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Bramford to Twinstead Reinforcement

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1. Preface

1.1 Background

1.1.1 The approach that National Grid Electricity Transmission plc (hereafter referred to as National Grid) takes to developing a new project is to first consider the strategic proposal or strategic options.

1.1.2 This includes considering whether the need for new transmission capability can be met without developing new infrastructure at all, for example by doing nothing, by upgrading existing infrastructure or changing the way that the network is operated. It also includes considering different ways in which new infrastructure could be developed, including different technologies, different locations for connection points, or a combination of these.

1.1.3 As set out in the Evolution of the Project (**application document 7.2.6**), the Bramford to Twinstead reinforcement ('the project') was first launched in 2009. The outcome of the initial strategic optioneering process, and the consideration of route corridors that it informed (presented in the Route Corridor Study, 2009, **application document 7.2.3**), was published at this time.

1.1.4 Following public and stakeholder consultation on the strategic options and route corridors, the conclusions of this 2009 strategic options work were subsequently reviewed in 2011. Informed in part by the 2011 strategic options appraisal review, the outcome of the route corridor selection exercise was also published in 2011.

1.1.5 The 2011 strategic options work (originally entitled 'Review of Strategic Options Report' due to its relationship with the 2009 strategic options exercise) is provided in this application as the 'Strategic Options Report (2011) ('the SOR 2011') (this document – **application document 7.2.2**).

1.2 Strategic Optioneering

1.2.1 In 2009, 18 potential strategic options for addressing the need case were identified. These were referred to as Options S1 – S18. While originally presented in 2009, detail of these options is set out in the SOR (2011).

1.2.2 The strategic options were evaluated against relevant technical, cost, environmental and socio-economic criteria to identify which option most appropriately meets National Grid's statutory and licence obligations.

1.2.3 The outcome of the strategic options appraisal in 2009 was that Options S6 (Bramford to Twinstead Tee, not using the corridor of the existing distribution line) and S7 (Bramford to Twinstead Tee, using the corridor of the existing distribution line) were recommended to be taken forward, as these provided the appropriate reinforcement to the transmission network. These options were considered to provide a relatively direct and efficient route, which would achieve a balance between National Grid's technical, economic and environmental obligations.

1.2.4 The conclusions of this work were subsequently reviewed and discussed with stakeholders in 2011. The SOR (2011) considers a shortlist of four options, referred to as PS1 – PS4, drawn from a long list of 18 strategic options identified by the 2009 work. This included combining the preferred Option S6 and S7 from 2009 into a single strategic option PS2 (Bramford to Twinstead Tee). The strategic options considered in 2011 are as follows:

- PS1: Sizewell to Bradwell
- PS2: Bramford to Twinstead Tee;
- PS3: Bramford to Braintree; and
- PS4: Bramford to Rayleigh.

1.2.5 The four options included various sub-options reflecting the potential use of alternative technologies. The outcome of this review was that a 400kV overhead reinforcement between Bramford and Twinstead remained the most appropriate strategic option. It would best meet National Grid's technical, economic and environmental obligations, taking account of National Grid's statutory obligations, its licence standards and all other relevant considerations.

1.2.6 In summary, the strategic proposal on which the project is based is a network reinforcement between Bramford Substation and Twinstead Tee. This was first identified in 2009 as Options S6 and S7 and reconsidered, and re-affirmed in the SOR 2011 as PS2.

1.3 Ongoing Review

1.3.1 Prior to the re-launch of the project in 2020, a new strategic optioneering exercise was carried out from first principles. This formed part of a wider review of project decisions and assumptions at that time. This exercise ensured that the outcomes took due consideration of the changes in the generation background and reflected up-to-date project development principles. This exercise considered 23 potential strategic options, referred to as PSO1 – PSO23. The outcome was that PSO19 (a predominantly overhead line 400kV reinforcement between Bramford and Twinstead) again remained the preferred strategic proposal.

1.3.2 Aside from this exercise, the conclusions of the original SOR (2011) were kept under ongoing review, and the up-to-date position is set out below.

Technical and Cost

1.3.3 Whilst absolute capital costs (for example materials and labour) have increased considerably since 2011, the relative cost of alternative technologies and approaches remain broadly as they were when the strategic option was progressed in 2011, and the SOR 2011 remains relevant and valid when considered against the latest cost information.

1.3.4 The number and variety of contracted generators in the region has increased since 2011 as summarised in Appendix 1 of the Need Case (**application document 7.2.1**). It concludes that the need for the reinforcement has not only re-emerged but is stronger than that which triggered the project previously. The strategic option selected remains the most economic, efficient, and co-ordinated approach to resolving the thermal and stability compliance requirements of the National Electricity Transmission System Security and Quality of Supply Standard (NETS SQSS) that is set out in the up to date Need Case (**application document 7.2.1**).

1.3.5 It is recognised that additional transmission network capability is needed in East Anglia beyond that which would be provided by a single double circuit reinforcement (this Project). However, the need for further network reinforcements in East Anglia, and possible ways of meeting this, does not alter the need for the Bramford to Twinstead reinforcement or the timing of that need which represents the first step in reinforcing the transmission network in East Anglia.

1.3.6 The broad technologies available to National Grid remain similar to those considered in 2011 – including onshore overhead lines, underground cables and offshore cables. The technical considerations that informed the selection of the Bramford to Twinstead strategic proposal remain relevant, and this project remains the most effective way to satisfy the initial need in the East Anglia area.

1.3.7 There have been no changes identified to the relevant technical or cost considerations that suggest that the outcome of the SOR 2011 does not remain valid on technical grounds. Similarly, no project decisions (including confirmation of additional sections of underground cables) taken since 2011 have changed the assumptions on which the strategic option was chosen.

Environmental

1.3.8 The environmental constraints that influenced the strategic options in 2011 include high-level features of international or national significance. These remain broadly the same now as they did when the strategic options were first considered, although there have been some changes to those considered previously as well as new designations introduced or considered.

1.3.9 The key changes are summarised below:

- the potential extension of the boundary of the Dedham Vale AONB westwards towards Sudbury (not yet approved) could pose a constraint to the PS2 Bramford to Twinstead and PS3 Bramford to Braintree strategic options;
- the presence of the Suffolk Coast Heritage Coast could be a constraint to the PS1 Sizewell to Bradwell route surrounding Sizewell;
- the Southern North Sea Special Area of Conservation (SAC) designated in 2019 on the coast (and extending offshore) at Sizewell could be a constraint to the PS1 Sizewell to Bradwell route surrounding Sizewell;

- the Suffolk Coast and Heaths AONB extension areas, designated in 2020, may pose additional constraints to the PS4 Bramford to Rayleigh strategic option;
- no Marine Conservation Zones (MCZ) were designated in 2011. The Blackwater, Crouch, Roach and Colne Estuaries MCZ designated in 2013 would now be a constraint to PS1. This MCZ also lies in close proximity to the western extent of PS4 near Maldon;
- the Alde Shellfish Waters (between Sizewell and Orford), Osea Island including extension Shellfish Waters, Dengie Shellfish Waters and Blackwater Shellfish Waters in the Blackwater and Colne Estuary complex and the Upper Crouch Shellfish Waters are all new constraints to route option PS1;
- numerous bathing waters are designated along the coast between Felixstowe and West Mersea which may pose a constraint to route option PS1; and
- the England Coast Path (sections of which are approved in part or whole, or already open) runs along the entire coastline of the study area and is a new potential constraint to route option PS1.

1.3.10 There have been no changes identified to the relevant environmental constraints that suggest that the outcome of the SOR (2011) does not remain valid on environmental grounds. Similarly, no project decisions taken since 2011 have changed the assumptions on which the strategic option was chosen.

1.4 Conclusion

1.4.1 Whilst some of the technical, cost and environmental factors considered have evolved since 2011, as summarised above, National Grid considers that a reinforcement between Bramford to Twinstead remains the most appropriate solution to resolving the need case, as set out in the following document, originally prepared in 2011.

JUNE 2011

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Bramford to Twinstead Tee Connection Project

Review of Strategic Options Report

1 Introduction

1.1 This Review of the Strategic Options Report (the "Report"), further considers the options previously published in Strategic Optioneering Report of October 2009[1] (the "2009 SOR"). This further review is part of the pre-application procedures adopted by National Grid Electricity Transmission plc ("National Grid") taking account of the Stage 1 consultation feedback received from stakeholders and the general public since National Grid began its consultation on the Bramford – Twinstead Route Corridor Study in Autumn 2009.

1.2 National Grid has identified a need for reinforcement of the electricity transmission system in the East Anglia region (documented in the Bramford-Twinstead Tee Connection Project Need Case June 2011 – the "Need Case"). This review takes account of relevant environmental and socio-economic information, additional information regarding High Voltage Direct Current ("HVDC"), undergrounding and gas insulated line (GIL) technology and the most recent cost data. Reinforcement of the electricity transmission system in the East Anglia region is required to ensure that National Grid continues to comply with its licence standards.

1.3 This Report provides:

(a) A description of National Grid's licence and legal obligations;

(b) A summary of the project need case;

(c) An analysis of the technical options;

(d) An overview of the options appraisal approach;

(e) An overall assessment of each option taking into account technical, economic, and

(f) Summary and identification of our preferred option

[redacted]

1.4 National Grid will continue to regularly review Strategic Options that could meet the identified Need Case in light of changes of circumstances that could materially affect the analysis. These include but are not limited to, technology developments, cost updates and changes to the connection dates of new generators in the region.

1.5 Comments on the content and analysis included in this Report are welcome and will be taken into account in the on-going development of the project and future reviews.

2 Background

2.1 Great Britain has a competitive electricity market guided by mechanisms for the trading of electricity between generators and suppliers. Generators produce electricity from a variety of fuel sources (including coal, gas, nuclear and wind) which is sold in the electricity wholesale market. Suppliers purchase electricity wholesale with most of them providing retail services to customers who use electricity.

2.2 Annual demand in Great Britain is around 310 TWh. This value represents the total amount of electrical energy used in one year. The peak electricity demand in winter is over 60 GW, which is the highest demand seen at an instance of time during the year, with a minimum demand in summer of approximately 40% of peak. The excess of generation capacity over maximum demand, known as the "Plant Margin", is needed to ensure that maximum demand can be met. This allows for uncertainty in the level of the maximum demand, and for the probability that at any given time any given generator may not be operational which also acknowledges the intermittency of wind powered generators.

2.3 The electricity industry is undergoing unprecedented change not least as a result of changes to UK and European legislation. In the next few years, at least 12GW of coal-fired power stations are expected to close as they are not able to meet the requirements of European emissions Large Combustion Plant Directive (LCPD) legislation[2] which comes into full effect by 1st January 2016. At the same time, 7.5GW of existing nuclear capacity will come to the end of its operating life.

2.4 In addition, the UK has two key environmental targets relating to renewable energy and greenhouse gas emissions. The first of these targets is part of the European Union's (EU) integrated energy and climate change proposal. This proposal sets a target of 20% of European Energy (including electricity, heat and transport) to come from renewable sources by 2020 (known as the

2 [redacted]

20/20/20 vision). The Renewable Energy Strategy[3] (published in July 2009) identified that, for the UK to meet its share of the EU target (UK's share is 15% of energy sources including electricity, heat and transport) 30% of UK's electricity would have to come from renewable sources.

2.5 The 2009 EC Renewable Energy Directive[4] sets a binding target for the UK to achieve 15% of its energy consumption from renewable sources by 2020. This compares to only 1.5% in 2005. The National Renewable Energy Action Plan[5] for the United Kingdom includes estimates that of the total 38,210 MW to be provided from renewable energy resources to meet the 2020 target, 14,910 MW would be met by onshore wind, as compared with 1351 MW in 2005.

2.6 The second target which is incorporated in the UK's Climate Change Act[6] 2008 goes further than the EU 20/20/20 vision, and sets a target of 80% reduction in greenhouse gases from 1990 levels by 2050. This equates to a 34% reduction in greenhouse gas emissions by 2020 as specified by the Climate Change Committee.

2.7 Within the parameters set by the UK government, generating companies determine which investments provide the most cost-effective method of satisfying consumer electricity demand. National Grid's role, as defined by legislation and by its licence, is to offer to connect new generation to the transmission system. It is also bound by further licence conditions which stipulate minimum standards for the design of the transmission system.

[redacted]

[6] http://www.legislation.gov.uk/ukpga/2008/27/notes/contents

3 National Grid Role and Obligations

3.1 Transmission of electricity in Great Britain requires permission by a licence granted under Section 6(1)(b) of the Electricity Act 1989 ("the Electricity Act").

3.2 National Grid has been granted a transmission licence and is therefore bound by the legal obligations primarily set out in the Electricity Act and transmission licence.

3.3 National Grid owns and operates the transmission system in England and Wales and is also responsible for operation of parts of the transmission system that are owned by other transmission licensees (SP Transmission Limited and Scottish Hydro Electricity Transmission Limited).

3.4 National Grid has a statutory duty to develop and maintain an efficient, coordinated and economical system of electricity transmission under Section 9 of the Electricity Act. These duties, which are documented in Standard Licence Conditions[7], are summarised in the following paragraphs.

3.5 Standard Condition C8[8] (Requirement to offer terms) of National Grid's transmission licence sets out obligations on National Grid regarding provision of offers to provide connections to and/or use of the transmission system. In summary, where a party applies for a connection National Grid shall offer to enter into an agreement(s)[9] to connect, or to modify an existing connection, to the transmission system and the offer shall make detailed provision regarding:

- the carrying out of works required to connect to the transmission system;
- the carrying out of works (if any) in connection with the extension or reinforcement of the transmission system; and
- the date by when any works required permitting access to the transmission system (including any works to reinforce or extend the transmission system) shall be completed.

[7] http://epr.ofgem.gov.uk/document_fetch.php?documentid=15184
[8] The condition also relates to the use of system and some embedded generating plant.
[9] Paragraph 6 of Licence Condition C8 sets out exceptions where National Grid is not obliged to make an offer e.g. where to do so would put it in breach of certain other contracts or regulations.

3.6 Standard Condition C10 (Connection and Use of System Code) requires National Grid to prepare a connection and use of system code ("CUSC") which sets out, among other things, the terms of the arrangements for connection to and use of the transmission system.

3.7 Standard Condition C14 (Grid Code) requires National Grid to "prepare and at all times have in force and shall implement and comply with the Grid Code". This document (among other things), sets out the technical performance and data provision requirements that need to be met by users connected to or seeking to connect to the transmission system. The document also sets out the process by which demand data from Network Operators and other users of the transmission system should be presented on an annual basis to allow National Grid to plan and operate the transmission system.

3.8 Standard Condition C17 (Transmission system security standard and quality of service) requires National Grid to at all times plan, develop and operate the transmission system in accordance with the National Electricity Transmission System Security and Quality of Supply Standard (NETS SQSS).

3.9 The NETS SQSS is a document that defines the minimum standards that National Grid must apply when planning and operating the transmission system. These criteria include the type of faults (or breakdowns) and combinations of faults that the transmission system must be able to withstand, the impact on customers in terms of maximum level of supply interruptions, and impacts on supply quality that are permissible.

3.10 The NETS SQSS is open to industry and public scrutiny, is subject to periodic review and consultation and any changes are implemented by a change to the licence Standard Conditions and approved by the industry regulator, Ofgem[10].

3.11 The NETS SQSS requires that National Grid must plan for all demand and generation conditions (or "backgrounds") "*which ought reasonably to be foreseen to arise in the course of a year of operation … [and] shall include forecast demand cycles, typical power station operating regimes and typical planned outage patterns.*"

[10] **http://www.ofgem.gov.uk/Pages/OfgemHome.aspx**

3.12 Application of the NETS SQSS achieves minimum performance requirements for the transmission system. These minimum performance requirements underpin the performance of the transmission system in terms of reliability of service delivered and availability of the system for use by generators, demand customers and other users of the transmission system.

3.13 As well as the technical standards described above, Section 38 and Schedule 9 of the Electricity Act 1989 require National Grid, when formulating proposals for new lines and other works, to:

"*…have regard to the desirability of preserving natural beauty, of conserving flora, fauna, and geological or physiographical features of special interest and of protecting sites, buildings and objects of architectural, historic or archaeological interest; and shall do what [it] reasonably can to mitigate any effect which the proposals would have on the natural beauty of the countryside or on any such flora, fauna, features, sites, buildings or objects*".[11]

3.14 National Grid's Stakeholder, Community and Amenity Policy[12] ("the Policy") sets out how the company will meet the duty to the environment placed upon it. These commitments include:

- only seeking to build new lines and substations where the existing transmission infrastructure cannot be upgraded technically or economically to meet transmission security standards;

- where new infrastructure is required seek to avoid areas nationally or internationally designated for their landscape, wildlife or cultural significance; and

- minimising the effects of new infrastructure on other sites valued for their amenity.

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[11] Schedule 9 of the Electricity Act (**http://www.legislation.gov.uk/ukpga/1989/29/contents**).

[12] [redacted]

3.15 The Policy also refers to the application of best practice methods to assess the environmental impacts of proposals and identify appropriate mitigation and/or offsetting measures. Effective consultation with stakeholders and the public is also promoted by the Policy.

3.16 In compliance with these legal duties and obligations, National Grid has conducted a technical, economic, environmental and socio-economic appraisal of the options to resolve the transmission system needs in the East Anglia region.

4 Overview of Technology Options

4.1 This section provides an overview of the technology options used in the evaluation of Potential Strategic options described later in this Report. This section provides a high level description of each technology, its relevant features, capabilities and costs.

4.2 The electricity transmission system in England and Wales operates at both 275kV and 400kV. 275kV was the original transmission voltage whereas the majority of National Grid's transmission system is now constructed and operates to 400kV which facilitates higher power transfers and lower transmission losses.

4.3 There are a number of different technologies that can be used to provide transmission connections. These technologies have different features which affect how, when and where can be used. The main technology options for electricity transmission include:

- Overhead transmission lines;
- Underground cable circuits;
- Gas insulated lines (GIL) and
- High Voltage Direct Current (HVDC) technology.

4.4 In this section each of these technologies is discussed in high level generic terms. Further information, including more detailed technical information is available in a series of factsheets that can be found at:

[redacted]

4.5 **Alternating Current (AC) Overhead transmission line solutions**

4.5.1 **Construction Overview**

4.5.2 Overhead lines form the majority of the existing transmission system in Great Britain (GB) and in transmission systems across the world and there is established understanding of their construction and use.

4.5.3 Figure 4.1 shows the typical configuration of a 275kV or 400kV transmission towers (normally referred to as pylons) each carrying two electrical circuits in three sets of conductors (wires). A standard pylon therefore has six arms, three either side, each carrying a set (bundle) of conductors. The number of conductors required in each set on an arm, depends on the amount of power to be transmitted and is normally between 2, 3 and 4 conductors per set. Newer installations tend to have 2 or 3 sets of conductors as technology developments mean these now carry sufficient capacity.

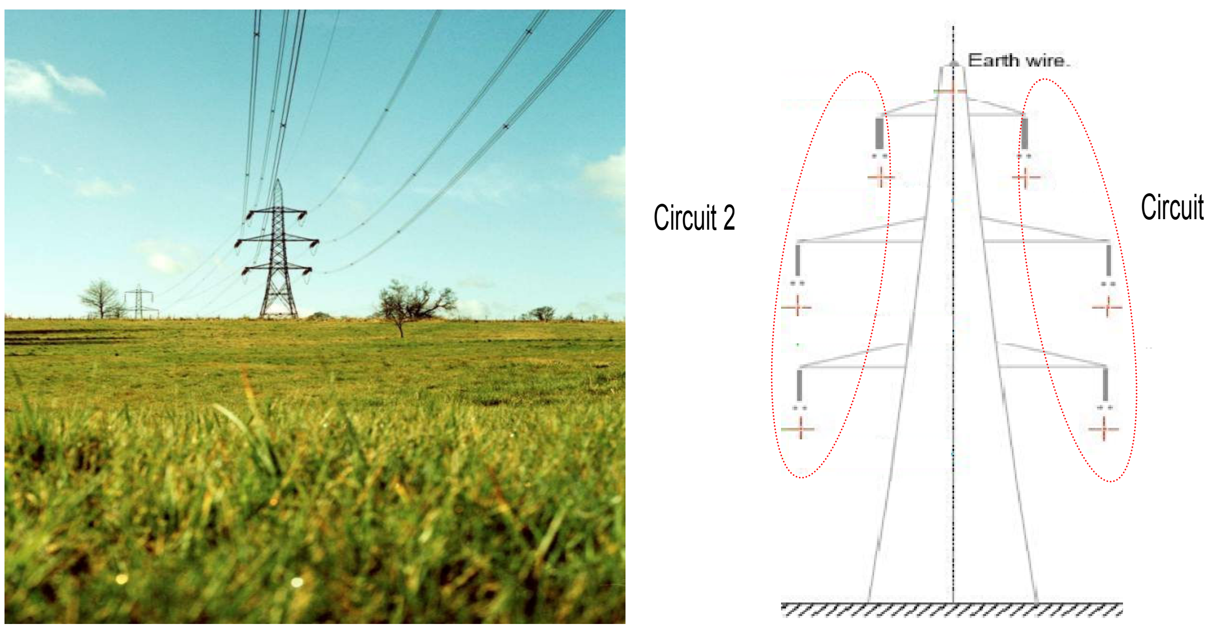

Figure 4.1: Example of a 400kV Double Circuit Tower

4.5.4 The height of 400kV and 275kV pylons is driven by safety considerations associated with providing the clearance needed to prevent the electricity jumping between the lines or to the ground, buildings or structures (known as 'flashover'). The minimum clearance of conductors to ground is set by the lowest point of the conductor which is normally at the mid point between the pylons. The "sag" of the conductor must allow sufficient clearance[13] for vehicles and obstacles as shown in Figure 4.2.

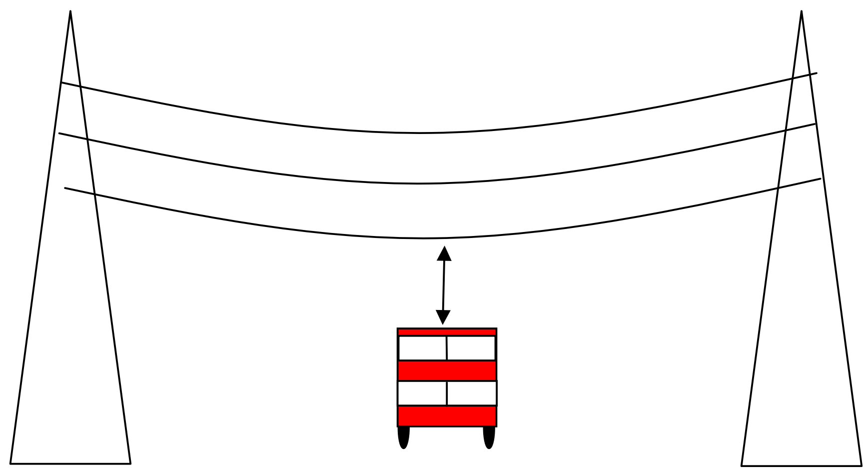

Figure 4.2: Safe height between sag of conductor and vehicle or other

4.5.5 Lower voltage circuits (132kV and below) need less clearance and are therefore smaller in size. However, lower voltage circuits are unable to transport the same levels of power as higher voltage transmission circuits.

4.5.6 On the transmission system, pylons are usually 300-400m apart which ensures the lowest point of the conductor does not infringe clearance distances as described above.

4.5.7 **Technical Overview of Overhead Lines**

4.5.8 Overhead lines are the most common technology used by National Grid and other transmission companies around the world and there is vast operational experience of their use. Transmission companies have established operational processes and requirements for overhead lines forming part of their transmission system.

[13] More information can be found in the brochure "Development near overhead lines" at [redacted]

4.5.9 At times, circuits must be taken out of service for repair and maintenance. However, rapid restoration times are achievable on overhead line circuits where they are needed to maintain a secure supply of electricity.

4.5.10 In addition, emergency pylons can be erected in relatively short timescales to bypass damage and restore supplies. Overhead line maintenance and repair therefore provides a good degree of operational flexibility which helps reduce security of supply risks to end consumers.

4.5.11 Overhead lines circuits are made up of three main component types which are conductors (used to transport power), pylons (used to support the conductors) and insulators (used to safely connect the conductors to pylons). Each of these component types has a different design life which are:

- Between 40 and 50 years for overhead line conductors;
- 80 years for pylons, and
- Between 20 and 40 years for insulators.

4.5 12 Based on the design life of component parts, National Grid assumes an initial design life of around 40 years for overhead line circuits. After the initial 40 year life of an overhead line circuit, substantial pylon replacement works would not normally be required and this is reflected in the indicative capital costs. As pylons have an 80 year life and can be re-used to carry new replacement conductors. The replacement costs for overhead line circuits at the end of their initial design life are assessed by National Grid as being around 50% of the initial capital cost, through the re-use of pylons.

4.5 13 Asset replacement is generally expected at the end of design life and indicative costs for overhead line circuits are assessed on this basis. However, National Grid's asset replacement decisions (that are made at the end of design life) will also take account of actual asset condition and may lead to actual life being longer than the design life.

4.5 14 Table 4.1 below shows the capital installation costs for overhead lines in financial year 2011/12 prices.

No of Conductors Sets (bundles) on each arm of a pylon	275kV Conductors Rating per circuit	400kV Conductors Rating per circuit	Capital Cost For a double circuit pylon route (equivalent cost for a single circuit)
2 conductor sets per arm	1500MVA (3150 Amp limit of National Grid 275kV systems)	3000MVA (circa 4300 Amps)	£1.6m/km (£0.8m/km)
3 conductor sets per arm	N/A	3450MVA (5000 Amp limit of National Grid 400kV systems)	£1.8m/km (£0.9m/km)

Table 4.1: Overhead Line Rating and Costs[14]

4.6 Alternating Current (AC) Underground Cable solutions

4.6.1 Construction Overview

4.6.2 Underground cables at 275kV and 400kV make up approximately 10% of the transmission system in England and Wales which is typical of the proportion of underground to overhead equipment in transmission systems world wide. Most of the underground cable installed in the transmission system is in urban built up areas where achieving an overhead route is not feasible. Examples of other situations where underground cables have been used in the past, in preference to overhead lines, include crossing rivers, passing close to or through parts of nationally designated landscape areas and protecting important views.

[14] Costs included in the table are for overhead lines in rural installations with no obstacles.

4.6.3 Cables consist of the electrical conductor in the middle, which is usually copper or aluminium, surrounded by insulating material and sheaths of protecting metal and plastic. The insulating material acts to prevent flashover, in this case electricity arcing to the ground in which the cable is buried. The properties of the insulating material ensure that although the conductor is operating at 400kV, the outside of the cable is at zero volts and therefore safe.

4.6.4 In order to connect underground cables to above ground equipment such as substations and/or overhead lines, cables require a termination compound or 'cable sealing end', where the cable emerges from the ground and is connected to the substation or line.

Figure 4.3: Key Components of underground cables

4.6.5 Technical Overview of Underground Cables

4.6.6 Due to the nature of the insulating material, cables introduce a significant capacitive effect (causing an increase in voltage) to the operation of the transmission system. This capacitive effect increases as the operating voltage increases and as the length of cable increases As a result, the effects seen on the transmission system include:

- High charging currents;
- Resonance within cable circuits;
- High Voltages (Over-Voltages).

4.6.7 These issues can be managed, but often require additional equipment and specific operational arrangements to do so. Additional equipment requirements include the installation of shunt reactors to counteract the capacitive effect of the cable on voltage. This may at times also require mid-point circuit switching stations for management of charging currents and the strategic placement of shunt reactors but is subject to detailed cable design.

4.6.8 Identifying faults in underground cable circuits will often require multiple excavations to locate the fault and some repairs will require extraction and installation of new cables which can take a number of weeks to complete.

4.6.9 For regular maintenance and inspection high voltage underground cables must be taken out of service and, depending on whether cable excavation has been required, emergency restoration for security of supply reasons, typically takes a lot longer than for overhead lines (days rather than hours).

4.6.10 Underground cable circuits require significant civil works associated with installation. These make the construction times for cable circuits longer than for overhead lines. The construction swathe required for two AC circuits comprised of 2-3 cables per phase is between 35-50m wide.

4.6.11 The costs of underground cables are dependent on the voltage and rating of cables (i.e. how much power they are required to carry). The costs of installation also depend upon the topography of the land and specifically whether the cables are to be directly buried or placed in a tunnel. In general, cable installation is more difficult and therefore expensive in steep and varied terrain than along level areas of easily worked land.

4.6.12 The number of cables which are needed in parallel for each phase depends on the power transfer requirement of the circuit. Table 4.2 below shows the cable requirements for different power transfer requirements. For example, for a 400kV underground circuit carrying up to 1500MVA 1 cable per phase is required. On each transmission circuit on the network there are 3 different phases (just like one side of an overhead line pylon) resulting in 3 cables in total for a 1500MVA circuit. However, for power transfers between 1500MVA and 3000MVA, 2 cables per phase are required, 6 in total.

No of Cables per phase	275kV Cable 2500mm^2 (maximum cable capacity per circuit)	400kV Cable 2500mm^2 (maximum cable capacity per circuit)	Capital Cost For a two circuit cable route (equivalent cost for a single circuit)
1 Cable per Phase (i.e. 3 cables per circuit)	1000MVA (circa 2000 Amp)	1500MVA (circa 2000 Amp)	£8.8m/km (£4.4m/km)
2 Cables per Phase (i.e. 6 cables per circuit)	1500MVA (3150 Amp limit of National Grid 275kV systems)	3000MVA (circa 4300 Amp)	£18m/km (£9m/km)
3 Cables per Phase (i.e. 9 cables per circuit)	N/A	3450MVA (5000 Amp limit of National Grid 400kV systems)	£22m/km (£11m/km)

Table 4.2: Cable Ratings and Costs[15]

4.6.13 The costs of underground cables vary significantly depending on the specific capacity required. For the purposes of this Report, cost estimates are based on the specified rating required for this transmission circuit and assumed topology.

4.6.14 Underground cable circuits are made up of two main component types which are underground cable and connectors (cable joints which connect a cable to another cable, am overhead line or equipment in a substation). Each of these component types has a design life of between 40 and 50 years.

4.6.15 Asset replacement is generally expected at the end of design life and indicative costs for underground cable circuits are assessed on this basis. However,

[15] Cost included in table are for cable elements only direct buried rural installations, with no obstacles. The costs exclude shunt reactors and any intermediate switching stations which are distance dependant. Cable tunnel installations would have a higher capital installation cost than direct buried rural installations, although the cost of cables replacement would be less than the cost of the initial installation because the tunnel would remain in situ.

National Grid's asset replacement decisions (that are made at the end of design life) will also take account of actual asset condition and may lead to actual life being longer than the design life.

4.6.16 Table 4.2 above shows the capital installation costs for underground AC cables in financial year 2011/12 prices. It should be noted that at the end of their initial design life, replacement costs for underground cables are estimated to be equal or potentially slightly greater than the initial capital cost. This is because of works being required to excavate and remove old cables prior to installing new cables in their place in some instances.

4.7 Gas Insulated Lines (GIL)

4.7.1 Gas-insulated transmission lines (GIL) are a developing alternative to conventional underground cables for high voltage transmission. GIL has been derived from the well-established technology of gas-insulated switchgear (GIS), which has been applied on the GB transmission system since the 1970s.

4.7.2 GIL uses a mixture of nitrogen and sulphur hexafluoride (SF_6) gas to provide the electrical insulation, whereas in underground cables the special polymer material provides insulation. Air is the insulator for overhead lines. The GIL is constructed from welded or flanged tube structures with a copper or aluminium conductor running through the centre. Three tubes are required per circuit, one tube for each phase. Six tubes are therefore required for two circuits, as illustrated in Figure 4.4 below.

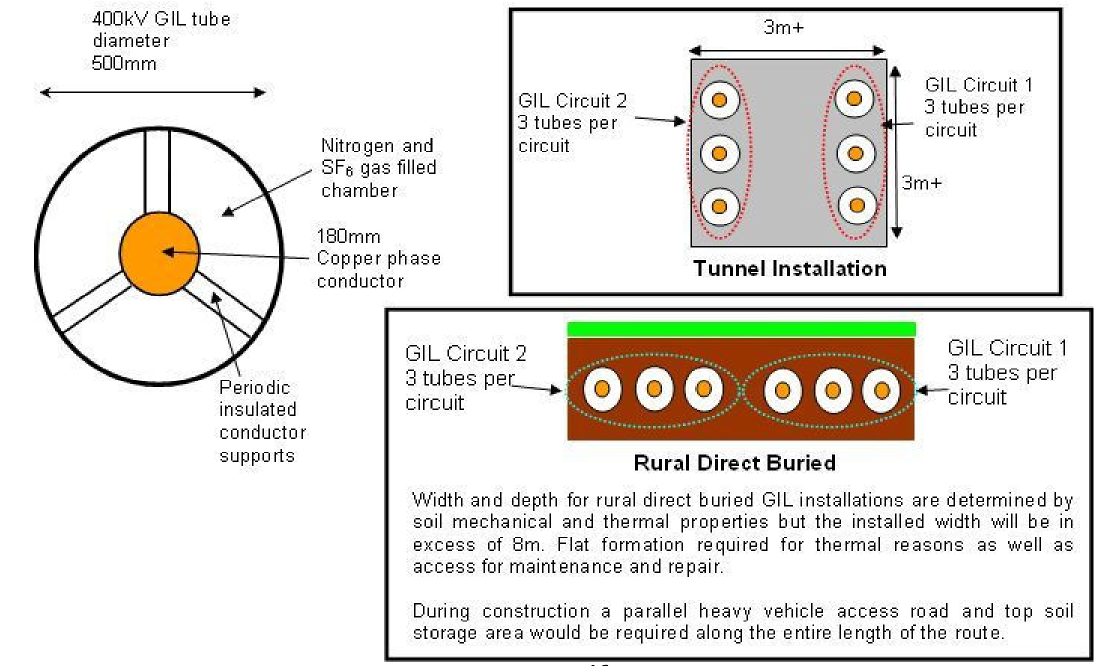

Figure 4.4: Key Components of GIL[16]

4.7.3 National Grid has two GIL installations on the transmission system which are 545m and 150m long. These are in electricity substations; one is above ground and the other is in a tunnel.

4.7.4 The longest length of directly buried transmission voltage GIL in the world, which is approximately 1km, was recently installed on the German transmission system around Frankfurt Airport.

4.7.5 The major advantage of GIL compared to traditional underground cable is that it does not require reactors or intermediate above ground installations that long underground cables require. The installation widths of land can also be smaller than cable installations, especially where more than 1 cable per phase is required. GIL also has a reliability benefit in that like overhead lines these circuits can immediately be reused after a fault. If the fault is permanent the circuit will automatically come out of service again, but if not the circuit can be reused. This cannot be done with underground cables due to the safety risk of a small explosion and resulting permanent cable damage.

[16] The distances are based on initial manufacturer estimates of tunnel and buried GIL dimensions which would be subject to full technical appraisal by National Grid and manufacturers to achieve required ratings which may increase the separation required. It should be noted that the diagram does not show the swathe of land required during construction. Any GIL tunnel installations would have to meet the detailed design requirements of National Grid for such installations.

4.7.6 A potential concern with GIL, from an environmental perspective, is that SF_6[17] gas used in the insulating gas mixture is a potent 'greenhouse gas'. It is not possible to eliminate SF_6 gas completely from the gas mixture with current technology. However, since GIL uses welded enclosure joints instead of bolted flanges, gas leakage is expected to be insignificant and because the enclosure will withstand arcing due to an internal fault, the probability of release of the insulating gas is remote. At the end of life of the GIL, SF_6 can be separated from the gas mixture and recycled or disposed of by incineration.

4.7.7 The GIL installations would also be broken into gas zones, comprising sections of pipes where the gas on either side is contained in separate compartments and can be isolated. This is done to ensure that if a failure does occur then only a limited amount of gas is lost. These zones will be every few kilometres and will need access so that the GIL installed can be filled with the gas mixture during installation.

4.7.8 GIL needs to be brought to site in 10-20m sections of pipe tubing. It is important that no impurities enter the tubing during construction and welding on site, as this would potentially cause the insulation to fail. Therefore the installation methods have additional special requirements over and above that required in natural gas pipeline installations.

[17] SF6 is a greenhouse gas with a global warming potential, according to the Intergovernmental Panel on Climate Change, Working Group 1 (Climate Change 2007, Chapter 2.10.2), of 22,800 times that of CO2. [redacted]

GIL Type based on current Amp rating	275kV GIL	400kV GIL	Capital Cost For a two circuit GIL route (equivalent cost for a single circuit)
Up to 2000A Rated GIL	1000MVA (circa 2000 Amp)	1500MVA (circa 2000 Amp)	£13.5m/km (£6.75m/km)
Up to 4000A Rated GIL	1500MVA (3150 Amp limit of National Grid 275kV systems)	3000MVA (circa 4300 Amp)	£15.2m/km (£7.6m/km)
5000A Rated GIL	N/A	3450MVA (5000 Amp limit of National Grid 400kV systems)	£22.8m/km (£11.4m/km)

Table 4.3: GIL Ratings and Costs[18]

4.7.9 The cost of GIL technology is in the region of £6.75m - £11.4m per circuit km. These costs are favourable when compared to XLPE underground cables when the circuit capacity requirements are very high, which is the case here.

4.7.10 GIL is a new technology and its operational life is not proven. In the absence of proven design life information and to promote consistency with assessment of other technology options, GIL has been assessed over a design life of 40 years.

4.7.11 Table 4.3 above shows the capital installation costs for underground GIL using financial year 2011/12 prices. It should be noted at the end of the initial design life estimated replacement costs for underground GIL would be equal to or potentially greater than the initial capital cost. This is because of works being required to excavate and remove GIL prior to installing new GIL in their place in some instances.

[18] Costs included in table are for GIL direct buried rural installations with no obstacles. GIL tunnel installations would have a higher capital installation cost than direct buried rural installations.

4.8 High Voltage Direct Current ("HVDC") solutions

4.8.1 The electricity that supplies most of the world's homes and businesses is called Alternating Current (AC) electricity. Direct Current (DC) electricity did not develop as the means of transmitting bulk power supplies from power stations because bulk transmission by low voltage DC could only supply homes over short distances. AC electricity however could supply over longer distance by use of transformers to change the voltage level (which only works with AC electricity). This meant that the electrification of whole countries was therefore delivered quickly and efficiently by adopting AC technology rather than DC. This largely remains the case today, with AC solutions normally being the most efficient way of adding transmission capacity.

4.8.2 However, HVDC transmission is used in some special cases and works by converting AC electricity at sending-end converter stations, into DC electricity for onward transmission, and then back to AC electricity at receiving-end converter stations.

Where is HVDC used?

4.8.3 HVDC solutions require converter stations, which have a very significant cost. Although HVDC conductors can cost much less than the AC alternative the overall cost of a HVDC solution including converter stations limits its application.

4.8.4 There are circumstances where HVDC has advantages over AC, generally where transmission takes place over long distances or between different, electrically-separate systems, such as between Great Britain and countries including France, Netherlands and Ireland.

4.8.5 HVDC links may also be used to connect generating stations that are located a long distance from the rest of the electricity grid, for example very remote hydro electric schemes in China utilise HVDC technology with very long overhead lines.

4.8.6 The capital costs of HVDC installations can be much higher than for equivalent AC overhead line transmission routes, although HVDC may be more economic than equivalent AC overhead lines where the route length is many hundreds of kilometres.

4.8.7 In the UK, offshore windfarms generally over 60km from shore will be likely to use HVDC technology as an alternative to an AC subsea cable. AC subsea cables suffer from a number of technical limitations for lengths over 60km, such as high charging currents and the need for mid-point compensation equipment. Cost estimates for HVDC, using the two types of converter station available, are given in Table 4 below:

HVDC Converter Type	2GW Converter Station Cost	2GW DC Cable Pair Cost
Current Source Technology or "Classic" HVDC	£160m (at each end)	£1.4m / km
Voltage Source Technology HVDC	£130m (at each end)	£1.4m / km

Table 4.4: HVDC Costs

4.8.8 Long HVDC systems incur a high capital cost associated with the converter stations as shown in table 4 above. However, the HVDC cables normally make up a lower proportion of the overall cost because when compared to AC equivalent cables they:

- require a minimum of two cables per circuit rather than a minimum of three;
- do not require reactive compensation mid-route, and
- require a cable of smaller cross-sectional area than equivalent AC cables for the same capacity.

4.8.9 DC cable circuits are therefore generally lower in cost than equivalent AC installations due to their construction. For the complete comparison it is also necessary to add in the cost of the 2 converter stations (one at each end) to the cable costs.

4.8.10 Evaluation of transmission projects needs to consider the costs of operating and maintaining equipment. Maintenance costs for DC systems are generally higher than AC because the complex converter stations require regular specialist maintenance. Maintenance costs for all technologies are described in appendix 1 "Lifetime Costs"

4.8.11 HVDC systems have a design life of about 40 years, and large parts of the converter stations (valves and control systems) are normally replaced after 20 years.

4.8.12 Table 4.4 above shows the capital installation costs for HVDC in financial year 2011/12 prices. It should be noted at the end of the initial design life replacement costs for HVDC are significant. This due to the large capital costs for the replacement of converter stations and the cost of replacing underground or subsea DC cables when required.

4.9 Electrical Losses Considerations for Technologies

4.9.1 Transmission losses occur in all electrical equipment and are related to the operation and design of the equipment.

4.9.2 The process of converting AC power to DC is not 100% efficient. Power losses occur in all elements of the converter station: the valves, transformers, reactive compensation/filtering and auxiliary plant. Depending on the specific type of converter, losses can be in the region of 1-2% per converter (2-4% per link).

4.9.3 As there is a cost associated with lost power, these losses can significantly increase the cost of a converter station over its lifetime. When compared to AC transmission, the converter station losses render HVDC transmission considerably less efficient than AC transmission over short distances.

4.9.4 Over short distances, the losses in both AC cables/GIL and AC overhead lines are very small. Losses in AC transmission are in the region of 0.7%-1% per 100km for an overhead line route and 0.3%-0.6% for a GIL/cable system. Consequently, very long lengths of AC cable or AC overhead line are required before the losses in the converter stations are offset and HVDC becomes more efficient than AC.

5 Summary of the Need Case

5.1 The existing transmission system in the East Anglia region is sufficient to comply with the NETS SQSS for current levels of generation and demand. However, a substantial amount of new generation is planning to connect within the region over the next few years.

5.2 A Need Case[19] has been published which explains in detail the current capacity of the transmission system and the requirement to add new capacity from 2016.

5.3 The Need Case explains the current transmission system and the two technical limits that have been identified as limiting factors for the current transmission system in the East Anglia region. The relevant technical limits for the transmission system in the East Anglia region are thermal (the physical ability to transfer power) and stability (specifically, generator transient stability). Each of these technical limits restricts the amount of electricity that can be safely and securely transmitted, which in turn limits the amount of electricity that can be generated.

5.4 The Need Case also explains that the technical limits of the existing transmission infrastructure will be breached over the next few years as new power stations connect to the transmission system and that to maintain compliance with the NETS SQSS, additional transmission capacity in the region is required. Specifically, by 2016 the transmission system infrastructure in the East Anglia region will not be compliant with the NETS SQSS and based on contracted generation of over 20GW of installed generation capacity connected in the East Anglia region by 2021, additional transmission capacity in excess of 8000MW is required across the East Anglia transmission boundary shown in Figure 5.1 below.

[19] Bramford to Twinstead Connection: Need Case for the East Anglia Region (June 2011)

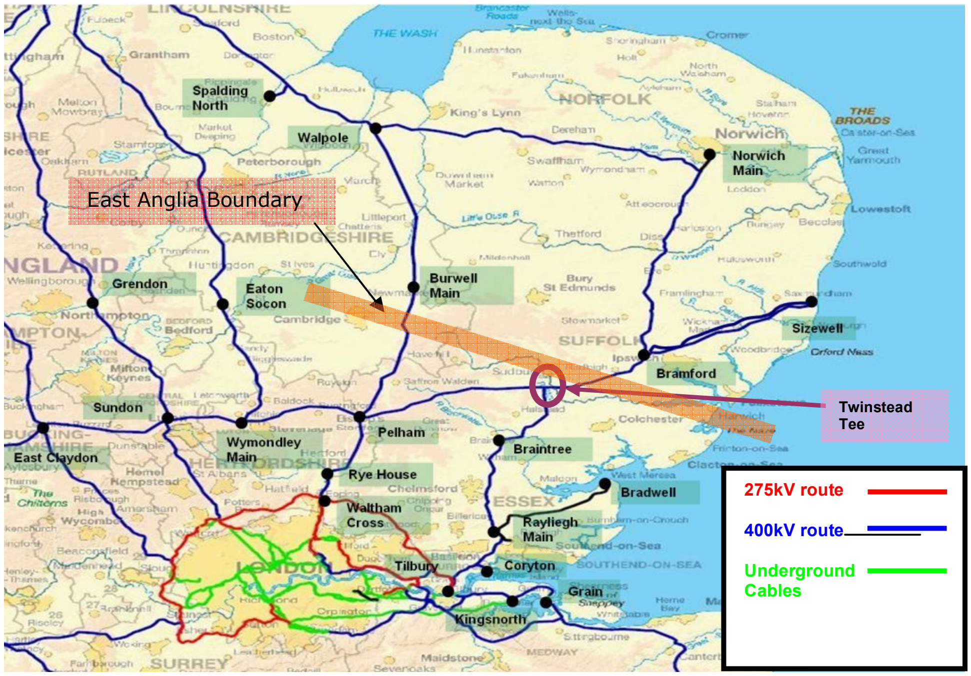

Figure 5.1 East Anglia Transmission Boundary

5.5 The majority of new generation proposing to connect in the East Anglia region, as set out in the Need Case, is low carbon generation. These generators will therefore contribute to government targets for the reduction of greenhouse gas emissions[20].

5.6 The following sections of this document assess a number of potential strategic options that could provide this additional transmission capacity.

[20] As set out in chapter 2 of this Report.

6 Review of Potential Strategic Options

6.1 The 2009 SOR explained the wide range of options that were considered to meet the need for additional transmission capacity in the East Anglia region as a consequence of the connection of 7.6GW of new generation. The 2009 SOR referred to the potential for an additional 7.5GW of wind farms outlined by the ENSG report[21]. However when the 2009 SOR was published, none of these additional wind farms had contracted with National Grid for connection to the transmission system. National Grid's analysis that informed the 2009 SOR showed that against the contracted position in 2009 circa 4GW of additional transmission capacity was required in the East Anglia region at that time.

6.2 The Need Case explains that the requirement for additional transmission capacity in the East Anglia region has increased as a consequence of the need to connect 15.4GW of new generation (an increase of 7.8GW from that used in the 2009 Report). National Grid's analysis from the this recent review (documented in the Need Case) shows that in excess of 8GW of additional transmission capacity is now required in the East Anglia region for the contracted background up to 2021 that is currently established.

6.3 National Grid has investigated a range of options that could resolve the predicted NETS SQSS compliance issues. The range of options considered at the initial investigation stage included the upgrade of existing transmission infrastructure as well as the development of new transmission infrastructure.

6.4 National Grid has a statutory duty under Schedule 9 of the Electricity Act 1989 to develop and maintain an efficient, coordinated and economical system of electricity transmission. It considers options of enhancing existing transmission infrastructure before options requiring wholly new transmission infrastructure. This is usually consistent with its statutory duty to have regard to amenity under Section 38 and Schedule 9 of the Act and promotes more sustainable development. This position is detailed in National Grid's Stakeholder, Community and Amenity Policy[22] ("the Policy").

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[21] Electricity Networks Strategy Group (ENSG) Report "Our Electricity Transmission Network: A Vision for 2020" July 2009 **http://webarchive.nationalarchives.gov.uk/20100919181607/http:/www.ensg.gov.uk/assets/ensg_transmission_pwg_full_report_final_issue_1.pdf**

[redacted]

6.5 National Grid has identified works to upgrade the existing transmission system in the East Anglia region (the "Upgrade Works"). These Upgrade Works, which would be common to any of the options considered are described in Table 6.1 below.

Common - System Upgrades	Total Estimated Capital Cost
Installation of switchable reactors within the existing Rayleigh substation	£283.1m
Reconductoring of Pelham – Twinstead Overhead Line	
Reconductoring of Bramford – Rayleigh Overhead Line	
Reconductoring of Rayleigh – Coryton Overhead Line	
Construction of a New Bramford Substation with increased capacity (sufficient for predicted, increased power flows on the transmission system in the East Anglia region) to replace the existing Bramford substation	

Table 6.1: System Upgrade Works required as part of the East Anglia region NETS SQSS Compliance

6.6 The Upgrade Works would increase the capacity of the existing transmission system in the East Anglia region by 1,240MW which would not be sufficient to connect the new generation documented in the 2009 SOR and far below the current requirement documented in the Need Case. Therefore, National Grid also needed to consider other transmission system reinforcement options for the East Anglia region.

6.7 Taking account of National Grid's statutory and licence obligations set out in section 3 of this Report, it is National Grid's view that the additional transmission capacity required in the East Anglia region can best be achieved by a combination of upgrading existing transmission system infrastructure and installing new transmission circuits.

6.8 The 2009 SOR identified an upgrade option of installing two new circuits between Bramford and Twinstead Tee by overhead line as the most appropriate option for installing new transmission capacity.

6.9 The 2009 SOR included two sets of options Pre-Sanction and Post-Sanction. Pre-sanction refers to the period of up to three months after a customer application is received by National Grid and before an offer is made by National Grid to a customer (in this case generator) seeking connection to the transmission system. Post-sanction refers to the period after the initial offer has been released. As part of National Grid's analysis work during the Post-

Sanction period, detailed Optioneering is undertaken that considers both pre-sanction and any other alternative options for detailed assessment. As the post-Sanction options superseded and incorporated the pre-Sanction options as part of its analysis, only the post-sanction options have been considered in this review.

6.10 The options reviewed and whether updates are provided in this Report are presented in Table 6.2 below.

2009 SOR Ref	Option	Decision 2009 SOR	Considered for Review in this Report	Revised Strategic option reference
S1	Do Nothing	Discount	No	N/A
S2	Enhance Sizewell – Bramford	Discount	No	N/A
S3	Generator action	Discount	No	N/A
S4	Sizewell – Bradwell HVDC undersea cable	Discount	Yes	Option PS1
S5	Sizewell – Bradwell AC undersea cable	Discount	Yes	Option PS1
S6	Bramford – Twinstead	Take forward	Yes	Option PS2
S7	Bramford – Twinstead (DNO route)	Take forward	Yes	Option PS2
S8	Bramford – Burwell	Park	No	N/A
S9	Bramford – Burwell (DNO route)	Park	No	N/A
S10	Sizewell – Twinstead avoiding Bramford	Park	No	N/A
S11	Bramford – Braintree	Park	Yes	Option PS3
S12	Bramford – Rayleigh (DNO route)	Park	Yes	Option PS4
S13	Upgrade Bramford – Twinstead	Discount	No	N/A
S14	Upgrade Bramford – Walpole – Pelham	Discount	No	N/A
S15	Bramford – Rayleigh via Lawford	Park	Yes	Option PS4
S16	Bramford – Rayleigh via Lawford and Bradwell	Discount	Yes	Option PS4
S17	Bramford – Pelham (not via Twinstead)	Park	Yes	N/A
S18	Sizewell – Walpole via Norwich	Park	Yes	N/A

Table 6.2: Options from 2009 SOR subject review in this Report

6.11 As part of the review in this report of the potential strategic options, National Grid has assessed the impact of the increase in contracted generation as well as technology developments. It has also considered, where appropriate, representations made in response to the Stage 1 Consultation including some specific comments on the 2009 SOR. The majority of the representations that National Grid received which addressed issues relevant to the 2009 SOR, were in respect of greater consideration needed of subsea cables and HVDC technology options, considering gas insulated line (GIL) as an alternative to underground AC cables and suggesting that greater account is taken of environmental and socio-economic issues.

2009 SOR Options Not Taken Forward for Review in this Report

6.12 Previous options S1, S2, S3, S13 and S14 in Table 6.2 above were discounted in the 2009 SOR because they failed to achieve compliance with NETS SQSS or other of National Grid's licence obligations. The reasons for discounting each option that were set out in the 2009 SOR remain valid and, in light of the increase in contracted generation, are unchanged and these options are not discussed further in this Report.

6.13 Each of previous options S10 (Sizewell – Twinstead avoiding Bramford) and S17 (Bramford-Pelham avoiding Twinstead) were not taken forward for further consideration in this Report, because the required route length of the new circuits would be much longer than another viable options (including Bramford – Twinstead Tee) and would achieve similar transmission system capacity benefits.

6.14 Each of previous options S8, S9 (Bramford-Burwell) and S18 (Sizewell-Walpole via Norwich) illustrated in Figure 6.1 would reinforce the transmission system in the northern parts of the East Anglia region and were assessed as viable options when the additional capacity requirement was 4GW. With the increased volume of new generation now contracted to connect to and/or use the transmission system, there is a need to increase the capacity of the East Anglia transmission system planning boundary by more than 8GW. None of the previous options S8, S9 or S17 sufficiently enhance the capacity of the East Anglia transmission system planning boundary capacity, as they do not cross the boundary which requires reinforcement, and as such would not meet the requirements of the NETS SQSS. These options are not reviewed further in this Report.

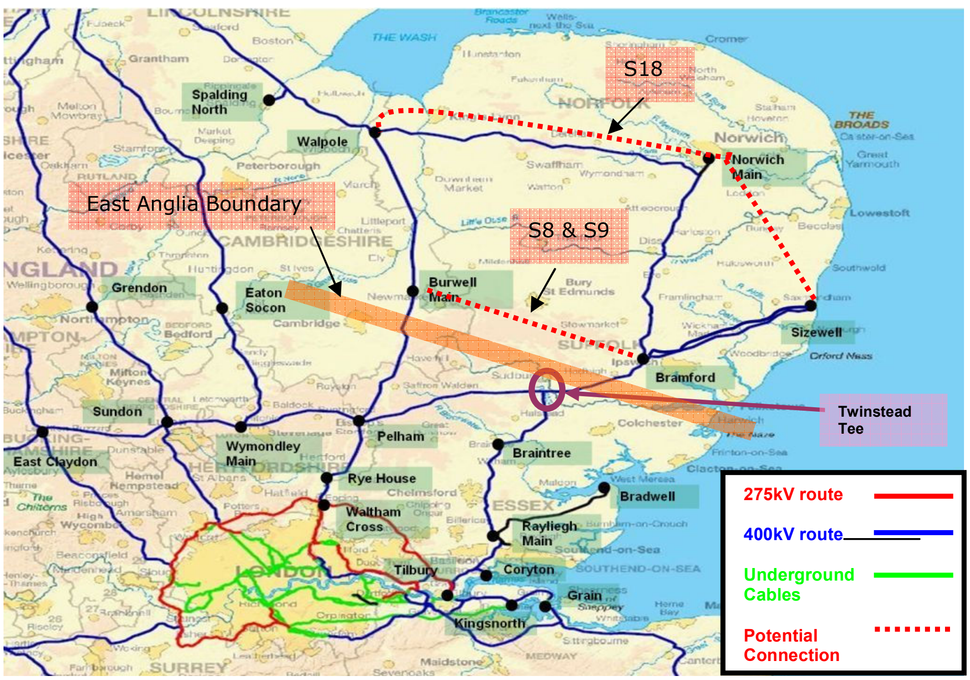

Figure 6.1 Options S8, S9 and S18 from 2009 SOR

2009 SOR Options Taken Forward for Review in this Report

6.15 The 2009 SOR identified that a connection between Bramford substation and Twinstead Tee should be taken forward for further investigation. This is the option that has been subject to Route Corridor Study and Stage 1 Consultation. The two previous variants comprising this option are S6 and S7 in Table 6.2. These variants have been included in the Route Corridor Study and are taken forward for further consideration in this review.

6.16 Previous options S4 (Sizewell–Bradwell HVDC undersea cable) and S5 (Sizewell-Bradwell HVAC undersea cables) have been reviewed in this Report in light of technology developments, increasing operational experience of subsea cable installations throughout the world and representations to Stage 1 Consultation requesting that greater attention is paid to these as alternatives to onshore connections in Suffolk and Essex. The review has also considered the impact of the increase in new generation seeking connection to the transmission system. National Grid now considers that these are potential strategic options that merit further review in this Report. As a result of this review, a subsea cable option between Sizewell and Bradwell has been identified as Option PS1. 2009 SOR previous option S4 (HVDC) is reviewed as variant PS1a and 2009 SOR previous option S5 (AC subsea cable) is reviewed as variant PS1b in this Report.

6.17 Previous option S11 (Bramford-Braintree) was discounted in the 2009 SOR because at that stage, it was considered to require circuits running through the majority of the Dedham Vale Area of Outstanding Natural Beauty. In this review of the 2009 SOR, National Grid has identified a possible route which would not pass through greater areas of the AONB than the Bramford-Twinstead option. Therefore this review now considers the option for a Bramford–Braintree connection as Option PS3.

6.18 2009 SOR previous options S12, S15 and S16 (Bramford-Rayleigh) have been reviewed. Each of these options would deliver equivalent changes to the transmission system and essentially only differ in the extent of changes required to distribution system infrastructure. These potential strategic options have been consolidated and the single consolidated option taken forward for review in this Report. The review considers the option for a Bramford – Rayleigh connection as Option PS4.

Summary of Potential Strategic Options Being Taken Forward for Review in this Report

6.19 Four potential strategic options for reinforcement of the electricity transmission system in the East Anglia region have been considered and are documented in this Report. National Grid considers that each of these options is able to meet the additional transmission system requirements in the East Anglia region (documented in the Need Case) and has taken these options forward for review in this Report.

6.20 The four potential strategic options that were reviewed are:

(a) PS1 Sizewell – Bradwell subsea

In the PS1 option, transmission system reinforcement would be achieved by the installation of a new subsea cable circuit between Sizewell and Bradwell. This option also discuses other necessary transmission changes required to establish connections closer to London and the Thames Estuary.

(b) PS2: Bramford – Twinstead Tee

In the PS2 option, transmission system reinforcement would be achieved by the installation of a new circuit between Bramford and the Twinstead Tee. This option also includes discussion of the variants available if changes to distribution system infrastructure are made to facilitate transmission system works.

(c) PS3: Bramford - Braintree

In the PS3 option, transmission system reinforcement would be achieved by the installation of a new circuit between Bramford and Braintree. It is noted that this option would achieve the same transmission system circuit configuration as PS2, but would involve the installation of approximately 34km of new circuit and would allow removal of approximately 8km of existing 400kV overhead line connections. This option also includes discussion of the variants available if changes to distribution system infrastructure can be made to facilitate transmission system works.

(d) PS4: Bramford – Rayleigh

In the PS4 option, transmission system reinforcement would be achieved by the installation of a new circuit between Bramford and Rayleigh. It is noted that this option would achieve the same transmission system circuit configuration as PS2, but would require the installation of approximately 90km of new circuit and would allow removal of approximately 22km of existing 400kV overhead line connections.

6.21 Each of these four potential strategic options is illustrated in Figure 6.2 below.

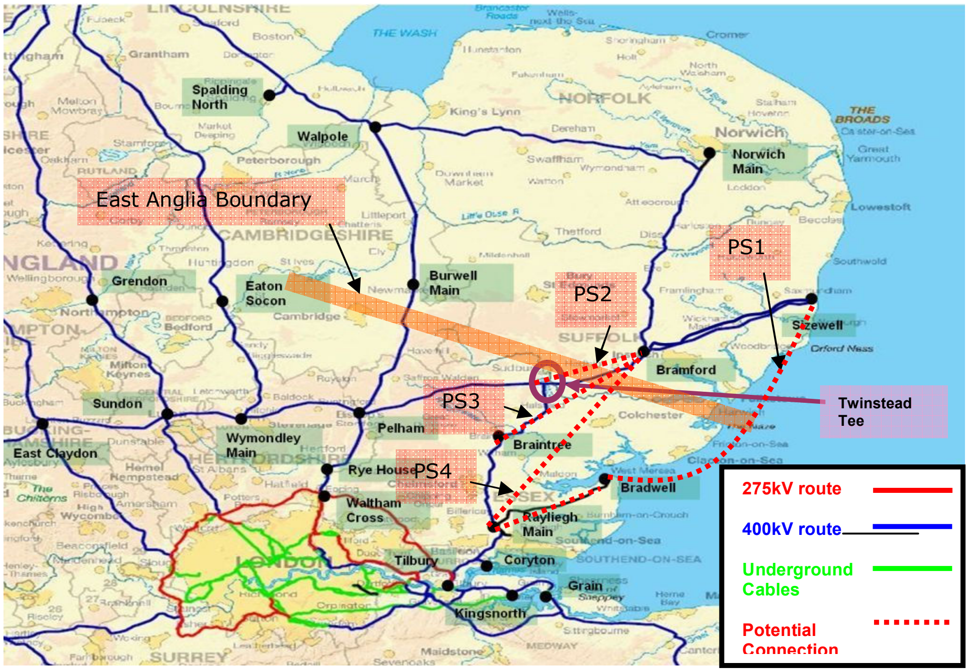

Figure 6.2 Potential strategic options and the East Anglia Transmission System Planning Boundary

6.22 Figure 6.2 shows that each of the identified potential strategic options crosses the East Anglia transmission system planning boundary which requires reinforcement. The scope of each of the potential strategic options includes the upgrade works set out in Table 6.1 which provides an increased capacity of 1,240MW. Each of the potential strategic options considered in this review (PS1, PS2, PS3 and PS4) are required to provide 6800MW capacity to give the 8GW required to increase the transmission capacity across the East Anglia transmission planning boundary.

Appraisal of Technology Suitability for Potential Strategic Options

6.23 Section 4 has described four technology categories for transmission infrastructure which are:

(a) AC underground cables;

(b) Gas insulated lines (GIL);

(c) Voltage source HVDC systems; and

(d) AC overhead lines.

6.24 PS1 would require a new subsea circuit. National Grid considers that only AC or HVDC subsea cables options should be assessed for the connection between Sizewell and Bradwell as overhead line and gas insulated line technologies are not feasible for this potential connection option. However it has been assumed for the purpose of this review that the 400kV connection which would be required between Bradwell and Rayleigh Main substation would be installed using a new overhead line built along the route of an existing 132kV line which would be dismantled and replaced with the new 400kV line. Consideration of other undergrounding technologies between Bradwell and Rayleigh will further add to the capital cost of this option.

6.25 PS2 and PS3 would require new transmission circuits. National Grid considers that overhead line, AC underground cable and gas insulated line technology options should be assessed. National Grid does not consider that HVDC underground technology options are feasible for either of these potential strategic options. This is because the route length of new transmission circuit required for either of these options is not long enough for HVDC solution options to offer any advantage over the AC underground technologies. Over such short distances, HVDC solutions are significantly more expensive than the AC underground technologies, for the required electrical capacity.

6.26 PS4 would require significant lengths of new transmission circuits of greater length than either of options PS2 and PS3. National Grid considers that only overhead line technology options should be assessed as other technology options are not considered to offer any system advantage over PS2 or PS3 and have a greater amenity impact and cost implications.

6.27 Table 6.3 provides a summary of the technology options that National Grid considered should be assessed as part of its review of options analysis of the four potential strategic options.

Technology	PS1 Sizewell – Bradwell Subsea	PS2 Bramford - Twinstead	PS3 Bramford - Braintree	PS4 Bramford – Rayleigh
AC Underground Cables	Yes (subsea cable)	Yes	Yes	No
Gas Insulated Line (GIL)	No	Yes	Yes	No
HVDC	Yes (subsea cable)	No	No	No
AC Overhead Line	No	Yes	Yes	Yes

Table 6.3: Technologies considered for each potential strategic option

6.28 The next section provides an overview of the options appraisal methodology.

7 Overview of Options Appraisal Methodology

7.1 The options appraisal is a multi-criteria analysis which considers relevant technical, environmental and socio-economic issues and the costs associated with each potential strategic option. Analysis of these factors allows National Grid to assess which option best meets its various statutory and licence obligations.

7.2 In accordance with its Policy[23], National Grid will only propose to build new transmission infrastructure where existing infrastructure cannot be technically or economically upgraded to meet system security standards and regulatory obligations. Where there is no viable existing upgrade option, National Grid will develop a solution (e.g. the installation or construction of a new circuit) that seeks to achieve the best integration of its various duties and obligations as set out in Section 3.

Technical Appraisal

7.3 Section 6 explains that each potential strategic option has been assessed initially to ensure that it meets the Need Case and that the resultant transmission system would comply with the standards set out in the NETS SQSS. This means that the implications of each option on both the local and wider transmission system are fully assessed before it is appraised further. Strategic options which do not meet the Need Case or otherwise would not meet the standards set out in the NETS SQSS have not been identified for further analysis.

7.4 In some cases wider transmission works are required to resolve overload or other technical issues arising from a strategic option. This is because the nature of each identified strategic option has a different effect on resolving the need for additional system capacity. The infrastructure works, including wider works, for each strategic option also take into account any construction deliverability and operational issues associated with that option.

[23] Stakeholder Community and Amenity Policy: http://www.nationalgrid.com/NR/rdonlyres/21448661-909B-428D-86F0-2C4B9554C30E/39991/SCADocument6_2_Final_24_2_10.pdf

Economic Appraisal

7.5 Once the full scope of works associated with each option is identified, an estimate of the capital cost of that scope of works is made. For the specific overhead line, underground AC cable, GIL and HVDC components of each option, operational lifetime costs are then estimated.

7.6 Capital cost is an estimate of the cost of equipment and installation costs. These costs are provided in current financial year prices applicable at the time of publication of this Report. For the purposes of reviewing strategic options, the cost estimates are based on generalised unit costs for the key elements of the option, reflecting recent contract values or manufacturers' or consultants' budget estimates. This is sufficient to allow a broad order of consistent costs to be established for the options, as necessary at the strategic level, and is not intended to provide a detailed cost for each option which can only be obtained at the detailed design stage.

7.7 The lifetime cost is an estimate of the transmission losses and maintenance costs for the specific overhead line, underground AC cable (including shunt reactors), GIL or HVDC converter and cable elements of the connection options over a 40 year lifetime. The costs for operation, maintenance and transmission losses are calculated based on a net present value (NPV) discount rate of 3.5%. The 3.5% value is that recommended by Her Majesty's Treasury Green Book[24]. The lifetime cost estimate methodology is explained in Appendix 1.

Environmental Appraisal

7.8 The environmental appraisal for each of the potential strategic options, (see Appendix 2), has considered environmental constraints of international and national importance. Features considered as potential environmental constraints to each strategic option are presented in Table 7.1 below. The table also summarises the legislation under which protection is conferred and the data sources from which information (where applicable) was taken.

[24] HM Treasury Green Book; Appraisal and Evaluation in Central Government; Guidance from HM Treasury to public bodies on how proposals should be appraised prior to significant commitment of funds. Reference Section on Discounting; 5.49; **http://www.hm-treasury.gov.uk/d/green_book_complete.pdf**;

Feature	Legislation	Routeing Response (and Reference)	Data Sources
National Parks	National Parks and Access to the Countryside Act 1949	Seek to avoid/consider undergrounding (NG Commitments/Holford Rule 1)	magic.gov.uk
Areas of Outstanding Natural Beauty	National Parks and Access to the Countryside Act 1949/ Countryside and Rights of Way Act 2000	Seek to avoid/consider undergrounding (NG Commitments/Holford Rule 1)	magic.gov.uk
Heritage Coasts	n/a	Seek to avoid (NG Commitments/ Holford Rule 1)	magic.gov.uk
World Heritage Sites	1972 World Heritage Convention	Seek to avoid (NG Commitments/ Holford Rule 1)	english-heritage.org.uk
Sites of Special Scientific Interest	Wildlife and Countryside Act 1981 Countryside and Rights of Way Act 2000	Seek to avoid/verify potential effects (NG Commitments/ Holford Rule 2)	gis.naturalengland.org.uk
Special Protection Areas	The Conservation of Habitats and Species Regulations 2010	Seek to avoid (birds interest) (NG Commitments/Holford Rule 2)	gis.naturalengland.org.uk
Special Areas of Conservation	The Conservation of Habitats and Species Regulations 2010	Seek to avoid (birds interest) (NG Commitments/Holford Rule 2)	gis.naturalengland.org.uk
Ramsar sites	The Conservation of Habitats and Species Regulations 2010	Seek to avoid (birds interest) (NG Commitments/Holford Rule 2)	gis.naturalengland.org.uk
National Nature Reserves	National Parks and Access to the Countryside Act 1949	Seek to avoid/verify potential effects (NG Commitments/ Holford Rule 2)	gis.naturalengland.org.uk
Scheduled Monuments	Ancient Monuments and Archaeological Areas Act 1979	Seek to avoid/consider effect on setting (NG Commitments/ Holford Rule 2)	english-heritage.org.uk
Settlements	n/a	Seek to avoid (Supplementary Note)	Digitised from Ordnance Survey
Historic buildings (Listed I, II and II*)	Planning (Listed Buildings and Conservation Areas) Act 1990	Seek to avoid/consider effect on setting (Note to Holford Rule 2)	english-heritage.org.uk
Conservation Areas	Planning (Listed Buildings and Conservation Areas) Act 1990	Seek to avoid/consider effect on setting (Note to Holford Rule 2)	Development plans
Registered Parks and Gardens	n/a	Seek to avoid (NG Commitments)	magic.gov.uk
Registered Battlefields	n/a	Minimise effects (NG Commitments)	english-heritage.org.uk
Woodlands	n/a	Seek to avoid (Note to Holford Rules 4 and 5)	National Inventory of Woodlands
Landform	n/a	(Holford Rules 4 and 5)	OS Open Data

Table 7.1 - Environmental constraints and data sources

7.9 In accordance with the National Policy Statement for Electricity Networks Infrastructure EN-5[25], when siting new overhead lines, the principles of the Holford Rules should be taken into account.

Environmental issues scoped out of the appraisal at this stage

7.10 There are some environmental factors that do not influence the high-level strategic appraisal. The factors scoped out of the appraisal at this stage are outlined in the following paragraphs of this section.

7.11 Although these factors have been scoped out of the options appraisal process at this stage, they will require consideration as part of routeing studies, detailed design and environmental assessment whichever strategic option is taken forward.

Flood Risk

7.12 National Grid considers its siting of installations such as substations very carefully in relation to flood risk. However, it is relatively straightforward to build flood resilience into overhead lines by addressing safety clearances from anticipated flood levels in the overhead line design. The presence of overhead line pylons in areas of flood risk has negligible effect on the risk of displacement of water as the lattice steel construction poses no material changes to surface water flow.

7.13 The presence of an underground cable circuit in areas of flood risk would not affect the circuit's operation and has a negligible effect on the risk or displacement of water as underground circuits pose no material changes to water flow.

7.14 As outlined at paragraph 4.8.2 converter stations are required for HVDC connections and in paragraph 4.5.7 outlined the possibility for mid-point switching stations which may be required for long AC cables. The location of the converter stations or mid-point switching stations would require further consideration and assessment in accordance with Planning Policy Statement

[25] Paragraphs 2.8.4 -2.8.7, Pages 13-15, National Policy Statement for Electricity Networks Infrastructure (EN-5), Version for Approval. Department of Energy and Climate Change, June 2011

(PPS) 25 if these technology solutions for potential strategic options were taken forward. At this stage of appraisal, available information on flood risk is indicative only and therefore has not been considered for any of the options. Flood risk will be considered in more detail for options that are taken forward.

Noise

7.15 Noise during construction will be temporary and managed by procedures and controls to ensure that it is not unacceptable. Noise during operation will be controlled primarily by separation of sources of noise from noise-sensitive receptors and also by noise-suppression measures as appropriate. The review of options considers whether there is likely to be appropriate distances from settlements and dwellings for amenity reasons which would also allow separation to mitigate effects of noise. The noise sources and measures taken will be applied as required for any option and noise is not a material factor in distinguishing between options..

Air quality

7.16 New transmission infrastructure will not give rise to any material effects on air quality. Temporary construction works can give rise to dust affecting air quality locally. This will be managed by procedures and controls to ensure that it is not unacceptable. These measures will be applied as required for any option and air quality is not a material factor in distinguishing between options.

Transport

7.17 Construction works will involve transport of materials and workforce to sites. The effects will be temporary and will be subject to management to ensure that effects are not unacceptable. This will be the case for any option and transport is not a material factor in distinguishing between options.

Socio-Economic Appraisal

Tourism and Recreation

7.18 The potential impacts of electricity transmission infrastructure on recreation, leisure and tourism are not well understood. It has been suggested in some representations made to consultation on the Route Corridor Study that there may be some impacts at a local scale on tourism based on the proximity of the proposed infrastructure to important landscape and views. . However, there is no evidence or studies that demonstrate a measurable economic effect from overhead transmission lines. National Grid acknowledges that tourism is important to some parts of the economy in the part of the East Anglia region where the need for new infrastructure has been identified. For the purposes of assessing strategic options, National Grid has assumed that there may be potential effects on tourism from the proposed transmission reinforcement options. However, it is not considered that potential effects on tourism comprise a significant factor in choosing between different options at this strategic level.

Agricultural Assessment

7.19 At the strategic options stage it is not necessary or appropriate to assess potential impacts on individual agricultural businesses. Agricultural Land Classification can be mapped for strategic options but is not anticipated to be relevant to the appraisal. The permanent land take from an overhead line would be very unlikely to result in a significant impact on this resource. Underground technologies of AC cable or GIL would potentially involve a greater impact on agricultural land quality but this would be anticipated to be temporary and of relatively short duration. Effects on agriculture are not anticipated to differentiate between options at this strategic level

Wider Economic Benefits

7.20 Wider economic benefits to the local community from a connection are likely to relate to the additional economic activity in the locality during construction. This is anticipated to be positive, although it will be temporary and relatively short-term. It is unlikely to give rise to any issues that would distinguish between options at the strategic options stage and is not considered in the appraisal.

Deprivation

7.21 The Index of Multiple Deprivation is generally acknowledged to be the main tool for examining impacts on deprived areas. The Index is a combined index derived from 37 different indicators, which cover specific aspects or dimensions of deprivation: income, access to employment, housing, education, skills and training, health and disability, living environment, and crime. These are weighted and combined to create the overall Index of Multiple Deprivation. It is not considered that any of these factors are likely to be affected by the connection options and the Index is not therefore considered in the appraisal of strategic options.

7.22 The paragraphs above explain that socio-economic issues have been "scoped out" of the appraisal of the strategic options with the exception of the appraisal of planning policy which is described below.

Property Values

7.23 In investigating potential connection options, National Grid seeks to avoid or minimise impacts upon settlements (or as route alignments become more certain in the later stages of detailed design, maximise the distance from individual homes) for reasons of general amenity. Analysis of the potential effects of different connection options on factors such as agricultural land, residential property and commercial property values is not included in this socio-economic appraisal. Those whose property will have National Grid equipment sited on or across it (e.g. if the conductors/ wires – oversail a landholding) are entitled to compensation under property law and these factors may be the subject of compensation assessment once the final route alignment is decided[26].

7.24 Potential effects on property prices are, therefore, scoped out of the appraisal at this stage.

Socio-Economic Planning Policy

7.25 A high level planning policy analysis has been undertaken to identify the main areas of economic importance in policy terms. The status of particular areas in employment terms is largely reflected in Development Plans and any supporting Economic Development Strategies, prepared by local authorities or

[26] The degree to which impact in terms of injurious affection of property and entitlement to compensation is something which can only really be assessed and agreed once a transmission connection is in place and the actual impact evaluated.

regional bodies. In considering the planning policy context[27] we have looked at:

- LDF Core Strategies;
- Saved policies in Local Plans/Unitary Plans;
- Saved policies in Minerals Local Plans (prepared at County level), and
- Minerals Core Strategies (prepared at County level, where available).

7.26 The following planning policy areas relevant to socio-economic issues have been considered where development implications might affect/be affected by potential connection Options:

- Spatial settlement policies;
- Employment policies, including tourism;
- Recreation/leisure policies including green infrastructure;
- Areas of current/potential mineral workings, and
- other significant development proposals with impacts relevant to strategic options.

7.27 Socio-economic effects have been assessed to determine the extent to which they assist in meeting policy objectives:

- Where there are some tensions between the policy approach and elements of the potential strategic option arising either from visual impacts or from the option's land take considerations, it should generally receive a negative assessment;
- Where there are no policy tensions e.g. where visual impact would be minimal or where the assumed land take is not considered likely to be

[27] A list of documents reviewed is given in Appendix 1.

significant (for agricultural or industrial interests), the option has been considered neutral;

- Where elements of the potential strategic option could contribute to overall policy objectives or where other planning objectives could be achieved, a positive assessment may be appropriate.

7.28 For each policy or allocation examined, an assessment has been made of the extent to which a strategic option to address the Need Case is likely to facilitate or hinder the delivery of the policy or allocation, taking into account the strategic nature of the options. The appraisal reports:

- Where there is a risk of significant potential conflict between the socio-economic policies and the selection of a particular option or if an option is likely to prevent the delivery of those policies, the assessment would be negative;

- Where there is no identified significant potential conflict between the option and the socio-economic policies or allocations, the assessment would be neutral;

- Where elements of the potential strategic option are likely to contribute to the delivery of overall socio-economic policy objectives or where other planning objectives could be achieved, the assessment would be positive.

8 Options Appraisal – Common Works

8.1 Section 6.5 describes the Upgrade Works that can enhance the capacity of the East Anglia transmission system by 1240MW. These Upgrade Works are a common requirement for all potential strategic options considered in this review. A summary of the Upgrade Works is shown in Table 8.1 below:

Upgrade Works	**Total Estimated Capital Cost**
Install switchable reactors at Rayleigh	**£283.1m**
Reconductoring Pelham – Twinstead Overhead Line	
Reconductoring Bramford – Rayleigh Overhead Line	
Reconductoring Rayleigh – Coryton Overhead Line	
Construction of a New Bramford Substation with increased capacity (sufficient for predicted, increased power flows on the transmission system in East Anglia) to replace the existing Bramford substation	

Table 8.1 common system upgrades

8.2 Each of the potential strategic options also requires a new substation for the connection of new generation at Sizewell C. For the purposes of the options analysis, the total capital cost for a new Sizewell C 400kV substation has been estimated as **£124.6m**.

8.3 The cost estimate for each of the potential strategic options includes a total of **£407.7m** for the Upgrade Works and a new 400kV substation at Sizewell C. These costs and the environmental and any socio-economic effects of these works (the "Common Works") are common to all potential strategic options and are not used in the appraisal of options.

9 PS1: Sizewell – Bradwell (Subsea)

9.1 Option PS1 would deliver the additional transmission capacity required in the East Anglia region by the installation of approximately 90km of new subsea cables between Sizewell and Bradwell. The installation of a new subsea cable circuit would resolve the transmission capacity issues associated with the East Anglia region. However, to resolve issues associated with negative phase sequence currents and thermal issues to the south of the East Anglia transmission system planning boundary, this options also requires:

(a) Replacement of the 132kV connection between Rayleigh and Bradwell with a new 400kV overhead line;

(b) Construction of a new 400kV substation at Bradwell, and

(c) Construction of a new 400kV substation at Twinstead.

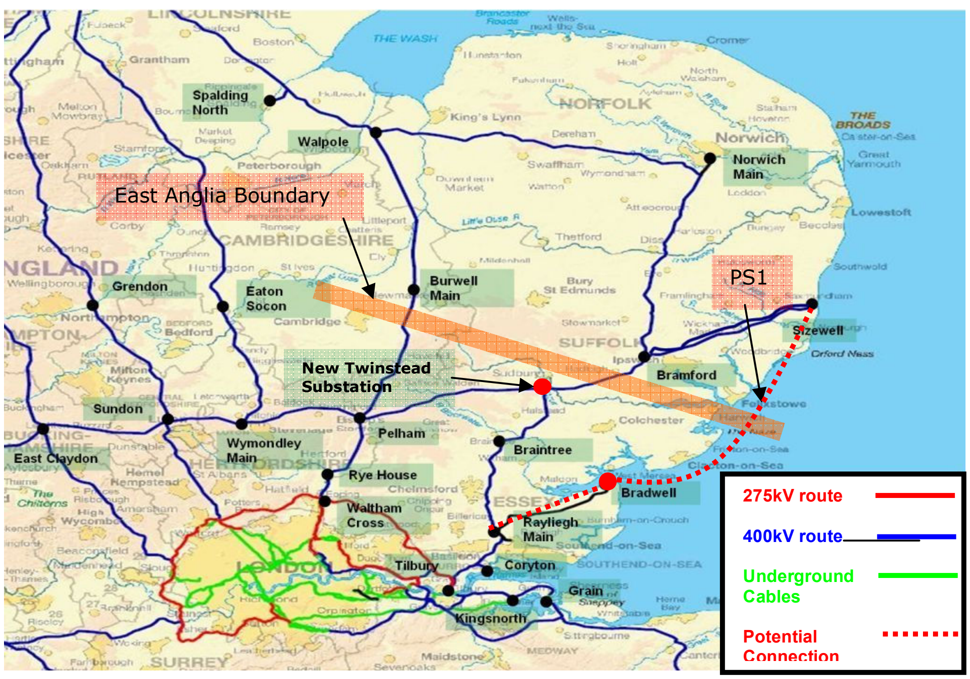

Figure 9.1 geographical representation of PS1

9.2 Figure 9.1 provides a geographical representation of the PS1 option.

9.3 Some respondents to National Grid's stage 1 consultation requested that subsea cable options that connected between Sizewell and the Thames Estuary or Central London were assessed. Either of these options would require long subsea cable circuit lengths with a minimum route length of:

(a) 110km between Sizewell and a connection point close to the Thames Estuary.

(b) 160km between Sizewell and a connection point close to Central London.

9.4 National Grid's consideration of the viability of options to connect in the Thames Estuary or central London also took account of the significant amounts of existing and proposed new generation in the Thames Estuary area, the limited land availability in central London and the density of existing underground cable infrastructure in central London.

9.5 The infrastructure works required to establish a subsea cable circuit between Sizewell and either of the Thames Estuary or central London options would be significantly greater than the works required to connect the subsea cable circuit at Bradwell.

9.6 Works in the Thames estuary would require additional transmission capacity including new circuits, in addition to the subsea costs. Works in central London would include additional costs to avoid the many number of buried services in the metropolitan area, also avoiding Thames Barrage and costs to connect converter stations from their locations to demand supply points, all in addition to increased subsea costs. National Grid does not consider that either option would be an efficient or economic alternative to PS1. Therefore these alternatives were not assessed in more detail.

9.7 Respondents to National Grid's stage 1 consultation also requested further information about the impact of alternative connection options for East Anglia offshore wind (i.e. to the transmission system outside of the East Anglia region) on the additional transmission system capacity needed in the East Anglia region and therefore on the scope of subsea cable options.

9.8 The 2009 SOR did not include any requirements for East Anglia offshore wind as contracts for connection were not then in place with National Grid at that time. The 2009 SOR documented the need for an additional 4GW of transmission system capacity for a subsea connection, without East Anglia

Offshore Wind in the background. National Grid considered options for the connection of East Anglia Offshore Wind, including possible options for connection outside of the East Anglia region, on receipt of the application from the customer. For the reasons set out above, National Grid does not consider that there are more efficient or economic alternatives for providing connections to the East Anglia offshore wind generation outside of the East Anglia region. This is because such options would lead to additional costs to the generator and more significant infrastructure works on the NETS (on National Grid's transmission system or for the development of offshore transmission networks).

9.9 As set out in Section 8, cost estimates are included in PS1 for Upgrade Works and a new 400kV substation at Sizewell C.

PS1 Technology options considered

9.10 Two technology options were considered as part of this review and are included as PS1a (HVDC) and PS1b (AC) in this Report.

9.11 For the analysis of option PS1a, a HVDC connection requiring three 2300MW (6900MW in total) converter stations was considered. For the analysis of option PS1b, a two circuit AC subsea cable connection, each circuit capable of carrying 3400MW of capacity (6800MW in total) and including reactive compensation equipment, was considered.

9.12 The 2009 SOR noted that Voltage Source (VSC) HVDC systems are required due to the requirements for fast response of any HVDC connection, where the system needs to change or reverse power flows quickly in response to faults elsewhere on the transmission system. There are currently no VSC HVDC systems of this size installed in the world, and a sufficiently fast response time within 100's of milliseconds has not yet been demonstrated. Whilst such response may be achievable, such issues remain a technical risk to this option.

PS1 Capital Costs

9.13 The cost estimates associated with PS1a and PS1b are summarised in Table 9.1 and 9.2 below.

Common Works		
As described in chapter 8		£407.7m
Potential Strategic Option - Transmission Reinforcement Assets		
Resolving East Anglia Transmission Boundary	3 Additional HVDC Connection Bays at the New Sizewell 400kV Substation	£14.4m
	Sizewell/Leiston 3 x 2300MW Converters	£450m
	Bradwell 400kV Substation	£70.6m
	Bradwell 3 x 2300MW Converters	£450m
	Sizewell/Leiston – Bradwell HVDC Cables 90km (3 x 2300MW bipole cables)	£378m
	Rebuild overhead line between Rayleigh and Bradwell at 400kV Build new 400kV double circuit between Sizewell and Leiston (for the purposes of the options analysis, costs for a new 400kV overhead line circuit have been included)	£76.7m
Resolving Negative Phase Sequence Currents	New Twinstead 400kV substation	£35.8m
Potential Strategic Option - Contingent Transmission Works		
New Quadrature Boosters at Rayleigh 400kV substation		£16m
TOTAL – excluding common works		**£1,491.5m**
TOTAL		**£1,899.2m**

Table 9.1 - PS1a (HVDC Cables) Capital Cost Summary

Common Works		
As described in chapter 8		£407.7m
Potential Strategic Option - Transmission Reinforcement Assets		
Resolving East Anglia Transmission Boundary	2 Additional AC Connection Bays at the New Sizewell 400kV Substation	£9.6m
	Bradwell 400kV Substation with Reactive Compensation (reactors compensation cost £75m)	£115.5m
	Sizewell/Leiston – Bradwell AC subsea Cables 90km (3 cores per phase)	£1,972.3m
	Rebuild overhead line between Rayleigh and Bradwell at 400kV; Build new 400kV double circuit between Sizewell and Leiston (for the purposes of the options analysis, costs for a new 400kV overhead line circuit have been included)	£76.7m
Resolving Negative Phase Sequence Currents	New Twinstead 400kV substation	£35.8m
Potential Strategic Option - Contingent Transmission Works		
Three sets of New Quadrature Boosters at Rayleigh 400kV substation		£48.1m
TOTAL – excluding common works		**£2,258m**
TOTAL		**£2,665.7m**

Table 9.2 - PS1b (AC Cables) Capital Cost Summary

9.14 The costs for each variant considered differ due to the cost differences for each type of cable technology (HVDC and AC). Tables 9.1 and 9.2 show that the HVDC option has a lower capital cost than the AC cable option. This is because HVDC cables are lower in cost than AC cables and this cost difference is sufficient to offset the difference in cost between HVDC converter stations and AC reactive compensation equipment.

PS1 Lifetime Cost

9.15 PS1 can be delivered by either AC subsea cable or by a HVDC connection which includes converter stations to convert electricity between AC and DC. Each of options PS1a and PS1b have the same scope of works other that in respect of the type of cable, conversion and reactive compensation equipment.

9.16 The lifetime cost methodology is explained in Appendix 1. The lifetime costs assessed for the transmission reinforcement assets (excluding common and wider works) for options PS1a and PS1b are shown in Table 9.3 below:

	PS1a **HVDC subsea cables and converters**	**PS1b** **AC subsea Cable and Shunt Reactors**
Capital Cost	£1,475.5m	£2,209.9m
Transmission Loss Cost	£587.3m	£301.6m
Maintenance Cost	£129.6m	£18.5m
Lifetime Cost	**£2,192.4**	**£2,530m**

Table 9.3: PS1 Lifetime Cost

9.17 The analysis shows that taking account of the lifetime costs of transmission losses and maintenance, that PS1a (HVDC solution) in this case is more economical than option PS1b (AC solution) for the subsea cable option (PS1).

9.18 **PS1a and PS1b Environmental Appraisal**

9.19 The study area for the Sizewell – Bradwell connection is illustrated at Figure 9.1 and extends for approximately 100km between Sizewell Power Station, Suffolk and Bradwell Power Station, Essex. The study area is focussed on the offshore route between Sizewell and Bradwell and the land associated with the connection points at both locations. The additional works associated with this potential strategic option comprise the 400kV overhead line from Bradwell to Rayleigh, Essex.

9.20 The most significant environmental constraint to the potential strategic option would be the Outer Thames Estuary Special Protection Area (SPA) where the qualifying feature is the wintering population of Red Throated Divers (a diving bird that is listed in Annex 1 of the Birds Directive). The supporting habitats for the Red Throated Divers, i.e. shallow coastal waters and the subtidal sandbanks are also within the study area. Additionally the sandbanks of the Thames Estuary provide important nursery, spawning and feeding grounds for many fish species.

9.21 There are three designated sites within the vicinity of Bradwell. These are Blackwater Estuary, Dengie Flats and Colne Estuary the subsea cables would need to travel through the Dengie Flats Site of Special Scientific Interest (SSSI).

9.22 The installation of either AC or HVDC subsea cables through the Outer Thames Estuary and Dengie Flats could result in the following effects on the SPA and SSSI:

- Disturbance of the mudflats and the bed of the estuary from cables installation across a construction swathe of approximately 440m for AC cables or between 150m - 350m for HVDC cables (depending on the number of cables required) which may alter the species composition of the flora and fauna;

- Smothering effects from suspended sediments resulting from the release of sediment from the cables installation activities;

- Mobilisation of contaminants in sediments could impact on the flora and fauna of the Estuary; and

- Disturbance from the cable laying activities could impact on species using the SPA and SAC.

9.23 The nature and scale of these effects would require further assessment in accordance with the Conservation of Habitats and Species Regulations 2010 to ensure that there would be no adverse effects on the integrity of the designation or its qualifying features. If the likelihood of significant adverse effect could not be ruled out, or if there was uncertainty, then an ‘appropriate assessment’ would need to be undertaken by the competent authority.

9.24 Where the appropriate assessment identified that there are likely to be significant effects, consent for development can only be granted where it would not adversely affect the integrity of the site taking into account the manner in which the development will be carried out and any conditions that might be imposed on the consent or, where there are no alternative solutions and the development must be carried out for imperative reasons of overriding public interest relating to human health, public safety or benefits of primary importance to the environment.

9.25 The construction of converter stations (for a HVDC variant) or reactive compensation equipment (for an AC variant) would require a large land take in the vicinity of the cables landing point. This infrastructure has the potential to result in effects on local amenity depending on the siting. The location of the converter stations or reactive compensation equipment would require further consideration and assessment as part of detailed siting studies if this connection option was taken forward. The reactive compensation could be placed at Bradwell, although converter stations would be needed at each end of the connection. Sizewell is in the Suffolk Coast and Heaths Area of Outstanding Natural Beauty where national planning policy seeks to conserve and enhance the natural beauty. Notwithstanding the existing and proposed development in the area, a converter station would contravene policy seeking to protect this national designation.

9.26 HVDC subsea cables would offer environmental benefits over AC subsea cables as they require the installation of fewer cables over a narrower installation corridor, resulting in less seabed disturbance and a shorter installation programme. However, the large converter stations required at either end of the HVDC connection would introduce effects on landscape and views at each end of the connection, including in the AONB at Sizewell. The AC cable variant would require compensation equipment which would also affect landscape and views and it has been assumed would be installed at the new substation at Bradwell to avoid the Sizewell AONB.

<u>New 400kV substation at Bradwell and Twinstead</u>

9.27 As outlined at paragraph 9.1, if this option was selected as the preferred strategic option and taken forward, a new 400kV substation would be required at Bradwell in Essex. The siting and design of this substation would be subject to detailed study in accordance with the guidelines presented in the Horlock

Rules[28]. For the AC variant, this substation would also accommodate the compensation equipment.

9.28 To make a landing connection at Bradwell, the potential strategic option would need to travel through land sections of Dengie Flats SSSI. The substation would need to avoid this designated area. Other environmental designations of international or national importance identified within or in close proximity to Bradwell which would constrain potential onshore connection routes include the marshland of the Mid Essex Coast SPA and Ramsar site, and Essex Estuaries SAC.

9.29 However, the construction of a new 400kV substation at Bradwell would introduce effects on landscape and views which would require further consideration and assessment as part of detailed siting studies.

9.30 A new substation at Twinstead would be needed to address Negative Phase Sequence Currents. The substation would be needed in the close vicinity of the existing Twinstead Tee or the existing overhead line circuits would need to be diverted to a suitable substation site. Constructing a substation in the area close to the existing Twinstead Tee would require creating appropriate access for delivery of equipment and clearing a site which would adversely affect the wooded landscape character of the area. Diverting the existing circuits to another site would also bring about adverse effects.

PS1a and PS1b Socio-Economic Assessment

9.31 The District's draft Core Strategy sets out a specific policy for Sizewell Nuclear Power Station. It identifies criteria to be taken into account which would be relevant to the infrastructure needed to support a subsea cable, including the need to maintain coastal access e.g. for the Heritage Coast Walk.

9.32 Maldon District's Local Plan makes specific reference to Bradwell Power Station in the context of decommissioning and safe storage of nuclear material. It highlights the need to safeguard rural and residential amenities nearby as the power station is in the 'Coastal Zone' and subject to development restraint policies. This is relevant in respect of the substation required at Bradwell.

[28] National Grid plc: NGC Substation and the environment – guidelines on siting and design: March 2003

9.33 Further south, South Woodham Ferrers is one of two main areas identified for development in Chelmsford Borough. Rayleigh in Rochford District is also targeted for development particularly to the west of the town. The route of the connection between Bradwell and Rayleigh would need to avoid areas allocated for development.

9.34 The potential impact of PS1 on achievement of socio-economic planning objectives is considered generally neutral i.e. it does not hinder nor support their achievement. Most potential effects on implementing policy should be capable of mitigation through detailed routeing and siting of infrastructure.

10 PS2: Bramford – Twinstead Tee

10.1 Option PS2 would deliver the additional 6800MW of transmission capacity required in the East Anglia region by the installation of a new two circuit transmission connection between Bramford and Twinstead Tee. This connection is 28km in length (estimate based on average of the 4 route corridors proposed in the Route Corridor Study). This option resolves the transmission issues associated with the East Anglia region and the system issues which were explained in Section 5 "summary of need case".

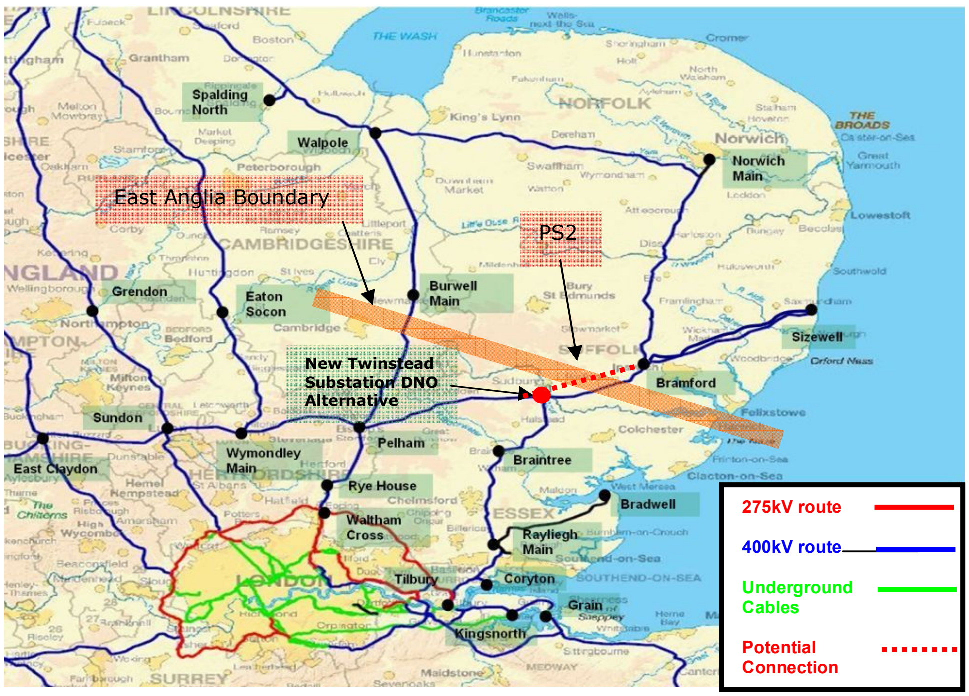

Figure 10.1 Geographical Representation of PS2

10.2 Figure 10.1 provides a geographical representation of the PS2 option.

10.3 The PS2 option would facilitate the removal of the Tee point at Twinstead. This option would deliver two sets of double circuits providing connections between Bramford and Pelham (one double circuit) and Bramford and Braintree (one double circuit). Both double circuits would have a capacity of 6800MW each (3400MW per individual circuit). This option would double the capacity provided by the single existing double circuit out of Bramford to the Twinstead Tee.

10.4 If a connection between Bramford substation and Twinstead Tee used the route of the existing 132kV DNO overhead line, a substation would be required in the general vicinity of Twinstead. The substation is also shown indicatively on the diagram. A substation at Twinstead would not be needed if the existing 132kV DNO overhead line was retained. It should be noted that variants that do not require changes to the existing 132kV DNO overhead line are considered within option PS2. It should also be noted that the substation required in this instance is different from that identified in PS1 above. The PS2a variant substation would be required in the general vicinity of Twinstead close to the existing 400kV and 132kV overhead lines west of Twinstead Tee, rather than in the near vicinity of Twinstead Tee as for PS1

10.5 As set out in Section 8, cost estimates are included in PS2 for Upgrade Works and a new 400kV substation at Sizewell C.

PS2 Technology options considered

10.6 PS2 is the shortest of the potential strategic options at approximately 28km. Overhead line, AC undergrounding and GIL technology options have each been considered for PS2 as set out below:

- PS2a: Bramford – Twinstead Tee new 400kV double circuit Overhead Line (2 x 3400MW = 6800MW total capacity)

- PS2b: Bramford – Twinstead Tee new 400kV two circuit AC underground cable (2 x 3400MW = 6800MW total capacity)

- PS2c Bramford – Twinstead Tee new 400kV two circuit AC Gas Insulated Line (GIL) (2 x 3400MW = 6800MW total capacity)

PS2 Capital Costs

10.7 The cost estimates associated with PS2a, PS2b and PS2c are summarised in Table 10.1-10.3 below.

Common Works		
As described in chapter 8		£407.7m
Potential Strategic Option - Transmission Reinforcement Assets		
Resolving East Anglia Transmission Boundary and Negative Phase Sequence Currents	2 Additional AC Connection Bays at the Bramford 400kV Substation	£11.7m
	Construction of a new Bramford – Twinstead Tee 28km 400kV double circuit overhead line	£50.3m
Potential Strategic Option - Contingent Transmission Works		
Reconductoring of all Sizewell to Bramford Overhead Line Circuits		£75.2m
TOTAL – excluding common works		**£137.2m**
TOTAL		**£544.9m**

Table 10.1 – PS2a (AC Overhead Line) Capital Cost Summary

10.8 The variant of this option that used the route of the existing DNO overhead line would include costs for a new Twinstead 400kV substation. The costs for Twinstead substation have been estimated as £30.4m. This variant of PS2a has a total cost of **£575.3m**.

Common Works		
As described in chapter 8		£407.7m
Potential Strategic Option - Transmission Reinforcement Assets		
Resolving East Anglia Transmission Boundary and Negative Phase Sequence Currents	2 Additional AC Connection Bays at the Bramford 400kV Substation	£11.7m
	Construction of a new Bramford – Twinstead Tee 28km 400kV two circuit AC Cables (3 Cores per phase)	£616m
	Shunt Reactors Bramford and Pelham	£18m
Potential Strategic Option - Contingent Transmission Works		
Reconductoring of all Sizewell to Bramford Overhead Line Circuits		£75.2m
TOTAL – excluding common works		**£720.9m**
TOTAL		**£1128.6m**

Table 10.2 – PS2b (AC Cables) Capital Cost Summary

Common Works		
As described in chapter 8		£407.7m
Potential Strategic Option - Transmission Reinforcement Assets		
Resolving East Anglia Transmission Boundary and Negative Phase Sequence Currents	2 Additional AC Connection Bays at the Bramford 400kV Substation	£11.7m
	Construction of a new Bramford – Twinstead Tee 28km 400kV two circuit GIL connection (6800MVA capacity)	£638m
Potential Strategic Option - Contingent Transmission Works		
Reconductoring of all Sizewell to Bramford Overhead Line Circuits		£75.2m
TOTAL – excluding common works		**£724.9m**
TOTAL		**£1,132.6m**

Table 10.3 – PS2c (GIL) Capital Cost Summary

10.9 The main differences between the costs of option PS2 variants are the differences in costs per kilometre of AC underground cables and gas insulated line as compared to an overhead line. There are also differences due to the additional equipment required for the AC underground cable option requiring additional reactive compensation equipment and management of operational issues (mid-point switching station).

10.10 The variant of PS2a which would use the route of the existing 132kV DNO overhead line route would require its removal and would replace it with a 400kV transmission circuit. The DNO would lose capacity in its network due to this line being removed and this capacity would need to be replaced. The 2009 SOR identified that this can be done by constructing a new substation in the general vicinity of Twinstead.

PS2 Lifetime Cost

10.11 AC overhead line, underground cable or by a GIL connection are all viable technology options for PS2. The options as detailed in Tables 10.1-10.3 above have the same scope of works except for the different technology used to provide the additional transmission circuits and in the case of AC cables the requirement for shunt reactors.

10.12 As set out in Paragraph 10.3 construction of two circuits between Bramford and Twinstead Tee would result in changes to the transmission system configuration. As this new circuit ultimately transmits electricity to Braintree it is important for the purpose of comparing this option to PS3 (Bramford to Braintree) that losses are calculated to Braintree. The Bramford to Twinstead option is 28km in length with a further 22km of existing line used to reach Braintree, giving an overall length of 50km for the purpose of calculating losses.

10.13 The lifetime cost methodology is explained in Appendix 1. The lifetime costs assessed for the transmission reinforcement assets (excluding common and wider works) for PS2a, PS2b and PS2c (connecting between Bramford and Twinstead Tee) are shown in Table 10.4 below.

	PS2a **OHL**	**PS2b** **AC Cable and Shunt Reactors**	**PS2c** **AC GIL**
Capital Cost	£62.0m	£645.7m	£694.7m
Transmission Loss Cost (50km to Braintree)	£135.0m	£96.9m	£62.7m
Maintenance Cost	£1.58m	£8.83m	£2.2m
Lifetime Cost	**£198.6m**	**£751.4m**	**£759.6m**
Lifetime Cost including Twinstead Substation capital cost £30.4m	**£229.0m**		

Table 10.4: PS2 Lifetime Cost

10.14 Taking account of the lifetime costs of transmission losses and maintenance for PS2, the analysis shows that an AC overhead line solution is more economical than an AC underground cable solution which is in turn, marginally more economical than a GIL solution.

PS2a, PS2b and PS2c Environmental Appraisal

10.15 The study area for the Bramford – Twinstead Tee connection is illustrated at Figure 10.1 and extends for approximately 28km from the existing National Grid 400kV substation at Bramford, Suffolk to Twinstead near Sudbury, Suffolk. An existing 132kV overhead line owned and operated by UK Power Networks (UKPN) travels through the study area in an east-to-west alignment close and approximately parallel to the Bramford – Twinstead/Rayleigh Main overhead line to Twinstead Tee. This area has been subject to the Route Corridor Study which formed the basis of Stage 1 Consultation.

10.16 The Dedham Vale Area of Outstanding Natural Beauty is mainly to the south of the existing 400kV and 132kV overhead lines running between Bramford and Twinstead although the lines run through a small part of the AONB. A new overhead line would bring about effects on the landscape and on views from and to the AONB. These effects would be largely avoided using AC underground cables or GIL (some effects may arise through felling trees which could not be replanted).

10.17 There are relatively few sites designated at a national level for nature conservation interest. The few SSSIs present are scattered throughout the study area. The Hintlesham Woods SSSI is to the east of Hadleigh. Elmsett Park Wood SSSI is to the east of Elmsett. Lineage Wood and Railway Track SSSI are to the west of Lavenham. Glemsford Pits SSSI is to the north of Long Melford. Arger Fen SSSI is to the east of Bures. These sites are considered avoidable in routeing using any of the technologies considered.

10.18 There are scattered Scheduled Monuments throughout the study area which are considered avoidable in routeing.

10.19 Tendring Hall Park is to the south of Stoke-by-Nayland in the Dedham Vale AONB. It would not be affected by a Bramford-Twinstead connection.

10.20 Listed buildings are concentrated in settlements, with some scattered throughout the rural areas. Settlements would be avoided in routeing and isolated listed buildings would be considered in detailed design of a connection, although any effects would only arise by use of an overhead line.

10.21 There are scattered conservation areas in the study area, which are in settlements including: Hadleigh; Kersey; Stoke-by-Nayland; Polstead; Boxford; Nayland; Bures St Mary; Bulmer; Sudbury; Thorington Street; Naughton; Bildeston, and Higham. These would be avoidable in routeing although only an overhead line would be likely to have any effects on setting.

10.22 There are scattered blocks of woodland throughout the study area, increasing in frequency around the Twinstead Tee, within the AONB and to the southwest of Bramford. The majority of these would be avoided in routeing. Where woodland is crossed by the connection, the effects are likely to be greatest where crossed by AC underground cables.

10.23 The study area has variable topography but no known slopes or ground conditions that may severely constrain a connection installed by overhead line, AC underground cables or gas insulated line.

10.24 Larger settlements in the study area include Hadleigh, Sudbury and Boxford. There are numerous smaller towns and villages dispersed throughout the study area. There are scattered farms and dwellings throughout the area. These would be avoided in routeing although any effects on amenity would arise from principally from use of an overhead line.

10.25 There are two airfields within the study area. Elmsett Airfield is a small private facility to the north east of Hadleigh to the west of Elmsett at Poplar Hall. Wattisham Airfield lies to the north of the study area between Wattisham and Great Bricett. The airport is managed by the Army Air Corps and is primarily used by regiments of the Army Air Corps and as a helicopter base.

10.26 Airfields would be at risk of potential effects from use of an overhead line, depending on detailed routeing.

PS2 - Socio-Economic Assessment

10.27 Sudbury, Hadleigh and the Bramford/Ipswich fringe are identified in planning policy for major housing and employment growth. Allocated areas could be avoided in routeing.

10.28 The potential impact of PS2 on the achievement of socio-economic planning objectives is considered to be generally neutral. Most potential effects on implementing policy should be capable of mitigation through detailed routeing and siting of infrastructure.

11 PS3: Bramford – Braintree

11.1 Option PS3 would deliver the additional 6800MW of transmission capacity required in the East Anglia region by the installation of a new two circuit transmission connection between Bramford and the existing overhead line to Braintree (34km). This option also allows the removal of 8km of existing 400kV overhead line between Braintree and Twinstead Tee. This connection resolves the transmission issues associated with the East Anglia region and the system issues which were explained in Section 5 "summary of need case"

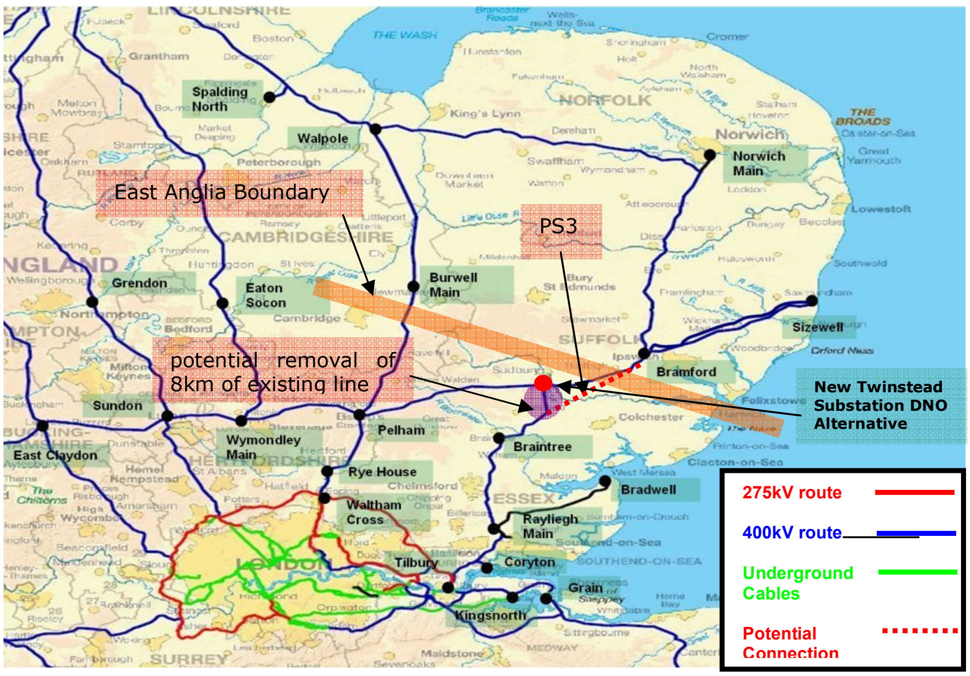

Figure 11.1 Geographical Representation of PS3

11.2 Figure 11.1 provides a geographical representation of the PS3 option.

11.3 In the 2009 SOR, the option considered for a Bramford-Braintree connection envisaged a relatively straight line drawn between the two substations which would comprise an overhead line through the Dedham Vale AONB. This performed poorly compared to the 2009 SOR options which avoided the AONB (S6) or ran through only a very short section of the AONB (S7). During back-check and review of the strategic options considered in 2009, a different route and other technology options have been included. The revised route seeks to avoid passing through the Dedham Vale AONB as far as possible and, for the overhead line technology option, considers using part of the route of the existing 132kV overhead line which runs west from Bramford substation towards Twinstead.

11.4 If this option was used, the Tee point at Twinstead would be removed along with up to 8km existing 400kV overhead line as highlighted in Figure 11.1. The two sets of double circuits out of Bramford providing connections between Bramford and Pelham (one double circuit) and Bramford and Braintree (one double circuit) would have a capacity of 6800MW each (3400MW per individual circuit). This option would double the capacity provided by the single existing double circuit out of Bramford to the Twinstead Tee.

11.5 If a connection between Bramford substation and Braintree involved removal of the existing 132kV DNO overhead line (for its route to be used for a new 400kV overhead line), a substation would be required in the general vicinity of Twinstead. The substation is also shown indicatively on the diagram. A substation at Twinstead would not be needed if the existing 132kV DNO overhead line was retained. It should be noted that variants that would not require removal of the existing 132kV DNO overhead line are considered within option PS3.

11.6 As set out in Section 8, cost estimates are included in PS3 for Upgrade Works and a new 400kV substation at Sizewell C.

PS3 Technology options considered

11.7 PS3 is a strategic option that requires a new circuit of approximately 34km. Overhead line, AC underground cables and GIL technology options have each been considered for PS3 as set out below:

- PS3a: Bramford – Braintree new 400kV double circuit Overhead Line (2 x 3400MW = 6800MW total capacity)

- PS3b: Bramford – Braintree 400kV new two circuit AC underground cable (2 x 3400MW = 6800MW total capacity)

- PS3c Bramford – Braintree 400kV new two circuit AC Gas Insulated Line (GIL) (2 x 3400MW = 6800MW total capacity)

PS3 Capital Costs

11.8 The cost estimates associated with PS3a, PS3b and PS3c are summarised in Table 11.1-11.3 below.

Common Works		
As described in chapter 8		£407.7m
Potential Strategic Option - Transmission Reinforcement Assets		
Resolving East Anglia Boundary and Negative Phase Sequence Currents	2 Additional AC Connection Bays at the Bramford 400kV Substation	£11.7m
	Construction of a new Bramford – Braintree 34km 400kV double circuit overhead line with 14km of existing overhead line retained (allowing removal of 8km of 400kV overhead line between Braintree and Twinstead Tee)	£61m
Potential Strategic Option - Contingent Transmission Works		
Reconductoring of all Sizewell to Bramford Overhead Line Circuits		£75.2m
TOTAL – excluding common works		**£147.9m**
TOTAL		**£555.6m**

Table 11.1 – PS3a (AC Overhead Line) Capital Cost Summary

11.9 The variant of this option that used the route of the existing DNO overhead line would include costs for a new Twinstead 400kV substation. The costs for Twinstead substation have been estimated as £30.4m. This variant of PC2c has a total cost of **£586.0m.**

Common Works		
As described in chapter 8		£407.7m
Potential Strategic Option - Transmission Reinforcement Assets		
Resolving East Anglia Boundary and Negative Phase Sequence Currents	2 Additional AC Connection Bays at the Bramford 400kV Substation	£11.7m
	Construction of a new Bramford – Braintree 34km 400kV two circuit AC Cables (3 Cores per phase) 14km of existing overhead line retained (allowing removal of 8km of 400kV overhead line between Braintree and Twinstead Tee)	£748m
	Shunt Reactors Bramford and Braintree	£18m
Potential Strategic Option - Contingent Transmission Works		
Reconductoring of all Sizewell to Bramford Overhead Line Circuits		£75.2m
TOTAL – excluding common works		**£852.9m**
TOTAL		**£1260.6m**

Table 11.2 – PS3b (AC Cables) Capital Cost Summary

Common Works		
As described in chapter 8		£407.7m
Potential Strategic Option - Transmission Reinforcement Assets		
Resolving East Anglia Boundary and Negative Phase Sequence Currents	2 Additional AC Connection Bays at the Bramford 400kV Substation	£11.7m
	Construction of a new Bramford –Braintree 34km 400kV two circuit GIL connection (6800MVA capacity) 14km of existing overhead line retained (allowing removal of 8km of 400kV overhead line between Braintree and Twinstead Tee)	£775m
Potential Strategic Option - Contingent Transmission Works		
Reconductoring of all Sizewell to Bramford Overhead Line Circuits		£75.2m
TOTAL – excluding common works		**£861.9m**
TOTAL		**£1,269.6m**

Table 11.3 – PS3c (GIL) Capital Cost Summary

11.10 The main differences between the costs are the differences in costs per kilometre of AC underground cables and gas insulated line as compared to an overhead line. There are also differences due to the additional equipment required for the AC underground cable option requiring additional reactive compensation equipment and management of operational issues (potential mid-point switching stations).

11.11 A variant of PC3a which used the route of existing 132kV DNO overhead line for a new 400kV overhead line would mean that the DNO would lose capacity in its network. This capacity would need to be replaced by constructing a new substation in the vicinity of Twinstead as described for the equivalent variant of PS2a.

PS3 Lifetime Cost

11.12 AC overhead line, underground cable and GIL connection are all technically appropriate technology options for PS3. The options as detailed in Tables 11.1-11.3 above have the same scope of works except for the different technology used to provide the additional transmission circuits and in the case of AC cables the requirement for shunt reactors and potential requirement for mid-point switching stations.

11.13 As referred to in paragraph 11.3 the system following the construction of two circuits between Bramford and Braintree, results in change in the system configuration. As this new circuit ultimately transmits electricity to Braintree it is important for the purpose of comparing this option to PS2 (Bramford to Twinstead Tee) that losses are calculated to Braintree. The Bramford to Braintree option is 34km in length with a further 14km of existing 400kV overhead line used to reach Braintree, giving an overall length of 48km for the purpose of calculating losses.

11.14 The lifetime cost methodology is explained in Appendix 1. The lifetime costs assessed for options PS3a, PS3b and PS3c (connecting between Bramford and Braintree) are shown in Table 11.4 below.

	PS3a OHL	PS3b AC Cable and Shunt Reactors	PS3c AC GIL
Capital Cost	£72.7m	£777.7m	£786.7m
Transmission Loss Cost (48km to Braintree)	£129.6m	£95.3m	£60.2m
Maintenance Cost	£1.52m	£8.6m	£2.11m
Lifetime Cost	**£203.8m**	**£881.6m**	**£849.0m**
Lifetime Cost including Twinstead Substation capital cost £30.4m	**£234.2m**		

Table 11.4: PS3 Lifetime Cost

11.15 Taking account of the lifetime costs of transmission losses and maintenance the analysis shows that for PS3 an AC overhead line solution is more economical than an AC underground cable solution which in turn is marginally more economical than a GIL solution. There are also differences due to the additional equipment required for the AC underground cable option requiring additional reactive compensation equipment and management of operational issues (potential mid-point switching stations)

PS3 Environmental Appraisal

11.16 The study area for the Bramford – Braintree connection is illustrated at Figure 11.1 and extends from the existing National Grid 400kV substations at Bramford, Suffolk to Braintree, Essex.

11.17 Dedham Vale AONB poses a significant area of constraint between Bramford and Braintree. The overhead line variant PS3a would pass through a short section of this designation if using the route of the existing 132kV overhead line. The new 400kV line would pass to the west of the AONB and would run parallel to its boundary as it runs south towards Braintree. There would be effects on the setting and views from the AONB in this area where there are no large overhead lines at present. These effects would be largely avoided using

AC underground cables or GIL (some effects may arise through felling trees which could not be replanted).

11.18 There are relatively few sites of nationally designated nature conservation interest, the main one being Chalkney Wood SSSI which is close to the existing Twinstead to Braintree line in the Colne Valley. Arger Fen SSSI is to the northeast of Bures. Hintlesham Woods SSSI is to the southwest of Bramford substation. A route corridor using any of the technology options would be able to avoid these designations.

11.19 There are several isolated Scheduled Monuments throughout the study area which are considered to be avoidable in routeing using any of the technologies considered.

11.20 There is a Registered Park and Garden at Tendring Hall near Stoke-by-Nayland within the AONB. It would not be affected by a Bramford-Braintree connection.

11.21 Listed buildings are concentrated in settlements, with a scattering throughout the rural areas. Settlements would be avoided in routeing and isolated listed buildings would be considered in detailed design of a connection, although any effects would only arise by use of an overhead line.

11.22 Conservation areas are generally located within settlements. These would be avoidable in routeing although only an overhead line would be likely to have any effects on setting.

11.23 There are scattered blocks of woodland throughout the study area with concentrations increasing towards Braintree. Woodland blocks would be avoided wherever possible in routeing, although this would be difficult to the east of Braintree and to the northeast of Polstead. Where woodland is crossed by the connection, the effects are likely to be greatest where crossed by AC underground cables.

11.24 The key topographic features in the topography are the Stour and Colne river valleys forming the vale landscape designated as the Dedham Vale AONB. There are no known slopes or ground conditions that may severely constrain a connection installed by overhead line, AC underground cables or gas insulated line.

11.25 Larger settlements in the study area include Colchester to the south and Manningtree to the east, with smaller towns and villages dispersed through the area, many are located within the AONB. There are scattered farms and dwellings throughout the area. These would be avoided in routeing although any effects on amenity would arise from principally from use of an overhead line.

11.26 Earls Colne Airfield is to the southeast of Halstead. Airfields would be at risk of potential effects from use of an overhead line, depending on detailed routeing.

PS3 – Socio-Economic Assessment

11.27 Hadleigh and the Bramford/Ipswich fringe are identified in planning policy for major housing and employment growth. Allocated areas could be avoided in routeing.

11.28 The potential impact of PS3 on the achievement of socio-economic planning objectives is considered to be generally neutral Most potential effects on implementing socio-economic policy should be capable of mitigation through detailed routeing and siting of infrastructure.

12 PS4: Bramford – Rayleigh

12.1 Option PS4 would deliver the additional 6800MW of transmission capacity required in the East Anglia region by the installation of a new two circuit transmission connection between Bramford and Rayleigh (90km). This option also allows the removal of 22km of existing overhead line between Braintree and Twinstead Tee, with Braintree remaining connected to the system via Rayleigh. This connection resolves the transmission issues associated with the East Anglia region and the system issues which were explained in Section 5 "summary of need case".

Figure 12.1 Geographical Representation of PS4

12.2 Figure 12.1 provides a geographical representation of the PS4 option.

12.3 As part of the PS4 option the Tee point at Twinstead would be removed along with up to 22km existing 400kV overhead line as highlighted. There would be two sets of double circuits out of Bramford providing connections between Bramford and Pelham (one double circuit) and Bramford and Rayleigh (one double circuit) both with a capacity of 6800MW each (3400MW per individual circuit). This option would double the capacity provided by the single existing double circuit out of Bramford to the Twinstead Tee.

12.4 The 2009 SOR included three variations of this connection option; S12 and S15 were similar as they proposed using part of an existing DNO 132kV line for the route of a 400kV connection with the addition of at least one DNO supply point. This is the option outlined in PS4. S16 introduced an additional £300m capital cost as compared to S12 and S15 but offered no additional benefit and is therefore not considered further as part of potential strategic option PS4.

12.5 As set out in Section 8, cost estimates are included in PS4 for Upgrade Works and a new 400kV substation at Sizewell C.

PS4 Technology options considered

12.4 With a total new circuit length of 90km between Bramford and Rayleigh, option PS4 is significantly longer than the shortest new on-shore connection length of PS2 which is 28km and PS3 which is 34km. The difference between AC underground cables and GIL technology options for the shorter PS2 and PS3 routes have been presented above. The capital costs for these technologies for PS4 would be greatly in excess of the costs for the equivalent overhead line. AC underground cables and GIL technology options have not been considered for PS4 as they would incur significantly higher costs whilst providing no amenity benefit over the use of these technologies on the shorter PS2 and PS3.

12.5 PS4 is therefore assessed for the use of AC overhead line technology.

PS4 Capital Costs

12.6 The capital cost estimates associated with PS4, is summarised in Table 12.1 below.

Common Works		
As described in chapter 8		£407.7m
Potential Strategic Option - Transmission Reinforcement Assets		
Resolving East Anglia Boundary and Negative Phase Sequence Currents	2 Additional AC Connection Bays at the Bramford 400kV Substation	£11.7m
	Extend Rayleigh 400kV substation	£15.2m
	Construction of a new Bramford – Rayleigh 90km 400kV double circuit overhead line (allowing removal of 22km of 400kV overhead line between Braintree and Twinstead Tee)	£162m
Potential Strategic Option - Contingent Transmission Works		
Reconductoring of all Sizewell to Bramford Overhead Line Circuits		£122.9m
Construct a new 400kV DNO supply point		
TOTAL – excluding common works		**£311.8m**
TOTAL		**£719.5m**

Table 12.1 – PS4 (AC Overhead Line) Capital Cost Summary

PS4 Lifetime Cost

12.7 PS4 can be delivered by AC overhead line technology.

12.8 The lifetime cost methodology is explained in Appendix 1, The lifetime costs assessed for the transmission reinforcement assets (excluding common and wider works) for PS4 (AC overhead line connection technology connecting between Bramford and Rayleigh) is shown in Table 12.1 below.

	PS4 OHL
Capital Cost	£188.9m
Transmission Loss Cost	£243.1m
Maintenance Cost	£2.85m
Lifetime Cost	**£434.9m**

*Note Cost using DNO route includes a new DNO substation at a cost £47.7m giving a revised total of **£482.6m**

Table 12.1: PS4 Lifetime Cost

PS4 Environmental Appraisal

12.9 The study area for the Bramford – Rayleigh connection is illustrated at Figure 12.1 and extends from the existing National Grid 400kV substations at Bramford, Suffolk to Rayleigh, Essex.

12.10 There are two AONBs that pose a significant area of constraint between Bramford and Rayleigh: Suffolk Coasts and Heaths AONB (approximately 11km southeast of Bramford) and Dedham Vale AONB (approximately 11km southwest of Bramford). The AONBs are approximately 1km apart. A route between the AONBs, avoiding each designation, is constrained by the settlement of Brantham. A route option along the eastern boundary of the Dedham Vale AONB or western boundary of the Suffolk Coasts and Heaths AONB to avoid Brantham is also constrained by the Stour and Orwell Estuaries Ramsar Site, SPA and SSSI. A route through the Suffolk Coasts and Heaths AONB is shorter than the Dedham Vale AONB, however it would require routeing through the Stour and Orwell Estuaries Ramsar Site, SPA and SSSI. An overhead line may introduce risk of collision with birds which is the nature conservation interest these designations protect.

12.11 There are other SSSIs between Bramford and Rayleigh which pose significant constraints. The Upper Colne Marshes SSSI, the Roman River SSSI, the Colne Estuary SSSI and the Abberton Reservoir SPA and SSSI are present to the south of Colchester. A route corridor in this vicinity is very unlikely to be able to avoid the designations. The Blackwater Estuary SPA, SSSI and National Nature Reserve (NNR) is to the east of Maldon along the River Blackwater. The Crouch and Roach Estuaries SSSI is to the east of South Woodham Ferrers. These designated areas restrict a route corridor in this vicinity but are avoidable.

12.12 The Stour and Orwell Estuaries SPA is to the east of the study area along the River Stour and extends between Brantham and Lawford and into the Dedham Vale AONB. A route corridor in this vicinity would not be able to avoid these designations due to constraints of built development. The Abberton Reservoir SPA and Colne Estuary SPA are to the south of Colchester. A route corridor avoiding these SPAs would cross other constraints in the vicinity. The Blackwater Estuary SPA is to the east of Maldon along the River Blackwater. The Crouch and Roach Estuaries SPA is to the east of South Woodham Ferrers. These designated areas restrict a route corridor in this vicinity but are avoidable.

12.13 The Essex Estuaries Special Area for Conservation (SAC) covers the area surrounding the River Blackwater and the River Crouch. A route corridor can be identified avoiding this designation.

12.14 There are several Scheduled Monuments in the study area, predominately in areas around Brantham, Colchester, Danbury and South Woodham Ferrers. These are considered avoidable in routeing.

12.15 There are Registered Parks and Gardens in the study area: Chantry Park to the west of Ipswich; Wivenhoe Park to the east of Colchester; Colchester Castle Park in the centre of Colchester; Layer Marney Tower to the east of Tiptree; Braxted Park to the east of Witham; Hatfield Priory to the south of Hatfield Preverel; and Danbury Park and Riffhams Park to the west of Danbury. These are considered avoidable in routeing.

12.16 Listed buildings are concentrated in settlements, with a scattering throughout the rural areas. Settlements would be avoided in routeing and an overhead line route corridor would be identified so that isolated listed buildings would be avoidable in detailed alignments although there may be some effects on setting of listed buildings.

12.17 Conservation areas are generally located in settlements. Settlements and conservation areas would be avoided in identifying a route corridor although there may be some effects on settings of conservation areas.

12.18 There are scattered blocks of woodland throughout the study area with concentrations increasing around the south of Colchester and surrounding Tiptree, Great Totham and Danbury. Woodland blocks would be avoided wherever possible in routeing. It would be difficult to identify an overhead line route avoiding woodland south of Colchester.

12.19 The key topographic features are the Stour and Colne river valleys. The Stour Valley forms the vale landscape designated as the Dedham Vale AONB. There are no topographic obstacles to an overhead line.

12.20 The main settlements in the study area include Brantham, Colchester, Witham, Tiptree, Maldon, Danbury and Wickford, with smaller villages dispersed throughout the area. Route corridors would seek to avoid settlements but would be constrained particularly southeast of Colchester. There are scattered farms and dwellings throughout the area. Route corridors for an overhead line would be able to avoid scattered dwellings and sensitive receptors.

PS4 - Socio-Economic Assessment

12.21 Hadleigh, the Bramford/Ipswich fringe, Manningtree and Lawford. Colchester, Wivenhoe, Tiptree, Maldon, South Woodham Ferrers and Rayleigh are identified in planning policy for major housing and employment growth. Allocated areas could be avoided in routeing a new overhead line although this may be difficult at Colchester, Manningtree and Lawford, Maldon and South Woodham Ferrers.

12.22 The potential impact on the achievement of socio-economic planning objectives is considered to be generally neutral Most potential effects on implementing socio-economic policy should be capable of mitigation through detailed routeing and siting of infrastructure.

13 Conclusions

13.1 This Report describes the review that National Grid has conducted of potential strategic options to extend the electricity transmission system in the East Anglia region and, at the same time, continue to ensure that National Grid complies with its statutory obligations and its licence standards. This analysis is summarised in Table 13.1.

13.2 The review assessed which of the strategic options available to meet the Need Case is the most appropriate, taking into account the considerations set out in this Report.

13.3 This Report:

- Reviews the technology options available to meet the identified need for system reinforcement, including the use of AC underground cables and overhead lines, gas insulated lines and HVDC technology;
- Assesses the lifetime costs of each technology option as well as the initial capital cost, and
- Assesses the environmental and socio-economic effects of each option.

13.4 There are four strategic options which would meet the Need Case including the requirements of the SQSS:

- PS1 Sizewell - Bradwell (subsea)
- PS2 Bramford – Twinstead Tee
- PS3 Bramford – Braintree
- PS4 Bramford – Rayleigh

13.5 There are a number of different technologies by which the required transmission connection can be made:

- Alternating Current (AC) Overhead transmission lines;

- AC Underground cable circuits;
- AC Gas Insulated lines (GIL), and
- High Voltage Direct Current (HVDC) technology.

Table 13.1: Options Summary

	Route Length	Environmental	Socio-economic	Technical	Economic	
					Capital Cost[29]	**Lifetime Cost[30]**
PS1a Sizewell – Bradwell (HVDC subsea cable / AC overhead line)	90km subsea cable plus 38km (rebuild) and 5km (Sizewell-Leiston)	Constrained by a number of international and national designations (e.g. Outer Thames Estuary SPA and Dengie Flats SSSI). Designated sites cannot be avoided, although significant adverse effects may be avoidable (assessment under the Habitat Regs (2010) would be required to determine the potential for significant adverse affects). Converter station sites at each end of the connection would bring adverse landscape effects and impacts on views, including in the Suffolk Coast and Heaths AONB.. Requires new 5km 400kV overhead line between Sizewell and Leiston with effect on landscape and views in AONB. Requires 38km new 400kV overhead line on route of existing 132kV Bradwell-Rayleigh overhead line with effects on landscape and views.	There are no significant socio-economic constraints that cannot be addressed by detailed alignment.	Multiple converter and cables need to accommodate power flows (maximum currently installed is 350MW although suppliers indicate they could achieve 2000MW). Subsea cable fault repair times are more complex and take longer. Refurbishment expected to be required after 20-25 years due to environmental factors.	£1,889m	£2,192m

[29] Capital Cost includes the capital cost of system upgrades, generator connection assets and contingent transmission works.

[30] Lifetime Cost of the proposed transmission connection assets (overhead lines, underground cables and shunt reactors, GIL and HVDC converters and cables).

	Route Length	Environmental	Socio-economic	Technical	Economic	
					Capital Cost[29]	Lifetime Cost[30]
PS1b Sizewell – Bradwell (AC subsea / AC overhead line)	90km subsea cable plus 38km (rebuild) and 5km (Sizewell-Leiston)	Constrained by a number of international and national designations (e.g. Outer Thames Estuary SPA and Dengie Flats SSSI). The designated sites cannot be avoided, although significant adverse effects may be avoidable (assessment under the Habitat Regs (2010) would be required to determine the potential for significant adverse affects). Requires new 5km overhead line between Sizewell and Leiston with effects on landscape and views in AONB. Requires 38km new 400kV overhead line on route of existing 132kV Bradwell-Rayleigh overhead line with effects on landscape and views.	There are no significant socio-economic constraints that cannot be addressed by detailed siting and alignment.	Long AC cables will require operational restrictions for management of both voltage and charging current issues. Subsea cable fault repair times are more complex and take longer.	£2,665m	£2,530m

	Route Length	Environmental	Socio-economic	Technical	Economic	
					Capital Cost[29]	Lifetime Cost[30]
PS2a Bramford – Twinstead Tee (Overhead line)	28km	Would pass through approximately 3.6km of Dedham Vale AONB if DNO route was used, with effects on landscape and views. If DNO route was not used, a new line would be visible from AONB with the scale of effects depending on the route. Constrained by settlements including Hintlesham, Hadleigh, Kersey, Polstead, Boxford, Stoke-by-Nayland and Sudbury.	There are no significant socio-economic constraints that cannot be addressed by detailed alignment and consideration of undergrounding in specific locations or other mitigation.	Well established and proven technology. Provides additional spare capacity. Ease of maintenance and repair that can extend life to 80 years. End of life replacement not onerous. Flexible technology able to accommodate further connections along the route.	£544.9m (£575.3m Using DNO Line)	£198m (£229m Using DNO Line)
PS2b Bramford – Twinstead Tee (AC underground cable)	28km	Effects on the AONB would relate to where trees or woodlands were cleared and could not be replanted. These effects would be less than those anticipated for an overhead line.	There are no significant socio-economic constraints that cannot be addressed by detailed routeing or other mitigation.	Proven technology. Long length will require voltage compensation and operational procedures. Cable failure will require identification, excavation, extraction, delivery of cable and installation which may be significant in duration.	£1,128m	£751m

	Route Length	Environmental	Socio-economic	Technical	Economic	
					Capital Cost[29]	Lifetime Cost[30]
PS2c Bramford – Twinstead Tee (GIL)	28km	Effects on the AONB would relate to where trees or woodlands were cleared and could not be replanted. These effects would be less than those anticipated for an overhead line.	There are no significant socio-economic constraints that cannot be addressed by detailed routeing or other mitigation.	Developing technology. Very limited experience at 400kV. Currently longest direct buried 400kV length in service is circa 1km. Gas Zone separation is required every few km with access to gas and de-gas system required. Failure will require excavation, de-gassing access, extraction, equipment delivery and installation.	£1,132m	£759m
PS3a Bramford – Braintree (OHL)	34km (new) with potential removal of 8km of existing overhead line.	Would pass through approximately 3.6km of Dedham Vale AONB using DNO route, with effects on landscape and views. Would also pass close to the western edge of the AONB for a significant distance affecting landscape and views. Constrained by settlements including Hintlesham, Hadleigh, Kersey, Polstead, Boxford, Stoke-by-Nayland, Colchester, Manningtree and several smaller towns and villages.	There are no significant socio-economic constraints that cannot be addressed by detailed alignment and consideration of undergrounding in specific locations or other mitigation.	Well established and proven technology.Provides additional spare capacity. Ease of maintenance and repair that can extend life to 80 years. End of life replacement not onerous. Flexible technology able to accommodate further connections along the route.	£555m (£586.0m Using DNO Line)	£203m (£234.2m Using DNO Line)

	Route Length	Environmental	Socio-economic	Technical	Economic	
					Capital Cost[29]	Lifetime Cost[30]
PS3b Bramford – Braintree (AC under-ground cable)	34km (new) with potential removal of 8km of existing overhead line.	Effects on the AONB would relate to where trees or woodlands were cleared and could not be replanted. These effects would be less than those anticipated for an overhead line.	There are no significant socio-economic constraints that cannot be addressed by detailed routeing or other mitigation.	Long AC cables will require operational restrictions for management of both voltage and charging current issues.	£1,260m	£881m
PS3c Bramford – Braintree (GIL)	34km (new) with potential removal of 8km of existing OHL.	Effects on the AONB would relate to where trees or woodlands were cleared and could not be replanted. These effects would be less than those anticipated for an overhead line.	There are no significant socio-economic constraints that cannot be addressed by detailed routeing or other mitigation.	Developing technology. Very limited experience at 400kV. Currently longest direct buried 400kV length in service is circa 1km. Gas Zone separation is required every few km with access to gas and de-gas system required. Failure will require excavation, de-gassing access, extraction, equipment delivery and installation.	£1,269m	£849m

	Route Length	Environmental	Socio-economic	Technical	Economic	
					Capital Cost[29]	Lifetime Cost[30]
PS4 Bramford - Rayleigh (overhead line)	90km (new) with potential removal of 22km of existing OHL.	Constrained by Suffolk Coasts and Heath AONB and Dedham Vale AONB. Would also travel close to AONB for significant distance. Constrained by a number of international and national designations (e.g. Stour and Orwell Estuaries Ramsar Site, SPA and SSSI, and numerous scheduled monuments). Settlements include Brantham, Colchester, Wiltham, Tiptree, Maldon, Danbury, Wickford and several smaller towns and villages.	There are no significant socio-economic constraints that cannot be addressed by detailed alignment and consideration of undergrounding in specific locations or other mitigation.	Well established and proven technology. Provides additional spare capacity. Ease of maintenance and repair that can extend life to 80 years. End of life replacement not onerous. Flexible technology able to accommodate further connections along the route.	£719m	£434m

13.6 The review has demonstrated that AC overhead line technology would be the most economical of the options considered. AC underground cable and GIL options considered are less economic, but could be used in combination which AC overhead lines if there is a need to mitigate the potential impacts of overhead lines on sensitive locations. HVDC generally becomes more economic where transmission takes place over long distances, which does not apply in this case and is therefore the most expensive of the options considered in this review. Differences in lifetime costs which have also been calculated and do not prove sufficient to outweigh the economic considerations.

13.7 An evaluation of potential impacts of each strategic option on socio-economic planning policy concluded that it was not possible to discriminate between options on this basis.

13.8 The significant cost of the Sizewell - Bradwell (PS1) subsea option, together with connection routes through the Outer Thames Estuary and Dengie Flats, which bring risk of potential significant adverse effects on the Special Protection Area, lead to the conclusion that this option should only be pursued if there were no other practicable options.

13.9 The greater length and amenity impact, capital and lifetime costs of connections between Bramford and Rayleigh (PS4) compared with those of Bramford to Twinstead or Braintree means that, of the overhead line options PS4 can be discounted.

13.10 PS3 Bramford-Braintree has been considered as an optimised option that reduces its adverse effect on the Dedham Vale AONB by taking the route of the existing 132kV overhead line which passes through the designation. This minimises the amount of the AONB that would be directly affected by the proposal as an overhead line. However the remainder of its route west and south to Braintree would take this option close to the western edge of the AONB introducing significant adverse effects on landscape character and on views to and from the AONB. These effects would be most pronounced if the technology option of an overhead line was used although there may also be enduring effects on landscape character and views, from loss of trees or woodlands, if one of the underground technologies is used.

13.11 Option PS3 Bramford-Braintree considered in this review has part of its route in common with the majority of PS2 Bramford-Twinstead, but whereas PS2 continues west moving further from the AONB to terminate at Twinstead Tee, PS3 runs approximately parallel and relatively close to the AONB as described above. There is no benefit in considering a further variant to PS3 running further west, more distant from the AONB, as it would then become a parallel circuit running south from Twinstead Tee, which can be avoided by option PS2.

13.12 Both PS2 and PS3 cross the Stour Valley which is an area of land managed as AONB by the Dedham Vale and Stour Valley Project. PS3 would cross the valley in a location where there are presently no overhead lines whereas PS2 could use the route of the existing 132kV overhead line to cross this area, thus bringing about a lesser scale of change.

13.13 PS3 offers some landscape benefit in the removal of 8km of existing 400kV overhead line. However this section of overhead line is more distant from the AONB than the section close to the AONB western boundary that would be built to replace it. The net effect of using PS3 with overhead line technology would be to introduce a greater length of overhead line closer to the AONB whilst removing a section of existing overhead line which has little or no effect on views from the AONB. Further, the removal of the 8km section of overhead line and replacement by 34km would not make best use of existing transmission infrastructure nor conserve natural resources as it would require additional construction effort, construction materials and thereby result in a less sustainable option.

13.14 If underground technology options are considered to avoid the adverse effects of PS3 on the AONB, their cost greatly exceeds that which would be needed to achieve the same level of benefit with PS2.

13.15 PS2 performs better than PS3 in the appraisal of environmental effects and PS2 is therefore preferred for further development.

13.16 One of the PS2 variants considers utilising the existing route of a 132kV overhead line circuit. This variant requires a new substation to provide a new connection to the Distribution Network Operator's distribution system. The cost of the substation works has been estimated as £30.4m. Utilisation of this existing 132kV route and/or the consideration of undergrounding part of any of the proposed routes during detailed alignment, would provide some amenity benefits.

13.17 The cost estimates for the two underground technology options considered for a Bramford to Twinstead Tee connection are greater than the estimates for an overhead line connection. GIL would be £587m more expensive and AC underground cables £583m more expensive. Both would offer benefits in terms of landscape and views over an equivalent length of overhead line, during construction, underground/GIL works would be more invasive than the works required for an overhead line and would have a greater scale of effect on sites important for their ecology or archaeology.

13.18 The conclusion of this Report is that the option of constructing a new 400kV overhead transmission line between Bramford and Twinstead Tee would achieve a balance between National Grid's technical, economic and environmental obligations and should remain the preferred strategic option. This is taking account of National Grid's statutory obligations, its licence requirements and all other relevant considerations. However, National Grid recognises due to amenity issues in some areas that sections of the proposed connection may need to be placed underground and that these and other mitigation measures will be investigated in the next stage of the project.

Glossary

AC	Alternating current
AONB	Area of Outstanding Natural Beauty
Boundary	Boundaries reflect the main weaknesses on the interconnected system. Such weaknesses can lead to the need to restrict power flows across the system
CCGT	Combined Cycle Gas Turbine
CDC	Capital Delivery Cost This is a calculated cost estimate based on generalised unit costs for the main elements (equipment cost, installation and commissioning) of an option. and is reflective of recent contract values of the. The cost are based on unit costs arising from a combination of manufacturer and completed project costs.
CSC	Current Source Converter
DNO	Distribution Network Operator
GIL	Gas Insulated Line
Grid Code	A document produced by National Grid Electricity Transmission (NGET) that details the operating procedures and principles governing NGET's relationship with all users of the national electricity transmission system. The Grid Code specifies day-to-day procedures for both planning and operational purposes and covers both normal and exceptional circumstances. The Grid Code is designed to permit the development, maintenance and operation of an efficient, co-ordinated and economical national electricity transmission system, to facilitate competition in the generation and supply of

	electricity and is conceived as a statement of what is optimal (particularly from a technical point of view) for all users and NGET itself in relation to the planning, operation and use of the national electricity transmission system.
GW	Gigawatt (one thousand Megawatts)
HV	High Voltage
HVDC	High Voltage Direct Current A HVDC is used where power transmission over long distances (e.g. greater than 100km) is necessary. At such distances, this technology is both highly technically effective and economic. The solution requires the development of at least 2 converter installations (one at each end) and either a cable or OHL link between the two. The converter installations are typically the size of a large warehouse.
km	Kilometre
kV	Kilovolt
LCPD	Large Combustion Plant Directive The LCPD is a European Union Directive that aims to reduce acidification, ground level ozone and particulates by controlling the emissions of sulphur dioxide, oxides of nitrogen and dust from large combustion plant. Large power stations in the UK must comply with the LCPD. All combustion plant built after 1987 must comply with the emission limits in LCPD. Those power stations in operation before 1987 (namely coal and oil in the UK) are defined as 'existing plant'. Existing plant can either comply with the LCPD by installing emission abatement (Flue Gas De-sulphurisation) equipment or 'opt-out' of the directive. An existing plant that chooses to 'opt-out' is restricted in its

	operation after 2007 and must close by the end of 2015 unless it implements changes that meet the requirements of the European Union Directive.
MAGIC	Multi-Agency Geographic Information for the Countryside
MVA	Mega Volt Ampere – This is a Standard Unit Of Power and is used to describe physical capabilities of electrical equipment.
MW	Mega watt – 1,000,000 watts
Need Case	Bramford to Twinstead Tee Connection Project: Need Case for the East Anglia Region. Published June 2011
NETS SQSS	National Electricity Transmission System Security and Quality of Supply Standard The NETS SQSS is a document that defines a set of criterion that specifies the robustness of the transmission system, in terms of the transmission faults and combinations of faults that it must be able to withstand without any interruption of electrical supplies, and the maximum interruption to supplies which is permitted under certain more onerous combination of faults. The SQSS is subject updates through industry and regulatory working groups, this periodic review and consultation changes to the NETS SQSS are implemented by changes to the electricity transmission licence Standard Conditions approved by the industry regulator, Ofgem. The NETS SQSS requires that National Grid must plan for all demand and generation conditions (or "backgrounds") "which ought reasonably to be foreseen to arise in the course of a year of operation … [and] shall include forecast demand cycles, typical power station operating regimes and typical planned outage patterns."

OFGEM	Office of Gas and Electricity Markets The regulatory body that is responsible for electricity and gas supply markets and networks.
OHL	Overhead Line
Ramsar	Covers all aspects of wetland conservation and wise use, recognising wetlands as ecosystems that are extremely important for biodiversity conservation in general and for the well-being of human communities.
SAC	Special Area of Conservation
SF6	Sulphur Hexafluoride Gas
SGT	Supergrid transformer
SPA	Special Protection Area Gives protection under the Birds Directive to rare and vulnerable birds, and for regularly occurring migratory species.
SSSI	Site of Special Scientific Interest Protect the country's best wildlife and geological sites.
VSC	Voltage Source Converter
XLPE	Cross-linked polyethylene cable

Appendix 1 – Lifetime Costs

A1.1 National Grid has prepared a lifetime valuation for each of the potential strategic options and applicable technology. The valuation includes the lifetime cost of energy losses and lifetime operation and maintenance costs.

A1.2 The following formula was used to assess the total Lifetime Cost of each potential strategic option discussed in the Report where new transmission circuits are required. This is to provide the basis for comparison of alternative connection technology options for the identified circuit route.

CTot = CDC + CL + COM

Where:

CTot	Total Lifetime Cost
CDC	Capital Delivery Cost of the equipment, delivered, installed and commissioned
CL	Net Present Value of the Cost of Losses over the lifetime (40years) of the assets
COM	The Net Present Value (NPV) of the typical Cost of Operation and Maintenance over the lifetime (40 years) of the assets.

A1.3 The discount rate used in the net present value calculations, 3.5%, being the figure recommended in Her Majesty's Treasury's Green Book for discounting future benefits and costs in project appraisal.

A1.4 The average load of a transmission circuit which is integrated into the transmission system is estimated to be 34%. This is based on the analysis of the load on each circuit in the National Grid transmission system over the course of a year, which includes varying generation and demand conditions. This analysis shows that the average loading is 34% of the circuit's capability and this figure has been used to determine the average losses for each new circuit connection option. The average loading is lower than expected because peak loads are seen typically for only limited periods during the year although all circuits must have sufficient capacity to accommodate the peak power flows in order to meet the requirements of the NETS SQSS.

Costs

A1.5 The cost used to assess losses on the system is the price of £60 per MWh as assumed by Ofgem in the Project Discovery documents.

A1.6 The available transmission technologies, as explained in Section 5 are:

a. Overhead Lines;

b. AC Underground Cables;

c. Gas Insulated Lines, and

d. High Voltage DC Underground Cables.

A1.7 For each technology, costs comprise:

a) the capital cost of procuring, installing and commissioning the transmission lines;

b) the on-going costs of the electrical energy lost in overcoming the electrical resistance in the conductors, and

c) the on-going other costs of operations and maintenance.

A1.8 It is unusual for a part of the transmission system to be decommissioned and the site reinstated. Typically, transmission assets will be decommissioned and removed only as part of an upgrade or replacement by different assets. Hence, decommissioning and reinstatement costs are not included in the lifetime costs.

Overhead Lines

A1.9 There are three principal designs in current use by National Grid. These designs vary by the number and cross-sectional area of the conductors used for each phase of each circuit:

a) double-circuit 2 x 570mm2 (resistance = 0.025Ω/km);

b) double-circuit 2 x 850mm2 (resistance = 0.0184Ω/km),

c) double-circuit 3 x 700mm^2 (resistance = 0.014Ω/km) (Required for East Anglia connections).

A1.10 Operations and maintenance costs consist principally of the cost of repainting the transmission pylons, which is scheduled to happen every 18 years, and the costs of regular inspection both from the ground and by helicopter. The annual costs are estimated to £0.80k/km.

AC Underground Cables

A1.11 AC underground cables installations vary principally by how the cables are laid. The principal methods employed by National Grid are direct burial and deep bore tunnels.

a. The Cable requirement for the East Anglia region connections is for three cores per phase 2500mm2 cables, 18 cables in total for two circuits (resistance = 0.0043Ω/km).

b. However with each circuit generating 30MVAr per km of capacitive gain, each circuit would require a minimum of 3 x 200MVAr reactors (6 in total for two circuits) for the shortest route length between Bramford and Twinstaed. Each Reactor has 0.4MW of losses associated with it (2.4MW for 6 reactors).

A1.12 O&M costs have an approximate annual cost of £2.80 k/km.

Gas Insulated Lines

A1.13 Like underground cables, gas insulated lines may be direct-buried or installed in tunnels. As with cables, tunnel installation is used where direct burial is impracticable.

a. The GIL requirement for the East Anglia connections is for 5000A, 3400MVA rated equipment (resistance = 0.0065Ω/km).

A1.14 The annual maintenance costs for gas insulated lines are estimated to be £1k per km.

HVDC Technology

A1.15 There are two broad categories of HVDC systems: voltage source converter (VSC) and current source converter (CSC).

A1.16 Converter stations dominate electrical losses with approximately 0.5-1% of the power transmitted being lost at each end for a CSC and 1-2% at each end for a VSC. Cable losses in HVDC systems are negligible.

A1.17 Annual operation and maintenance costs are significant and estimated to be approximately £1m per converter station.

Calculation of the Cost of Transmission Losses

A1.18 The cost of transmission losses are calculated as follows:

Step 1: Calculate the Average Circuit Loading

- Peak Circuit Power Flow * Average Circuit Utilisation (34%)

Generic Example: 3100MW x 0.34% peak load would be 1054MW Average Loading

Step 2: Calculate the Average Loading per Circuit in KW:

- Average Loading per Circuit kW =

(Average Loading (MW) / number of circuits) * 1000 (to convert to kW)

There are 2 circuits in most cases.

Example: (1054MW / 2) x 1000 = 527,000 kW

Step 3: Calculate the Average Current per Circuit in Amps:

- I = Average Loading Per Circuit kW / (√3 X Operating Voltage in kV)

Operating Voltage 400kV or 275kV

Example: 527,000/ (√3 x 400) = 760.7 Amps

Step 4: Calculate the Resistance per Circuit:

- R = resistance/km * circuit length kms

Example: 2 x 850mm Overhead Line = 0.0184Ω/km x 60km = 1.104 Ω

Step 5: Calculate the Three Phase Lost Power per Circuit in MW:

- Three Phase Lost Power per circuit = 3 x I^2 x R

Example: 3 x 760.7^2 x 1.104 = 1.9MW

Step 6: Calculate the Lost Power in a 2 Circuit Route:

- This is multiplied by 2 to get the losses in a two circuit route

Example: 1.9 x 2 = 3.8MW

Step 7: Calculate the Annual Cost of Losses:

- Annual Loss Cost = Lost Power x Cost per MWh x 24hrs x 365 days a year

Example: 3.8 x £60 per MWh x 24hrs x 365 days a year = £2m per annum

Step 8: Calculate the Average Loading per Circuit in KW:

- The net present value of transmission losses is then derived by applying a discount rate of 3.5% to the annual cost over 40 years.

Appendix 2 – Environmental Appraisals

ENVIRONMENTAL COMMENTARY:
PS1 SIZEWELL – BRADWELL

Approximate Length of Overhead Line Required: 90km subsea and 38km Bradwell - Rayleigh

Other Works Required:

- Common Upgrade Works as set out in chapter 8
- 3 Additional HVDC Connection Bays at the New Sizewell 400kV Substation
- Sizewell/Leiston 3 x 2300MW Converters
- Bradwell 400kV Substation
- Sizewell/Leiston – Bradwell HVDC Cables 90km (3 x 2300MW bipole cables)
- Rebuild overhead line between Rayleigh and Bradwell at 400kV
- Build new 400kV double circuit between Sizewell and Leiston (for the purposes of the options analysis, costs for a new 400kV overhead line circuit have been included)
- New Twinstead 400kV substation
- New Quadrature Boosters at Rayleigh 400kV substation

CRITERIA FOR IDENTIFYING ROUTE CORRIDORS		
Feature	**Routeing Response (and Reference)**	**Sizewell – Bradwell**
National Parks	Seek to avoid/consider undergrounding (NG Commitments/Holford Rule 1)	N/A
Areas of Outstanding Natural Beauty (AONB)	Seek to avoid/consider undergrounding (NG Commitments/Holford Rule 1)	The Suffolk Coast and Heaths AONB poses a significant area of constraint surrounding Sizewell. The existing Sizewell substation is in the AONB, along with two existing overhead lines. It would be difficult to site a new converter station route corridor to avoid this designation.
Heritage Coasts	Seek to avoid (NG Commitments/ Holford Rule 1)	N/A
World Heritage Sites	Seek to avoid (NG Commitments/ Holford Rule 1)	N/A
Sites of Special Scientific Interest (SSSI)	Seek to avoid/verify potential effects(NG Commitments/ Holford Rule 2)	The Sizewell Marshes border Sizewell substation to the west and the Minsmere to Walberswick Heaths and Marshes SSSI border the Sizewell substation to the north. Both are within the AONB. Leiston-Aldeburgh SSSI is to the south of Sizewell substation. Dengie SSSI borders Bradwell substation to the north, east and west along the coast. Sandbeach Meadows SSSI is to the southeast of Bradwell substation, which is avoidable in routeing an overhead line connection to Rayleigh.

CRITERIA FOR IDENTIFYING ROUTE CORRIDORS		
Feature	**Routeing Response (and Reference)**	**Sizewell – Bradwell**
Special Protection Areas (SPA)	Seek to avoid (birds interest) (NG Commitments/Holford Rule 2)	The Minsmere to Walberswick SPA and Breckland Forest SPA are also designated SSSIs, as referenced earlier. Sandlings SPA is to the south of Sizewell substation. A route corridor could avoid this designation. Dengie SSSI is also designated as a SPA as referenced earlier.
Special Areas of Conservation (SAC)	Seek to avoid/verify potential effects (NG Commitments/ Holford Rule 2)	Dew's Pond SAC is also designated as a SSSI as referenced earlier. The Essex Estuaries SAC borders Bradwell substation to the north, east and west along the coast.
Ramsar sites	Seek to avoid/verify potential effects (NG Commitments/ Holford Rule 2)	The Minsmere to Walberswick Ramsar Site is to the north of Sizewell substation. It is also an SPA and SSSI as referenced earlier. Dengie SSSI is also designated as a Ramsar site as referenced earlier.
National Nature Reserves (NNR)	Seek to avoid/verify potential effects (NG Commitments/ Holford Rule 2)	Westleton Heath NNR is to the north of Sizewell substation. This restricts a route corridor, but is avoidable. Dengie SSSI is also designated as a NNR as referenced earlier.
Scheduled Monuments (SM)	Seek to avoid/consider effect on setting (NG Commitments/ Holford Rule 1)	There are SMs scattered around Bradwell substation to the east onshore and offshore to the northeast and southwest. These are considered avoidable in routeing.
Registered Parks and Gardens	Seek to avoid (NG Commitments)	N/A
Historic buildings (Listed I II and II*)	Seek to avoid/consider effect on setting (Note to Holford Rule 2)	Listed buildings are concentrated in settlements, with a scattering throughout the rural areas. Settlements would be avoided in routeing and corridors would be identified so that isolated buildings would be considered in detailed alignments of an overhead line between Bradwell and Rayleigh.
Conservation Areas	Seek to minimise effects/consider effect on setting (Note to Holford Rule 2)	Conservation areas are generally located in settlements. Settlements and conservation areas would be avoided in identifying a route corridor between Bradwell and Rayleigh.
Woodlands	Seek to avoid (Note to Holford Rules 4 and 5)	There are scattered blocks of woodland throughout the study area with concentrations increasing around Sizewell substation and to the south of Bradwell substation. It would be difficult to identify a route avoiding woodland around Sizewell substation.

CRITERIA FOR IDENTIFYING ROUTE CORRIDORS		
Feature	**Routeing Response (and Reference)**	**Sizewell – Bradwell**
Topography	Use topography to screen/background and avoid skylines and ridges (Note to Holford Rules 4 and 5)	The study area is generally flat and low-lying although there are slight reliefs in the topography in the Suffolk Coasts and Heaths AONB and towards Rayleigh from the Bradwell site.
Settlements	Seek to avoid (Supplementary Note)	The main settlements in the study area include Leiston to the west of Sizewell substation and Bradwell-on-Sea to the south of Bradwell substation. Route corridors would seek to avoid settlements.
Scattered dwellings/ sensitive receptors	Seek to identify corridors that allow for separation between possible alignments and receptors (Supplementary Note)	There are scattered farms and dwellings throughout the area. Route corridors would seek to ensure alignments would be able to avoid scattered dwellings and sensitive receptors.
Airfields/airstrips	Avoid airfields and protection zones (CAA/MoD requirements)	N/A

Summary

A subsea cables connection between Sizewell and Bradwell would pass through the Outer Thames Estuary SPA where the qualifying feature is the wintering population of Red Throated Divers (Annex 1 of the Birds Directive). Parts of the Thames Estuary provide important nursery, spawning and feeding grounds for many fish species.

There are three designated sites within the vicinity of Bradwell: Blackwater Estuary, Dengie Flats and Colne Estuary. The subsea cables would need to travel through the Dengie Flats SSSI.

Installing subsea cables through the Outer Thames Estuary and Dengie Flats could result in the following effects on the SPA and SSSI:

- Disturbance of the mudflats and bed of the estuary from cables installation across a construction swathe of approximately 440m for AC cables or 150m - 350m for HVDC cables (depending on the number of cables required) which may alter the species composition of the flora and fauna;
- Suspended sediments – resulting from the release of sediment from the cabling activities;
- Mobilisation of contaminants in sediments could impact on the flora and fauna of the Estuary; and
- Disturbance from the cable laying activities could impact on species using the SPA and SAC.

The nature and scale of these effects would require further assessment in accordance with the Conservation of Habitats and Species Regulations 2010 (‘appropriate assessment). Mitigation in the form of detailed routeing and timing of installation of the works may mitigate adverse environmental effects.

The construction of converter stations would require a large land take in the vicinity of the cables landing point. This would bring adverse environmental effects and would be particularly constrained at Sizewell where the designation of Suffolk Coast and Heaths AONB would be adversely affected by development.

Constructing a replacement 38km 400kV overhead line between Bradwell and Rayleigh would give rise to adverse effects on landscape and views, although the scale of change would be lower if the route of the existing 132kV overhead line was used than for a new additional route.

If the subsea cables can be installed without serious adverse environmental effects on the marine environment and designations, the onshore works would be greater than the Bramford-Twinstead Tee required works. The Bramford-Twinstead Tee option could use the route of a shorter 132kV overhead line than that between Bradwell and Rayleigh, although the Bramford-Twinstead Tee option would pass through a short section of the Dedham Vale AONB. However the Sizewell-Bradwell option would require a new converter station adversely affecting the Suffolk Coast and Heaths AONB.

This option PS1 brings additional environmental risks as compared to the Bramford-Twinstead Tee option.

The environmental issues associated with additional substation and network reconfiguration have not been factored in at this stage.

ENVIRONMENTAL COMMENTARY:
PS2 BRAMFORD – TWINSTEAD TEE

Approximate Length of Overhead Line Required: 28km

Other Works Required:
- Common Upgrade Works as set out in chapter 8
- 2 Additional AC Connection Bays at the Bramford 400kV Substation
- Reconductoring of all Sizewell to Bramford Overhead Line Circuits

CRITERIA FOR IDENTIFYING ROUTE CORRIDORS		
Feature	**Routeing Response (and Reference)**	**Bramford to Twinstead Tee**
National Parks	Seek to avoid/consider undergrounding (NG Commitments/Holford Rule 1)	N/A
Areas of Outstanding Natural Beauty (AONB)	Seek to avoid/consider undergrounding (NG Commitments/Holford Rule 1)	Dedham Vale AONB poses an area of constraint between Bramford and Twinstead Tee. The Bramford to Twinstead Tee option could avoid or use the shortest route through the north of the AONB.
Heritage Coasts	Seek to avoid (NG Commitments/ Holford Rule 1)	N/A
World Heritage Sites	Seek to avoid (NG Commitments/ Holford Rule 1)	N/A
Sites of Special Scientific Interest (SSSI)	Seek to avoid/verify potential effects(NG Commitments/ Holford Rule 2)	There are relatively few designated sites of nature conservation interest at this level. The Hintlesham Woods SSSI is to the east of Hadleigh. Elmsett Park Wood SSSI is to the east of Elmsett. Lineage Wood and Railway Track SSSI are to the west of Lavenham. Glemsford Pits SSSI is to the north of Long Melford. Arger Fen SSSI is to the east of Bures.
Special Protection Areas (SPA)	Seek to avoid (birds interest) (NG Commitments/Holford Rule 2)	N/A
Special Areas of Conservation (SAC)	Seek to avoid/verify potential effects (NG Commitments/ Holford Rule 2)	N/A
Ramsar sites	Seek to avoid/verify potential effects (NG Commitments/ Holford Rule 2)	N/A
National Nature Reserves (NNR)	Seek to avoid/verify potential effects (NG Commitments/ Holford Rule 2)	N/A
Scheduled Monuments (SM)	Seek to avoid/consider effect on setting (NG Commitments/ Holford Rule 2)	There are several isolated SMs throughout the study area which are considered to be avoidable in routeing.

CRITERIA FOR IDENTIFYING ROUTE CORRIDORS		
Feature	**Routeing Response (and Reference)**	**Bramford to Twinstead Tee**
Registered Parks and Gardens	Seek to avoid (NG Commitments))	There is a Registered Park and Garden at Tendring Hall near Stoke-by-Nayland within the AONB. A route corridor would be able to avoid this designation.
Historic buildings (Listed I II and II*)	Seek to avoid/consider effect on setting (Note to Holford Rule 2)	Listed buildings are concentrated in settlements, with a scattering throughout the rural areas. Settlements and conservation areas would be avoided in routeing and corridors could be identified so that isolated listed buildings would be considered in detailed alignments.
Conservation Areas	Seek to minimise effects/consider effect on setting (Note to Holford Rule 2)	Conservation areas are generally located within settlements. Settlements and conservation areas would be avoided in identifying a route corridor.
Woodlands	Seek to avoid (Note to Holford Rules 4 and 5)	There are scattered blocks of woodland throughout the study area, increasing in frequency around Twinstead Tee, within the AONB and to the southwest of Bramford. Woodland blocks would be avoided wherever possible in routeing.
Topography	Use topography to screen/background and avoid skylines and ridges (Note to Holford Rules 4 and 5)	The key features in the topography are the Stour and Colne river valleys forming the vale landscape designated as the Dedham Vale AONB.
Settlements	Seek to avoid (Supplementary Note)	Larger settlements in the study area include Hadleigh, Sudbury and Boxford. There are numerous smaller towns and villages dispersed throughout the study area. Route corridors would be able to avoid settlements.
Scattered dwellings/ sensitive receptors	Seek to identify corridors that allow for separation between possible alignments and receptors (Supplementary Note)	There are scattered farms and dwellings throughout the area. Route alignments would seek to avoid the scattered dwellings and sensitive receptors.
Airfields/airstrips	Avoid airfields and protection zones (CAA/MoD requirements)	Elmsett Airport is to the west of Bramford.

Summary

A route alignment between Bramford and Twinstead Tee would provide the shortest connection at approximately 28km. It appears that a Bramford to Twinstead Tee route corridor would pass through the least environmental and landscape designations, which National Grid seeks to avoid.

The Bramford to Twinstead Tee option PS2 offers the potential of a shorter route through the Dedham Vale AONB or to avoid it completely; is shorter in total length than others; and appears to have no greater effects on other environmental features.

The above commentary refers solely to a possible 400kV route corridor between Bramford and the Twinstead Tee. The environmental issues associated with additional substation and network reconfiguration have not been factored in at this stage.

ENVIRONMENTAL COMMENTARY:
PS3 BRAMFORD - BRAINTREE

This option has been 'optimised' from a straight line connection between Bramford and Braintree and considers using the approximate route of the existing overhead lines southwest from Bramford towards the Twinstead Tee to minimise the crossing of the Dedham Vale AONB. It considers a route from east of Twinstead Tee that avoids the AONB and connects to the existing Twinstead Tee to Braintree overhead line.

Approximate Length of Overhead Line Required: 34km

Other Works Required:

- Common Upgrade Works as set out in chapter 8
- 2 Additional AC Connection Bays at the Bramford 400kV Substation
- Reconductoring of all Sizewell to Bramford Overhead Line Circuits

CRITERIA FOR IDENTIFYING ROUTE CORRIDORS		
Feature	**Routeing Response (and Reference)**	**Bramford to Braintree**
National Parks	Seek to avoid/consider undergrounding (NG Commitments/Holford Rule 1)	N/A
Areas of Outstanding Natural Beauty (AONB)	Seek to avoid/consider undergrounding (NG Commitments/Holford Rule 1)	Dedham Vale AONB poses a significant area of constraint between Bramford and Braintree. A route to the north of the AONB is constrained by the existing 400kV Bramford to Pelham (via Twinstead Tee) overhead line and a route to the east is constrained by the built development of Manningtree beyond which is the River Stour estuary. Route options through the AONB range from 3.5-12km. The shortest route option through the AONB is approximately 3.5km and runs close to the existing 400kV line. An overhead line running southwest and west of the AONB would be visible from the designated area.
Heritage Coasts	Seek to avoid (NG Commitments/Holford Rule 1)	N/A
World Heritage Sites	Seek to avoid (NG Commitments/Holford Rule 1)	N/A
Sites of Special Scientific Interest (SSSI)	Seek to avoid/verify potential effects (NG Commitments/ Holford Rule 2)	There are relatively few sites of nature conservation interest, the main one being Chalkney Wood SSSI which is close to the existing Twinstead Tee to Braintree line in the Colne Valley. Arger Fen SSSI is to the northeast of Bures. Hintlesham Woods SSSI is to the southwest of Bramford substation. A route corridor would be able to avoid these designations.

CRITERIA FOR IDENTIFYING ROUTE CORRIDORS		
Feature	**Routeing Response (and Reference)**	**Bramford to Braintree**
Special Protection Areas (SPA)	Seek to avoid (birds interest) (NG Commitments/Holford Rule 2)	N/A
Special Areas of Conservation (SAC	Seek to avoid/verify potential effects (NG Commitments/ Holford Rule 2)	N/A
Ramsar sites	Seek to avoid/verify potential effects (NG Commitments/ Holford Rule 2)	N/A
National Nature Reserves (NNR)	Seek to avoid/verify potential effects (NG Commitments/ Holford Rule 2)	N/A
Scheduled Monuments (SM)	Seek to avoid/consider effect on setting (NG Commitments/ Holford Rule 2)	There are several isolated SMs throughout the study area which are considered to be avoidable in routeing.
Registered Parks and Gardens	Seek to avoid (NG Commitments)	There is a Registered Park and Garden at Tendring Hall near Stoke-by-Nayland within the AONB. A route corridor would be able to avoid this designation.
Historic buildings (Listed I II and II*)	Seek to avoid/consider effect on setting (Note to Holford Rule 2)	Listed buildings are concentrated in settlements, with a scattering throughout the rural areas. Settlements and conservation areas would be avoided in routeing and the corridor would be identified so that isolated listed buildings would be considered in detailed alignments.
Conservation Areas	Seek to minimise effects/consider effect on setting (Note to Holford Rule 2)	Conservation areas are generally located within settlements. Settlements and conservation areas would be avoided in identifying a route corridor.
Woodlands	Seek to avoid (Note to Holford Rules 4 and 5)	There are scattered blocks of woodland throughout the study area with concentrations increasing towards Braintree. Woodland blocks would be avoided wherever possible in routeing, although this would be difficult to the east of Braintree and to the northeast of Polstead.
Topography	Use topography to screen/background and avoid skylines and ridges (Note to Holford Rules 4 and 5)	The key features in the topography are the Stour and Colne river valleys forming the vale landscape designated as the Dedham Vale AONB. The route seeking to minimise crossing the AONB would require a long crossing of the Stour valley.

CRITERIA FOR IDENTIFYING ROUTE CORRIDORS		
Feature	**Routeing Response (and Reference)**	**Bramford to Braintree**
Settlements	Seek to avoid (Supplementary Note)	Larger settlements in the study area include Colchester to the south and Manningtree to the east, with smaller towns and villages dispersed through the area, many are located within the AONB. Route corridors would be able to avoid settlements.
Scattered dwellings/ sensitive receptors	Seek to identify corridors that allow for separation between possible alignments and receptors (Supplementary Note)	There are scattered farms and dwellings throughout the area. Route alignments would be able to avoid the scattered dwellings and sensitive receptors.
Airfields/airstrips	Avoid airfields and protection zones (CAA/MoD requirements)	Earls Colne Airfield is to the southeast of Halstead. All route corridors would need to avoid the airfield. Consultation would need to be undertaken with regard to surrounding protection zones.

Summary

A connection between Bramford and Braintree using the 'optimised' route would be approximately 48km. There would be opportunity to use approximately 14km of the existing overhead line for the connection. The length of new overhead line would be approximately 34km which is longer than the connection between Bramford and Twinstead Tee.

There are similar levels and density of constraints in the general area through which a Bramford-Braintree route corridor would pass as for a Bramford to Twinstead Tee connection. As the Bramford to Braintree route is longer, it would be anticipated to give rise to greater environmental effects. However the 'optimised route' could not avoid the same direct effects on the AONB as a connection between Bramford and Twinstead Tee. It would also bring additional effects on the designated area as it would run close to the western edge of the AONB as it headed southwest towards Braintree.

The removal of approximately 8km of existing 400kV overhead line between Twinstead Tee and Braintree would bring environmental benefits. However the removal would not directly benefit any sites subject to the highest level designations such as the AONB whereas the new overhead line would be installed in and close to the designation.

The Bramford to Twinstead Tee option offers the potential of an equivalent relatively short route through the AONB or to avoid it completely; is shorter in total length; and appears to have no greater effects on other environmental features.

The Bramford to Braintree route PS3 performs less favourably in environmental terms than the Bramford to Twinstead Tee option.

The above commentary refers solely to a possible 400kV route corridor between Bramford and Braintree. The environmental issues associated with additional substation and network configuration works have not been factored in at this stage. These would introduce additional environmental effects which further weigh against this option as compared to the Bramford to Twinstead Tee option.

ENVIRONMENTAL COMMENTARY:
PS4 BRAMFORD - RAYLEIGH

Approximate Length of Overhead Line Required: 65km

Other Works Required:

- Common Upgrade Works as set out in chapter 8
- 2 Additional AC Connection Bays at the Bramford 400kV Substation
- Extend Rayleigh 400kV substation
- Reconductoring of all Sizewell to Bramford Overhead Line Circuits
- Construct a new 400kV DNO supply point

CRITERIA FOR IDENTIFYING ROUTE CORRIDORS		
Feature	**Routeing Response (and Reference)**	**Bramford to Rayleigh 132kV Route**
National Parks	Seek to avoid/consider undergrounding (NG Commitments/Holford Rule 1)	N/A
Areas of Outstanding Natural Beauty (AONB)	Seek to avoid/consider undergrounding (NG Commitments/Holford Rule 1)	There are two AONBs that pose a significant area of constraint between Bramford and Rayleigh: Suffolk Coasts and Heaths AONB (approximately 11km southeast of Bramford) and Dedham Vale AONB (approximately 11km southwest of Bramford). The AONBs are approximately 1km apart. A route between the AONBs, avoiding each designation, is constrained by the settlement of Brantham. A route option along the eastern boundary of the Dedham Vale AONB or western boundary of the Suffolk Coasts and Heaths AONB to avoid Brantham is also constrained by the Stour and Orwell Estuaries Ramsar Site, SPA and SSSI. A route through the Suffolk Coasts and Heaths AONB is shorter than the Dedham Vale AONB, however it would require routeing through the Stour and Orwell Estuaries Ramsar Site, SPA and SSSI.
Heritage Coasts	Seek to avoid (NG Commitments/ Holford Rule 1)	N/A
World Heritage Sites	Seek to avoid (NG Commitments/ Holford Rule 1)	N/A

CRITERIA FOR IDENTIFYING ROUTE CORRIDORS		
Feature	**Routeing Response (and Reference)**	**Bramford to Rayleigh 132kV Route**
Sites of Special Scientific Interest (SSSI)	Seek to avoid/verify potential effects(NG Commitments/ Holford Rule 2)	There are SSSIs between Bramford and Rayleigh which pose significant constraints. The Stour Estuary SSSI along the River Stour restricts routes to the east and west of Brantham. To the east of the Stour Estuary SSSI the route would be in the Dedham Vale AONB. The Upper Colne Marshes SSSI, the Roman River SSSI, the Colne Estuary SSSI and the Abberton Reservoir SSSI are present to the south of Colchester. A route corridor in this vicinity is very unlikely to be able to avoid the designations. The Blackwater Estuary SSSI is to the east of Maldon along the River Blackwater. The Crouch and Roach Estuaries SSSI is to the east of South Woodham Ferrers. These designated areas restrict a route corridor in this vicinity but are avoidable.
Special Protection Areas (SPA)	Seek to avoid (birds interest) (NG Commitments/Holford Rule 2)	The Stour and Orwell Estuaries SPA is to the east of the study area along the River Stour and extends between Brantham and Lawford and into the Dedham Vale AONB. A route corridor in this vicinity would not be able to avoid these designations due to constraints of built development. The Abberton Reservoir SPA and Colne Estuary SPA are to the south of Colchester. A route corridor avoiding these SPAs would cross other constraints in the vicinity. The Blackwater Estuary SPA is to the east of Maldon along the River Blackwater. The Crouch and Roach Estuaries SPA is to the east of South Woodham Ferrers. These designated areas restrict a route corridor in this vicinity but are avoidable.
Special Areas of Conservation (SAC)	Seek to avoid/verify potential effects (NG Commitments/ Holford Rule 2)	The Essex Estuaries SAC covers the area surrounding the River Blackwater and the River Crouch. A route corridor can be identified avoiding this designation.
Ramsar sites	Seek to avoid/verify potential effects (NG Commitments/ Holford Rule 2)	The Stour and Orwell Estuaries Ramsar Site is in the east of the study area surrounding the River Stour. The designation is also an SPA and SSSI. Refer to these above descriptions for an assessment.

CRITERIA FOR IDENTIFYING ROUTE CORRIDORS		
Feature	**Routeing Response (and Reference)**	**Bramford to Rayleigh 132kV Route**
National Nature Reserves (NNR)	Seek to avoid/verify potential effects (NG Commitments/ Holford Rule 2)	The Blackwater Estuary NNR is along the River Blackwater to the east of the study area. The Blackwater Estuary is also designated a SSSI as referenced earlier.
Scheduled Monuments (SM)	Seek to avoid/consider effect on setting (NG Commitments/ Holford Rule 2)	There are several SMs in the study area, predominately surrounding Brantham, Colchester, Danbury and South Woodham Ferrers. These are considered largely avoidable in routeing.
Registered Parks and Gardens	Seek to avoid (NG Commitments)	There are Registered Parks and Gardens in the study area: Chantry Park to the west of Ipswich; Wivenhoe Park to the east of Colchester; Colchester Castle Park in the centre of Colchester; Layer Marney Tower to the east of Tiptree; Braxted Park to the east of Witham; Hatfield Priory to the south of Hatfield Preverel; and Danbury Park and Riffhams Park to the west of Danbury. Proposed routeing would seek to avoid this designation.
Historic buildings (Listed I II and II*)	Seek to avoid/consider effect on setting (Note to Holford Rule 2)	Listed buildings are concentrated in settlements, with a scattering throughout the rural areas. Settlements would be avoided in routeing and the corridor would be identified so that isolated listed buildings would be considered in detailed alignments.
Conservation Areas	Seek to minimise effects/consider effect on setting (Note to Holford Rule 2)	Conservation areas are generally located in settlements. Settlements and conservation areas would be avoided in identifying a route corridor.
Woodlands	Seek to avoid (Note to Holford Rules 4 and 5)	There are scattered blocks of woodland throughout the study area with concentrations increasing around the south of Colchester and surrounding Tiptree, Great Totham and Danbury. Woodland blocks would be avoided wherever possible in routeing. It would be difficult to identify a route avoiding woodland south of Colchester.
Topography	Use topography to screen/background and avoid skylines and ridges (Note to Holford Rules 4 and 5)	The key features in the topography are the Stour and Colne river valleys. The Stour Valley forms the vale landscape designated as the Dedham Vale AONB.

CRITERIA FOR IDENTIFYING ROUTE CORRIDORS		
Feature	**Routeing Response (and Reference)**	**Bramford to Rayleigh 132kV Route**
Settlements	Seek to avoid (Supplementary Note)	The main settlements in the study area include Brantham, Colchester, Witham, Tiptree, Maldon, Danbury and Wickford, with smaller villages dispersed throughout the area. Route corridors would seek to avoid settlements but would be constrained particularly southeast of Colchester.
Scattered dwellings/ sensitive receptors	Seek to identify corridors that allow for separation between possible alignments and receptors (Supplementary Note)	There are scattered farms and dwellings throughout the area. Route corridors would seek to ensure alignments would be able to avoid scattered dwellings and sensitive receptors.
Airfields/airstrips	Avoid airfields and protection zones (CAA/MoD requirements)	N/A

Summary

A connection between Bramford and Rayleigh using part of the existing 132kV route between Bramford and Rayleigh would be approximately 65km. This is approximately 37km longer than the connection between Bramford and Twinstead Tee. The PS4 route uses the 132kV route between Bramford and the southeast of Colchester, and between the south of Colchester and Rayleigh. Route PS4 does not follow the existing 132kV route between the southeast and south of Colchester because this is highly constrained passing through part of the town.

The Bramford to Rayleigh 132kV route presents greater numbers of the highest level designations as constraints than the Bramford to Twinstead Tee connection. It would be difficult to avoid the Dedham Vale AONB, unless routeing was close to the settlement of Brantham. It would also be difficult to avoid routeing through the Stour and Orwell Estuaries Ramsar Site, SPA and SSSI, whilst also avoiding settlements.

National Grid seeks to avoid areas which are nationally or internationally designated for their landscape and environmental value such as AONBs, Ramsar Sites, SPAs and SSSIs. The Bramford to Twinstead Tee option offers the potential of a shorter route through an AONB or to avoid it completely. It is also shorter in total length and avoids the risk of effects on high level designations of Ramsar, SPA and SSSIs.

The above commentary refers solely to a possible 400kV route corridor based on the existing 132kV route between Bramford and Rayleigh. The environmental issues associated with additional substation and network reconfiguration have not been considered at this stage. These would introduce additional environmental effects.

Using the 132kV route reduces scale of change but introduces negative change in high level designations: Ramsar Sites; SPAs; and SSSIs. The removal of the existing 400kV overhead line between Twinstead Tee and Braintree (approximately 22km) would bring environmental benefits. However the removal would not directly benefit any sites subject to the highest level designations such as AONB and SPA which would be crossed by the Bramford to Rayleigh 132kV route.

The Bramford to Rayleigh 132kV route option PS4 performs less favourably in environmental terms than the Bramford to Twinstead Tee option.

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