation. The present contract position would indicate 2028/29, but there is significant uncertainty with respect to the timing of development of this generation. Furthermore, Operational solutions can be implemented to manage this uncertainty to minimise potential stranding risk. It should also be noted that this solution does not provide any additional transmission capacity across boundary SC2.

12.4 The Need for the Bramford to Tilbury OHL is driven by development of Offshore Wind, Sizewell C Nuclear Power Station a development of new HVDC Interconnectors. Given the uncertainty of volume and speed of development of generation in this group and the opportunity to locate the HVDC interconnectors outside this group, there remains significant uncertainty with regard the need and timing for this proposed reinforcement.

13. Conclusion

13.1 In considering the transmission capacity needs against the ESO Contracted Generation position as stated in the TEC register there is need for additional transmission capacity from both Norwich/Necton and Sizewell 400kV substation to Tilbury and Richborough respectively by 2030.

13.2 There are two credible alternative solutions, either:

Option 1 – 'Onshore solution'

a. Development of a 400kv OHL between Norwich via Bramford to Tilbury 400kv substation.
b. Reconductoring the existing circuits between Sizewell to Bramford.
c. HVDC link between Sizewell and Richborough 400kv substations.

Option 2 – 'Offshore solution'

a. HVDC links between Norwich to Tilbury and Sizewell to Richborough 400kv substation.

13.3 Table 13.1 below provides a comparison of the capital cost in developing Option 1 & Option 2 (note – cost/benefits of connecting offshore wind into the HVDC system have not been included in cost comparison).

Table 13.1 - Cost Comparison of Viable Solutions						
Onshore Solution (HVAC OHL + HVDC link)			HVDC Solution			
Project	Capacity	Cost (£M)	Project	capacity	Cost (£M)	Ratio
Norwich - Tilbury OHL Sizewell - Richborough HVDC Link uprate Sizewell - Bramford circuits	6.6GW 2GW	864 985 175	2 X Norwich Main - Tilbury HVDC Link 2 X Sizewell - Richborough HVDC Link	4 GW 4GW	2508 1930	2.9 1.96
Total	8.6GW	2024	**Total**	8 GW	4437	2.19

Table 13.1 – Table detailing cost comparison of viable solutions.

13.4 However, as noted by the ESO, a high proportion of Contracted generation does not progress in accordance with its contracted position and given the uncertainty of likely generation connection, further sensitivity studies should be undertaken to assess both the robustness of need and timing of any additional transmission capacity which is required to support generation development in the East Anglia Region. These sensitivity studies should consider: -

a. The Timing of Connection of Sizewell C: presently a connection date of 31 October 2029 & 31 October 2030 for Units 1 & 2, respectively. Earliest connection date is more likely to be +2035.

b. Connection points for future Interconnectors – Two Interconnectors with a total capacity of 3GW are planned to connect at or close to Sizewell. The ESO should give further consideration about the connection points to the UK network, with the potential to move further South (potentially either Tilbury or Bradwell) thus freeing up capacity to accommodate offshore wind generation.

c. Volume and timing of Offshore Wind development – there is presently circa 12GW of offshore wind generation being developed which may connect into the East Anglian region. To meet the government targets a further 35GW of offshore wind will be required to connect by 2030 (i.e., Government Target of 50GW from Offshore wind by 2030). There is presently over 110 GW of offshore wind farm generation projects in the Contracted Generation Background. Whilst it's recognised that many of the East Anglian projects are actively being progressed, there remains significant uncertainty if and when these Generations projects will connect.

d. To consider impact of the revised methodology in modelling Batteries and other energy storage technologies in line with the revised ESO recommendations.

13.5 Following the establishment of the proposed Bramford to Twinstead developments NGET have confirmed that this will release significant additional capacity to support offshore development in the East Anglian Region. Table 12.2 below provides a high-level analysis of how much generation could be accommodated against a range of credible scenarios.

13.6 The results of this analysis his shown in Table 13.2 below.

a. The capacity column shows volumes of offshore wind that could be accommodated in each group for the scenario being considered.

b. Generation accommodated shows the percentage of contracted generation which could be accommodated in 2030 and 2035, respectively.

Table 13.2 - Maximum renewables which can be accommodated without Norwich - Tilbury development

Sensitivity studies	EC5N		EC5		SIEX		Max	
	Capacity	Generation accommodated	Capacity	Generation accommodated	Capacity	Generation accommodated	Capacity	Generation accommodated
(a) Contracted Generation	5GW	86% (63%)	0.4GW	5% (4%)	0	N/A	0.4GW	4% (3%)
(b) As (a) but Sizewell C assumed to connected post 2035	5GW	86% (63%)	4.4GW	40% (42%)	0.5GW	N/A	4.4GW	40% (37%)
(c) As (b) but with the Sizewell to Richborough HVDC link commissioned 2030	5GW	86% (63%)	7.2GW	66% (66%)	2.5GW	N/A	7.2GW	66% (61%)
(d) As (c) but with Interconnectors moved out of group	5GW	86% (63%)	11.8GW	100% (100%)	5.5GW	N/A	9.0GW	83% (76%)

Table 13.2 – Table detailing the maximum capacity of renewable energy that can be accommodated in the East Anglia region without the Norwich to Tilbury project.

13.7 From this analysis it can be seen that delaying the decision to commit to a further network expansion of the East Anglia network whilst additional sensitivity studies are undertaken would not delay development of the offshore Wind generation projects and it would ensure risk of stranded investment in Transmission Assets are reduced.

13.8 If this review concludes that there is a reduced need for additional transmission capacity out of the EC5 group, then the economics of the alternative HVDC solution compared to the OHL becomes more economical attractive as shown in Table 13.3 below. A detailed assessment of total cost may show that incorporating appropriate offshore wind development directly into HVDC links could further reduce total cost.

Table 13.3 - Cost Comparison of Viable Solutions with reduced EC5 capacity requirements						
Onshore Solution (HVAC OHL + HVDC link)			HVDC Solution			
Project	Capacity	Cost (£M)	Project	capacity	Cost (£M)	Ratio
Norwich - Tilbury OHL	6.6GW	864	1 X Norwich Main - Tilbury HVDC Link	2 GW	1214	1.4
Sizewell - Richborough HVDC Link	2GW	985	2 X Sizewell - Richborough HVDC Link	4GW	1930	1.96
Total	8.6GW	1850	**Total**	6 GW	3143	1.70

Table 13.3. – Table detailing the cost comparison of viable solutions with reduced EC5 boundary capacity requirements.

13.9 Whilst the proposed OHL from Norwich to Bramford to Tilbury may be the best solution to meet the future needs of the Generation development in East Anglia, given the level of uncertainty associated with the Contracted Generation background it too early at this stage to conclude it does presently represents the best solution in meeting future system needs.

13.10 Further sensitivity analysis is needed to determine both the need and timing for the proposed development. Given the earliest likely need is +2035 undertaking a more in-depth analysis would not delay the development of offshore projects in the East Anglian Region

END