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Bramford to Twinstead 400kV Overhead Line Project

Strategic Optioneering Report

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1 PURPOSE OF REPORT

1.1 This report describes the process of developing and assessing options which led to a proposal to create a new 400kV overhead line connection between Bramford substation (near Ipswich, Suffolk) and Twinstead Tee (near Sudbury, Suffolk) being identified as the subject of a Route Corridor Study. The proposal is promoted by National Grid Electricity Transmission plc (referred to in this report as "National Grid").

1.2 The report first considers the background to the development of new electricity transmission infrastructure, then addresses the need for new connections in East Anglia. The process of option development and assessment is described and finally a range of options is described and evaluated.

2 BACKGROUND

2.1 National Grid owns the high voltage electricity transmission system in England and Wales and operates the electricity transmission system across Great Britain. The Company is responsible for operating the high voltage network, carrying power between generating stations and the local electricity supply networks of the regional Distribution Network Operators (DNO).

2.2 The high voltage electricity transmission system in England and Wales, which operates at 275,000 volts (275kV) and 400,000 volts (400kV), comprises some 7,000 route kilometres (km) of overhead lines, over 600km of underground cable and over 320 substations. At the substations, generated power is connected to the system, and the primary transmission voltage of 400kV or 275kV is transformed to lower voltages to companies with direct connections, and to the Distribution Network Operators who take supplies and distribute electricity at lower voltages to factories, offices and homes.

2.3 The network of transmission lines is focussed on historic generation locations and urban areas where demand for electricity is high.

2.4 In England and Wales, the installed generation capacity is 65GW, with a maximum demand of 54.3GW. A number of generating stations are planned to close in the next 5-10 years, with 12.5GW of coal/oil generation lost as a result of EU emissions legislation and 7.5GW of nuclear generation lost as the power stations

reach the end of their asset lives. Coupled with moves towards a low carbon economy, this will lead to the need to procure significant new generation and a change in the generation mix. Demand for electricity is forecast to remain constant from 2010 which means around 20 gigawatts of new generation will be required to meet demand.

2.5 National Grid has a statutory duty to connect new generating stations to the transmission system. The form which these connections might take will depend on a number of factors including the location, capacity and timing of new generating stations. In particular it should be noted that wind farms are often remote from the main centres of electricity demand and the existing transmission network and that new nuclear power stations will have a higher generating capability and may require additional transmission capacity over and above that used to connect the existing nuclear power stations. Applications for connections of new nuclear power stations have been made on the basis of periods of parallel running between old and new stations. In order to connect this additional generation, reinforcement of the transmission system, including uprating and reconductoring existing lines, new overhead lines and new or extended substations may be required. Because of the interconnected nature and topology of the existing transmission system, system reinforcement or enhancement works may be required some distance from the new generating stations which are to be connected.

2.6 At privatisation, and as required by its transmission licence, National Grid implemented the Grid Code[1], which is designed to permit the development, maintenance and operation of an efficient, co-ordinated and economical system for the transmission of electricity, to facilitate competition in the generation and supply of electricity and to promote the security and efficiency of the power system as a whole. This reflects National Grid's statutory duties under the Electricity Act 1989. It does this by providing a clear technical basis for its requirements for suitable performance from electrical equipment connected to the transmission system, and by specifying clear levels of expected performance from the transmission system on which the design of other parties' equipment may be based or reviewed. By application of these standards, material damage to other parties' equipment, resulting from credible events in the development, maintenance and operation of the transmission system, may be avoided.

[1] NGET : The Grid Code Issue 4 : 24/06/09

2.7 Under the terms of its transmission licence, National Grid is required to plan, develop and operate its transmission system in accordance with the National Electricity Transmission System Security and Quality of Supply Standard (NETSQSS)[2]. It is required to offer and honour terms for connection of new generation which do not conflict with this obligation[3]. Accordingly such offers are assessed on the basis of :

- overall capital cost;
- the technical viability of the connection;
- the connection not unduly adversely impacting the connection dates and broader commitments made to other connectees.

2.8 Section 38 and Schedule 9 of the Electricity Act 1989[4] requires 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".

2.9 National Grid's Schedule 9 Statement[5] sets out how the company will meet the duty placed upon it by the aforementioned legislation. This includes :

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

[2] National Electricity Transmission System Security and Quality of Supply Standard Version 2.0 : 24/06/09
[3] Based upon the Ofgem consultation of 8th May 2009, National Grid may also apply to Ofgem, in restricted circumstances, to be derogated in its connection to new users, provided it can demonstrate a manageable solution not giving rise to excessive cost and not compromising other obligations including Nuclear Site Licences. Such "connect and manage" positions will only be deemed acceptable by the regulator if the works restore compliance with the NETSQSS.
[4] Electricity Act 1989 c29
[5] National Grid Electricity Transmission plc : Electricity Act 1989 - Schedule 9 Statement : November 2006

- seeking to avoid nationally and internationally designated areas where new infrastructure is required; and

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

2.10 The Statement also refers to the application of best practice methods to assess the environmental impacts of proposals and identify appropriate mitigation measures. Effective consultation is promoted by the Statement.

3 NEED

3.1 The transmission system in East Anglia was originally constructed in the 1960s and subsequently upgraded in the early 1990's, to provide a connection to the Sizewell B nuclear power station.

3.2 The transmission network in East Anglia (see diagram in Appendix C) consists of a 212km loop formed by double circuit 400kV overhead lines :

- to the north between Walpole and Norwich (4VV) c.79.2km;

- to the east between Norwich and Bramford (4YM) c.61.2km;

- to the south between Bramford and Twinstead Tee near Sudbury (4YL) c. 28km , connecting westwards to Pelham (4YL)- a further 43.2km away;

3.3 These routes loop off the main transmission corridor in the area to the west of East Anglia which runs between Walpole and Pelham via Burwell (4ZM), c. 93.1km in length. From Pelham, connections are made to the London conurbation and to the west. From Twinstead Tee (on the 4YL line near Hadleigh), the 4YLA route runs south to Braintree and then on (4VB) to Rayleigh and the Thames Estuary network.

3.4 Two double circuit 400kV overhead lines (4ZX / 4ZW) bring power into Bramford substation from a substation at Sizewell nuclear power station.

3.5 In East Anglia, demand amounts to approximately 2GW during peak system load conditions. Existing contracted generating capacity in the area covered by the

Walpole - Twinstead loop is 3.5GW, and will have increased to 4.2GW by the end of 2009 with new renewable connections underway.

3.6 The network is adequate for the current generation / demand balance. East Anglia is, however, an area of significant generation development. There is currently a further 7.6GW of generation contracted to connect to the transmission system in the area between Walpole and Bramford, with a further 0.8GW of capacity at Spalding in the vicinity of Walpole also affecting this area of the network. These connections are due to be made between 2011 and 2021, with many in the advanced stages of delivery. National Grid is also aware, via the Electricity Networks Strategy Group (ENSG), of further offshore wind farm and power station connections totalling around 5GW, and potentially up to 7.5GW that will require connection in the East Anglia area in the period 2014-2020.

3.7 Whilst a number of the above new connections have been accommodated by the upgrading of the existing system in the area, parts of the existing network have reached the limits of their capacity even with such upgrading.

3.8 There are three key issues affecting the existing transmission system which drive the need for a new route - thermal conditions, quality of supply; and transient stability.

Thermal conditions

3.9 Conductors are designed for a certain operating temperature and safe clearances between the conductors and the ground/structures are based on this assumption. Overloading causes conductors to overheat which will increase the sag of the conductors and reduce clearances. Operating at a temperature greater than their design temperature could also lead to a reduction in conductor strength.

3.10 In the event of the double circuit overhead line running west of Bramford to Twinstead (4YL) being out of commission, the existing main transmission route south of Walpole (4ZM route to Burwell) would become overloaded as a result of the power flow needing to be supported on the remaining network. In addition, the impact of existing and proposed Thames Estuary generation leads to more onerous flow conditions from East Anglia due to the way in which the network runs to accommodate East Anglia and Thames Estuary area generation. This leads to uneven loading of the Bramford-Pelham 400kV and Bramford - Rayleigh/Braintree

400kV circuits, which would cause the overloading of the latter, in the event of the loss of the main transmission corridor (4ZM route Walpole- Burwell). Given the limited number of exporting circuits available out of the Spalding-Walpole-Norwich-Bramford area and the existing thermal limitations, of the 4.2GW of generation requiring accommodation, less than 1GW is possible for a NETSQSS compliant connection. National Grid is required to operate to the license requirements of the NETSQSS, under the Electricity at Work Regulations[6] and Electricity Safety, Quality and Continuity Regulations[7] National Grid is required not to operate its assets outside of their proven capability- otherwise National Grid would incur risk to its personnel and the general public and be at risk of uncontrolled electrical failure of the transmission system that could lead to widespread loss of supply, not least to the East Anglia area.

3.11 Quality of supply – Negative Phase Sequence (NPS)

Overhead lines, whether single or double circuit, have some degree of unbalance due to the lack of physical symmetry between the position of the phase conductors with respect both to each other and to any earth wire(s). These differences will, as a result of power transfer through the circuit, give rise to unbalance both in the conductor phase currents and the phase voltages. An individual double circuit is generally phased with the same phase colour (or designation) on the middle cross arms and a top to bottom change for the other phase colours e.g. RYB to BYR assuming that the power flow on both circuits is in the same direction. The result of this phasing configuration is that the imbalance is partially self-compensated. However any partial self-compensation on a double circuit is lost when one circuit is out of service, or the phasing intended to provide some unbalance compensation may introduce an adverse effect if the system configuration is such that the current flows are in the opposite direction. The existing connections to the west of Bramford (4YL route) are such that under maintenance conditions, power can flow in opposite directions in the two circuits on the same tower and hence create unbalanced voltages. The NPS component of voltage causes NPS currents to flow in the transmission system, and consequently in three phase generators and motors connected to the system. This in turn produces heating effects, which can damage the machine or cause its protection to operate. It may also effect the operation of three-phase equipment; in particular rectification and inverter equipment may

[6] Electricity at Work Regulations 1989 : SI 1989/635
[7] Electricity Safety Quality and Continuity Regulations 2002 : SI 2002/2665

produce more harmonic currents. It is therefore necessary to assess levels of NPS voltage on the transmission system in order that the transmission system may be operated reliably within the technical limits specified in the Grid Code.

3.12 Transient stability

All large generators connected to the National Grid transmission system are synchronous machines. Synchronous generators throughout the GB transmission system operate at the same electrical frequency of 50 hertz (or 3000rpm) and are furthermore electrically coupled together by the system so that they remain in step with each other. It is, therefore, important that synchronism is maintained. In the event of instantaneous faults occurring on the transmission system (a transient situation), circumstances can arise in which generators close to the fault begin to accelerate relative to others further away. If the fault is not removed sufficiently quickly, then the generator or generators affected may accelerate so much that they become out of step with the remainder of the system (loss of synchronism / pole slipping). Generators themselves can be severely damaged possibly leading to failure of major components. Pole slipping can also have a very severe impact on local consumers and in particular nuclear power station auxiliary loads such as coolant pumps. The precise behaviour of generators prior to, during and following a fault is unique to: their individual locations on the transmission system; the control systems used to manage that generator; and its physical design. They therefore have to be considered in particular detail when planning any new connection to the transmission system.

3.13 The loss of circuits west of Bramford could lead to a situation in which power normally flowing west out of Bramford is diverted north from Bramford via Norwich to Walpole, and from Walpole to Pelham, effectively increasing the distance of power transmission by around 162km. This would lead to a risk of instability, which is currently managed by the design of the existing generators and transmission system in the area. The existing situation would be exacerbated by further levels of generation feeding onto the network between Walpole and Bramford, in that more power would need to flow on the same amount of overhead line for the same additional distance following a fault.

3.14 Further, for Essex-based generation in the south of East Anglia (at Tilbury, Coryton and Bradwell), network configuration changes in the Thames Estuary will lead to an enhanced reliance on the East Anglian network for stability. Any new route

solution out of East Anglia needs, therefore, to work not just for East Anglia but also for existing and committed connections in the Essex area - again to avoid the risk of damage to these generators following a fault.

Future connections

3.15 National Grid has received a number of additional connection requests in East Anglia that require additional network infrastructure beyond the upgrading available on the existing system. At present, National Grid is contractually obliged to provide the following connections :

- Sizewell C 3300MW nuclear power station (Stage 1 1650MW 2016 and Stage 2 1650MW 2021);
- Bradwell B 1650MW nuclear power station (2016);
- Kings Lynn B 984MW gas fired power station (2016);
- South Holland 840MW gas fired power station (2014);
- Thames Haven Power, Coryton 840MW (2023, which may be accelerated to 2014)

3.16 In addition, it is anticipated that connection of an additional 7.5GW of power generated by offshore wind will need to be made. This is related to the Crown Estates Round 3 process and is expected to be required by 2016.

3.17 In London, demand amounts to 10GW. This level of demand compares to only 1GW of installed generation capacity in the London area. The network of transmission lines out of East Anglia was originally designed to provide support to inner and outer London from the north and east, however the advent of increased interconnection between the South East and the Continent (new interconnectors at Grain and Richborough in Kent to export up to 1390MW to the Netherlands, and 1000MW to Belgium respectively) and also additional generation in the Thames Estuary means that the area is now operating as a major transfer corridor. It will therefore be important to ensure adequate connections between the East Anglian generation and London/Thames Estuary.

3.18 Additionally in March 2009, the Electricity Networks Strategy Group (ENSG) identified a strategic need for a new line to support the achievement of the Government's 2020 renewable energy targets.

3.19 During the Transmission Access Review (TAR), Government and Ofgem considered the changes that are required to facilitate the timely connection of new generation. The Review was conducted because network access is seen as a barrier to entry for new generators, particularly renewable ones. In June 2008, the TAR Final Report[8] made a number of recommendations on how to improve transmission access. At the same time, Government published its Renewable Energy Strategy consultation[9]. In both documents, Ofgem and Government asked the transmission companies to initiate work to identify the transmission reinforcements needed to support the 2020 targets.

3.20 Following on from this, the Electricity Networks Strategy Group (ENSG), a cross industry group jointly chaired by the Department of Energy and Climate Change and Ofgem, asked the three GB Transmission Licensees, National Grid Electricity Transmission (NGET), Scottish Hydro Electric Transmission Ltd (SHETL) and Scottish Power Transmission (SPT) with the support of an Industry Working Group to take forward a study to:

- Develop electricity generation and demand scenarios consistent with the EU target for 15% of the UK's energy to be produced from renewable sources by 2020; and

- Identify and evaluate a range of potential electricity transmission network solutions that would be required to accommodate these scenarios.

3.21 The report of the study[10] presents a number of network reinforcements based on a range of scenarios that take into account the significant changes anticipated in the generation mix between now and 2020. In particular, the scenarios examine the potential transmission investments associated with the connection of large volumes of onshore and offshore wind generation required to meet the 2020 renewables

[8] Department for Business Enterprise and Regulatory Reform/Ofgem : Transmission Access Review : Final Report : June 2008
[9] Department for Business Enterprise and Regulatory Reform : UK Renewable Energy Strategy Consultation : June 2008
[10] Electricity Networks Strategy Group : Our Electricity Transmission Network : A Vision for 2020 : March 2009

target, whilst, at the same time, facilitating the connection of other essential new generation, such as new nuclear that will be needed to reduce carbon emissions and maintain continued security of supply.

3.22 To ensure that the justifications for the identified reinforcements are sufficiently robust, they have been tested against a range of background scenarios, which take account of likely developments up to the year 2020. In identifying the potential transmission reinforcements, the opportunity was taken first to maximise the utilisation of the existing assets. Thereafter the options identified are based on new or replacement assets. In both circumstances consideration has been given to employing the latest technology, especially where additional economic and/or additional environmental benefits can be expected. In such cases, due account has been taken of the lead time required to develop robust engineering solutions and the need to obtain the necessary planning consents for each reinforcement.

3.23 The National Electricity Transmission System Security and Quality of Supply Standard (NETSQSS) was used in determining the reinforcements necessary under the scenarios.

3.24 In relation to the English East Coast Reinforcement - East Anglia Stage 1, the report concludes :

"5.7.1 It is anticipated that between 3 and 4 GW of Round 3 offshore wind generation will be developed in waters directly east of East Anglia. The nearest onshore substations for connection are either Norwich Main or Sizewell, which are both located on the same 400 kV route. Therefore Round 3 offshore wind projects will interact significantly with the potential for nuclear replanting at Sizewell (of up to an additional 3.3 GW) on this part of the network. Reinforcement of the network is required for either offshore wind generation and/or nuclear replanting at Sizewell.

5.7.2 The reinforcements proposed for this area of the network include reconductoring the double circuit route from Walpole to Norwich through Bramford, a new 400 kV substation at Bramford with all circuits from Norwich Main, Sizewell, Pelham and Rayleigh turned in and a new section of 400 kV double circuit overhead line, approximately 27 km in length from Bramford to the existing tee point down to Rayleigh (near Twinstead). This would then create two double circuit routes to the west out of Bramford.

5.7.3 The cost of onshore works is estimated to be £400M, for completion in 2017."

4 PROCESS

4.1 The trigger for the strategic optioneering process was the connection offer made by National Grid to British Energy in November 2007 for a new nuclear power station of 3300MW at Sizewell with due consideration being given to the parallel connection of 1650MW nuclear generation at Bradwell. The making of the offer was mandatory as it was the result of a customer application and the works were consistent with the NETSQSS.

4.2 In developing the connection offer, consideration was given to a number of options which are identified in **Appendix A**. The proformas in Appendix A are based on the information available at the time of the consideration of the connection offer. Under the terms of its license, National Grid has only three months following receipt of a technically competent application, and appropriate payment, to provide an offer to a customer committing it to a date by which it can provide a license compliant connection. The assessments which go on during that period are necessarily time constrained and focused towards identification of the optimal works necessary to effect that connection within the bounds of confidence and information available at that time. In this context, it was concluded that a new connection would be needed between Bramford substation and the Twinstead Tee junction of the Bramford-Pelham/Rayleigh routes, as well as extensive substation works at Sizewell and Bramford to accommodate high power flows from the proposed European Pressurised Water reactor design.

4.3 The connection offer made to British Energy took account of the technical specification and development programme for the proposed power station and the need to provide the most economic and efficient solution to meet the customer's request for a connection. Consideration was also given to potential impacts on amenity and a range of commercial issues.

4.4 The identified infrastructure works, forming part of the connection offer, included :

- 20 bay substation Sizewell

- Two 3000 MVA reactors Sizewell
- 22 bay substation Bramford
- Extend the AIS substation Bramford
- Modifications to Tilbury substation
- c 28km overhead line Bramford to Twinstead Tee
- Various reconductoring works

4.5 One of the options considered at this stage was the use of 5000A equipment[11], as described in Pre-Sanction Option 2 in Appendix A. At the time of the connection offer, 5000A equipment was not available and it was uncertain whether such equipment could become available in the required timescale. The risk to project delivery of making an offer based on this equipment was therefore deemed unacceptable. However it was agreed that National Grid would keep developing this option and seek to modify the offered position if such equipment became available and would demonstrate programme and cost efficiencies. Subsequent discussions with equipment suppliers have provided confidence that 5000A equipment can be supplied in the required timescale. This has enabled significant savings to be achieved and has reduced the potential for environmental impact by reducing the scale of works required at Bramford.

4.6 The option to modify the offered position is enshrined within the Connection and Use of System Code[12]. The opportunity to re-appraise the original optimisation and optioneering may occur where time/ improved information allows a fuller appraisal of options and the further exploration of risks and opportunities. Sometimes this leads to altered delivery approaches or revisions to the works involved in a project.

[11] Standard 400kV equipment has a load current carrying capability of 4000A. The 3x700mm 75°C overhead line has a rating significantly in excess of 4000A and hence the circuit would be limited by switchgear. 5000A switchgear most closely matches the 3 x 700mm overhead line rating.
[12] National Grid Electricity Transmission plc : Connection and Use of System Code : June 2001 with amendments

4.7 Due to the nature of the changing system and market conditions, National Grid keeps its requirements and the scope and timing of works under constant review, always noting its requirement to provide a timely and deliverable solution to meet the agreements in place with its customers. Changes may need to be made, for example, if another connection has to be incorporated into the same area of the system or due to another generator terminating its agreement, or some other change to the generation or demand background. It is also possible to vary an agreement where a review following the initial three month offer period identifies a more efficient option being available. This is in line with National Grid's duty to manage the system in the most economic and efficient way.

4.8 In August 2008, an optioneering workshop was held to consider and review the aforementioned connection offer. Those attending included representatives of the System Development group, Land and Development group and Communications team within National Grid, the Electricity Alliance and Eastern Overhead Lines Alliance, and 3G Communications. The purpose of the meeting was to capture, consider and assess a wide range of options to facilitate the connection offer and meet the commitments of National Grid as a licence holder. All the options previously considered (whether discounted or not) were reviewed by the workshop to determine the robustness of the connection offer decision. In the event that another option appeared to be more beneficial in terms of the key criteria of economy, efficiency and amenity, further detailed work would need to be undertaken to determine whether a revised connection offer should be made.

4.9 This optioneering exercise assumed :

- the design of the generators were as per the connection applications received (or as subsequently amended) - this could not be changed, as it is for the generator to determine and is outside the remit of National Grid;

- that, as requested by British Energy, Sizewell B will continue to operate at current capacity during and post- commissioning/connection of Sizewell C and the other additional generation projects in the area. In respect of other existing generators connected in East Anglia, National Grid has had no formal notice of closure. Given that none of these projects are more than 18 years old at this time it was assumed that all would have the potential to be operating in parallel with the proposed new generation;

- the impact of other generation connections where a formal offer had been made by National Grid and signed contractual agreements were in place;

- the demand forecasts provided by the Distribution Network Operator (DNO) in the area - EDF Energy Networks (EPN) plc – as provided under the Grid Code against a formal annual process of bilateral dialogue and assessment between National Grid and the DNO.

4.10 The strategic options are described in Chapter 5 and **Appendix B**. This includes three options which were developed after the optioneering workshop, as potential variants of options considered at the workshop.

4.11 When discussing each option, a consensus was reached on whether to take it forward for further investigation or whether the option should be "parked". Parking an option meant that further assessment would not be undertaken unless those options which had been selected for assessment proved not to be deliverable and/or baseline assumptions changed. The main reasons for parking options were that they could not provide a practicable solution to securing the necessary connections within the required timeframe or that they would be likely to result in high costs and significant environmental impacts where other shorter routes are available.

4.12 The first workshop concluded that Options S6, S7, S8 and S9 in Appendix B should be taken forward for further investigation. These options were:

- S6 : Bramford to Twinstead Tee (not using the corridor of the existing distribution line);

- S7 : Bramford to Twinstead Tee (using the corridor of the existing distribution line);

- S8 : Bramford to Burwell;

- S9 : Bramford to Burwell (part using the corridor of the existing distribution line, part new route).

4.13 As Options S6 and S7 were variants of the original sanctioned offer and were supported by the results of the ENSG study, initial consultation with the key

stakeholders was carried out on these options. However, due consideration was given to all four options.

4.14 A further workshop was held in August 2009. This reviewed the outputs of the first workshop in the light of more recent information. In some cases this resulted in options being discounted where they would not be system compliant, would involve extreme costs or would be clearly unacceptable on amenity grounds. For the reasons set out in Section 5, it was confirmed that Options S8 and S9 should be parked and that further investigations should concentrate on Options S6 and S7.

4.15 The inclusion of Options S6 and S7 in a Route Corridor Study, carried out by an independent environmental consultancy, is separately reported.

5 OPTIONS EVALUATION

5.1 In evaluating the options which were considered following the connection offer, due regard was given to the key criteria (as set out in National Grid's statutory and licence obligations) of economy, efficiency (including system compliance and deliverability) and amenity.

5.2 For the purposes of strategic optioneering, the cost estimates for individual post-sanction options were based on generalised unit costs for the key elements of the option, reflecting recent contract values. This is sufficient to allow a broad order of relative costs to be established for the options, as necessary at the strategic level, and is not intended to provide an accurate cost for each option which can only be obtained at the detailed design stage. The cost of DNO works, other than the provision of grid supply points has not been included. Options which were discounted for other reasons were not costed in detail.

5.3 Issues of system compliance and deliverability were addressed by National Grid's Systems Development team and the Eastern Overhead Lines Alliance.

5.4 Amenity impacts were advised by the results of a desk study of key environmental constraints such as high level nature conservation, heritage and landscape designations and the definition of major urban areas. The Route Corridor Studies then take into account a wider range of environmental constraints.

5.5 Additional information on individual options is provided in **Appendix B** and diagrammatic representations of options are provided in **Appendix C**.

Do Nothing option

5.6 The Do Nothing option (**Option S1**) was discounted because it would be a clear breach of NGET's transmission licence obligations to provide a connection. The current infrastructure is unable to accommodate additional generation without breaching thermal, quality of supply and stability constraints. Failure to provide a connection would have wider consequences for the electricity supply, and government targets for renewable and low carbon generation would not be met.

System enhancement option

5.7 The transmission network in East Anglia is limited in its extent. It has already been enhanced to accommodate new generation. Further limited enhancements on their own would not deliver the required capacity or system stability. It should be noted that most of the options under consideration also encompass enhancements of the existing transmission network, such as reconductoring overhead lines or other asset replacement work.

5.8 Reconductoring the existing 400kV overhead lines between Sizewell and Bramford (**Option S2**) would not, on its own, solve issues of thermal capacity west of Bramford, nor would it provide for the connection of generation beyond 2020. Current connection obligations could not be fulfilled. The decision was therefore taken to discount this option because it would not comply with National Grid's transmission licence obligations.

Generator action options

5.9 Consideration was then given to a number of measures which may be open to the generators to modify the performance of their equipment which could have implications for the design of the transmission system. Examples include the use of fast valving, to reduce the energy input to the steam turbines during fault conditions, or various AC/DC control systems. These were encompassed in **Option S3**.

5.10 National Grid is obliged to offer a connection based upon the generator's equipment specification. Modifications to generator control systems alone would not allow the transmission system to accommodate any more generation without breaching thermal, quality of supply and stability constraints.

5.11 The decision was therefore taken to discount this option.

Subsea cable options

5.12 Achieving connections using subsea cables could potentially reduce the amount of overhead line construction. Options for providing a cable connection between Sizewell and Bradwell could involve both HVDC (**Option S4**) and AC (**Option S5**) solutions with cable routes approximately 80km in length. However, both would still require a new 400kV overhead line to be constructed between Bradwell and Rayleigh (c 38 km).

5.13 Whilst power can flow in both directions on an HVDC link, converting an AC power flow into a DC power flow in a particular direction involves rectification (AC to DC) and inversion (DC to AC) via thyristor valves at each end of the HVDC link. In the event of faults close to Sizewell or Bradwell generation, the HVDC link would need to be reversed almost instantaneously to cause power to flow in the opposite direction. The current generation of HVDC equipment could not provide such capability with a DC cable. Whilst clearly uneconomic, technical investigations continue in this area.

5.14 There are no known worldwide 400kV AC cable installations that would contain as much cable in a single circuit, as required to meet the distance and required rating for the circuits. Very significant technical challenges would have to be overcome in terms of: switching transients; circuit breaker duty; voltage step change; compensation configuration / location; and possible resonance issues. For a subsea cable above 30km in length, where midpoint compensation is not possible, charging currents become so significant as to severely limit the power carrying capability. Whilst clearly uneconomic, technical investigations continue in this area.

5.15 It was concluded that, in neither case could a technically feasible, system compliant or economic, solution be delivered. Options S4 and S5 were therefore discounted.

5.16 **Option S16** would incorporate both an overhead line route between Bramford and Colchester, a distance of about 30km, and a combination of cable tunnel under Colchester and cabling under the Blackwater estuary. Substations would be required at; Bramford, Sizewell and Bradwell.

5.17 This was discounted because the deliverability of the tunnel sections (or of alternative direct buried cable) raises technical, environmental and safety issues. The option would be unlikely to be able to meet current contracted connection dates and, like the other cable options, would incur very high costs.

Overhead line options

5.18 Given the above, various options for constructing new overhead lines were considered. It was assumed that an overhead line for an appropriate connection would be a double circuit 400kV overhead line with triple Araucaria conductors per phase, supported by lattice steel towers. In order to accommodate both stages of the proposed Sizewell C generation, the new route would need to have a year-round 6200 MVA rating to provide compliance to the NETSQSS and National Grid's license conditions. The only way to achieve the level of year-round rating required on this route, based on the designs of towers and conductors currently available, is by using the Type L13 lattice steel tower construction and the 3x700mmsq AAAC "Araucaria" conductor design.

5.19 The above optioneering is not inconsistent with the conclusions of the ENSG report (see paragraph 3.24 above), and it was clear that the alternate overhead line options would be of greater length and would present greater routing challenges given the designations present in these area the next step was to consider options for a connection between Bramford and Twinstead Tee, near Sudbury.

<u>Bramford - Twinstead Tee</u>

5.20 **Option S6** is effectively the option sanctioned in 2007, modified to reflect the use of 5000A equipment. It would involve construction of an overhead line between Bramford and Twinstead Tee, including new substations at Bramford and Sizewell and modifications to arrangements at Twinstead Tee. Depending on route selection, this would be likely to involve a route length of about 28km. The option complies with system requirements and could be delivered in the required timescale. While it was recognised that, depending on the route selected, the

overhead line may need to negotiate the fringes of the urban area of Hadleigh and/or a number of areas of environmental constraint including the Dedham Vale Area of Outstanding Natural Beauty (AONB), Ramsey Wood/Hintlesham Great Wood Sites of Special Scientific Interest and Twinstead Nature Reserve, the decision was taken to take this option forward for further consideration because it offers a deliverable and cost effective solution.

5.21 **Option S7** proposes the adoption of the route of an existing DNO 132kV overhead line which runs parallel to the existing 400kV overhead line between Bramford and Twinstead - approximately 26km in length. A new 400kV overhead line would be built along this existing 132kV line route, however the new line may require a different alignment in some places, for instance where the existing line runs close to housing. A short section of the existing route passes through the Dedham Vale AONB. A new section of line between Burstall and Bramford would be necessary to complete the new 400kV Bramford- Twinstead route with substations at Bramford and Sizewell.

5.22 Separate option review work was undertaken by the DNO (EDF Energy Networks) to confirm the potential scope and options for consequential works to the DNO network.

5.23 The main options which were identified included:

- replacing the existing 132kV overhead line between Burstall and Twinstead with underground cables along its whole length;
- constructing a grid supply point west of Twinstead;
- constructing an overhead line or underground cable between the Twinstead area and Braintree;
- constructing a grid supply point east of Braintree with an overhead line or underground cable connection between there and the Twinstead area.

5.24 Further work is under way to determine a preferred option. For the purposes of this report it has been assumed that a grid supply point would be required to the west of Twinstead Tee.

5.25 Option S7 was considered to offer a deliverable and cost effective solution and the decision was taken to take this option forward for further consideration. The involvement of a third party (Distribution Network Operator) would make implementation of Option S7 more complex and could carry programme implications.

Other routes from Bramford

5.26 Consideration was given to a number of other routes which could provide a connection between Bramford and substations elsewhere on the network.

5.27 **Option S8** and **Option S9** both involve securing a 400kV overhead line connection between Bramford and Burwell, near Newmarket, a distance of approximately 60km. Both would require new substations at Sizewell, Bramford, Pelham, Twinstead and south of Bury St Edmunds, with an extension at Burwell substation. Option S9 would make use of the route of the DNO 132kV overhead line between Bramford and Bury St Edmunds (approximately 30km) and would involve extensive undergrounding of DNO overhead lines in the Bury St Edmunds area. A further substation would be required at Stowmarket under this option.

5.28 The initial evaluation had indicated that, while options S8 and S9 would be system compliant, they would not significantly improve the diversity of export routes out of East Anglia. Further consideration of the options confirmed that, with these options in place, additional overhead lines would be needed to support future generation. Coupled to concerns about the deliverability of the options and the potential impacts upon amenity, given their extent and the scope of works required at multiple sites, this led to the options being parked. Option S9 would also have had a significant effect on DNO assets which would pose a further risk to delivery.

5.29 **Option S11** would involve the construction of an overhead line between Bramford and Braintree, avoiding Twinstead Tee (approximately 45 km). If this option were implemented, it would permit the removal of approximately 22km overhead line between Twinstead and Braintree. While this option is considered to comply with system requirements, it would require a crossing through the middle of the Dedham Vale AONB which is a nationally protected area. While there may be some landscape and visual benefits associated with the removal of the Twinstead to Braintree overhead line, the impact on the AONB and the potential impact on other designated sites and residents on the fringe of Colchester would outweigh them.

Routes between Bramford and Rayleigh (**Options 12 and 15**) would also have to cross through the middle of the Dedham Vale AONB, involving a longer crossing than Option S7. All these options were therefore parked.

5.30 A route which would have no impact on the AONB was considered (**Option S17**). This would involve constructing about 75km of overhead line between Bramford and Pelham and would pass to the north of Twinstead. Substation works would be required at Bramford, Sizewell and Twinstead. If it proved possible to use parts of the existing DNO Belchamp-Twinstead-Bramford route, it would require construction of a new GSP at Belchamp and possibly a new DNO route Braintree to Abberton. While this option is considered to be system compliant, the decision was taken to park this option because of the environmental impacts of the greater route length compared to other options and the possible need to construct a substation at Twinstead.

Options avoiding Bramford

5.31 Two overhead line options were considered which avoided Bramford. **Option S10** would run from Sizewell to Twinstead Tee bypassing Bramford (approximately 70km). While this line would satisfy the Sizewell connection requirement, it would not on its own meet wider system requirements and could not be pursued independently of a new line between Bramford and Twinstead Tee with substations at Sizewell and Bramford. It would therefore have no advantage over Options S6 and S7 and the decision was taken to park the option.

5.32 **Option S18** would involve constructing about 127km of overhead line between Sizewell and Walpole via Norwich. Of this, 79km would run in parallel with the existing 4VV line between Norwich and Walpole. An additional substation would be required at Walpole and other works at Sizewell and Bramford. Although compliant in the short term, the option would be expensive and not solve issues of thermal capacity west of Bramford post-2020. The option would involve constructing a third overhead line in the Suffolk Coast and Heaths AONB and Suffolk Heritage Coast and the visual impact of a long section of parallel running could also be significant. The decision was therefore taken to park this option because of economic issues and the extensive impact on amenity when other shorter routes may be available.

Application of new technology

5.33 Outside the UK, some electricity transmission systems now employ four circuit towers or ultra high voltage (UHV) connections.

5.34 **Option S13** considered whether the existing 400kV overhead line between Bramford and Twinstead could be replaced with 80m high towers carrying four circuits. Substations would also be required at Bramford and Sizewell. This option would not resolve system issues, as the risk of failure of this route west of Bramford would not be acceptable when considered against the NETSQSS and nuclear safety case. As such this option was discounted.

5.35 Changing to Ultra High Voltage (**Option S14**) would involve upgrading the 230km of overhead line between Bramford and Pelham (via Walpole) to operate at 800kV and would require wholesale replacement of the route with taller towers (probably 70-80m in height) and new substations at six locations. This would be prohibitively expensive and there would be significant difficulties in integrating the 800kV network with the rest of the system. The decision was taken to discount this option for these reasons and because the technology is currently untested and unavailable in the UK.

Undergrounding

5.36 Undergrounding of 400kV transmission lines was not considered at the strategic optioneering stage, although it is accepted that the justification for undergrounding sections of route should be considered when detailed route alignments are being developed. National Grid has a policy related to the use of underground cables which, in summary, reserves consideration of their use to areas of high technical constraint and to areas of the highest recognised amenity value.

Changes to the DNO network

5.37 Some of the options which would involve taking over sections of DNO routes may result in changes to the DNO network, including additional Grid Supply Points and/or new sections of overhead line. Reference to such changes is made in the options proformas in Appendix B. Discussions between National Grid and the DNO are continuing in order to determine more precisely the extent of such provision, in the context of the DNO's Regional Development Plan. The IPC development

consent application and accompanying EIA will add further clarification to option content and in particular be clear about implications for the EdF network.

Conclusions

5.38 A summary of the options evaluation is provided in Table 5.1. The evaluation has confirmed that Options S6 and S7 are the appropriate transmission network reinforcements that should be considered in the context of its proposed application for development consent. The Route Corridor Studies are undertaken on this basis.

Table 5.1 Summary of options evaluation

Reference	Option	Decision
Pre-Sanction options		
Pre-Sanction 1	Sanctioned scheme Bramford - Twinstead	Park
Pre-Sanction 2	5000A equipment Bramford - Twinstead	Take forward
Pre-Sanction 3	Third circuit Sizewell - Twinstead	Discount
Pre-Sanction 4	Bramford - Twinstead (DNO route)	Take forward
Pre-Sanction 5	Sizewell - Bradwell AC undersea cable	Discount
Post-Sanction options		
S1	Do Nothing	Discount
S2	Enhance Sizewell - Bramford	Discount
S3	Generator action	Discount
S4	Sizewell - Bradwell HVDC undersea cable	Discount
S5	Sizewell - Bradwell AC undersea cable	Discount
S6	Bramford - Twinstead	Take forward
S7	Bramford - Twinstead (DNO route)	Take forward
S8	Bramford - Burwell	Park
S9	Bramford - Burwell (DNO route)	Park
S10	Sizewell - Twinstead avoiding Bramford	Park
S11	Bramford - Braintree	Park
S12	Bramford - Rayleigh (DNO route)	Park
S13	Upgrade Bramford - Twinstead	Discount
S14	Upgrade Bramford - Walpole - Pelham	Discount
S15	Bramford - Rayleigh via Lawford	Park
S16	Bramford - Rayleigh via Lawford and Bradwell	Discount
S17	Bramford - Pelham (not via Twinstead)	Park
S18	Sizewell - Walpole via Norwich	Park

6 ABBREVIATIONS

AC	Alternating current
AIS	Air insulated switchgear
AONB	Area of Outstanding Natural Beauty
bn	Billion
DC	Direct Current
DNO	Distribution Network Operator
EdF	Electricité de France
ENSG	Electricity Networks Strategy Group
EPR	European Pressurised Reactor
EU	European Union
GIS	Gas Insulated Switchgear
GW	Gigawatt
HV	High Voltage
Hz	Hertz
kA	Kiloampere
km	Kilometre
kV	Kilovolt
MVA	Megavolt Ampere
MW	Megawatt
NETSQSS	National Electricity Transmission System Security and Quality of Supply Standard
NGET	National Grid Electricity Transmission
NPS	Negative phase sequence
Ofgem	Office of the Gas and Electricity Markets
rpm	Revolutions per Minute
RSPB	Royal Society for the Protection of Birds
SHETL	Scottish Hydro Electric Transmission Ltd

SPT	Scottish Power Transmission
SSSI	Site of Special Scientific Interest
TAR	Transmission Access Review

Appendix A

Options considered in making the connection offer September 2007

OPTIONS EVALUATION PROFORMA

Scheme :	Sizewell
Option Reference and Title :	**Pre-Sanction Option 1 : Sanctioned scheme Bramford to Twinstead**
Option Description :	• 20 bay 400kV GIS substation Sizewell • Two 400kV 3000 MVA reactors Sizewell • 22 bay 400kV GIS substation Bramford • Extend 400kV AIS substation Bramford • Modifications at Twinstead Tee • Modifications to Tilbury substation • c 28km 400kV overhead line Bramford -Twinstead • Reconductoring works

Evaluation criteria	Issues
Economy Cross if reason to park/discount	• Estimated cost £867m
Efficiency - system compliance Cross if reason to park/discount	• System compliant
Efficiency - deliverability Cross if reason to park/discount	• Deliverable
Amenity Cross if reason to park/discount	• Potential impact on Dedham Vale AONB • Issues with protected species at Tilbury • Affects areas designated for their environmental and amenity value

Recommendation :	Option to be parked - the availability of 5kA equipment (see Pre-sanction option 2) means that a lower cost solution with reduced environmental impact can be achieved.

OPTIONS EVALUATION PROFORMA

Scheme :	Sizewell
Option Reference and Title :	**Pre-Sanction Option 2 : 5000A equipment Bramford to Twinstead**
Option Description :	• Use of 5000A continuous rated equipment • 20 bay 400kV GIS substation Sizewell • Two 400kV 3000 MVA reactors Sizewell • 22 bay 400kV GIS substation Bramford • Modifications at Twinstead Tee • Modifications to Tilbury substation • c 28km 400kV overhead line Bramford -Twinstead • Reconductoring works

Evaluation criteria	**Issues**
Economy Cross if reason to park/discount	• Estimated cost £530m
Efficiency - system compliance Cross if reason to park/discount	• System compliant • Type registered 5000A equipment developed in consultation with suppliers
Efficiency - deliverability Cross if reason to park/discount	• Deliverable
Amenity Cross if reason to park/discount	• Potential impact on Dedham Vale AONB • Issues with protected species at Tilbury • Affects areas designated for their environmental and amenity value

Recommendation :	Option to be investigated further

OPTIONS EVALUATION PROFORMA

Scheme :	Sizewell
Option Reference and Title :	**Pre-Sanction Option 3 : third circuit Sizewell - Twinstead**
Option Description :	• c 70km 400kV overhead line Sizewell - Twinstead • 23 bay 400kV GIS substation Sizewell • Extend 400kV AIS substation Bramford • Modifications at Twinstead Tee • c 28km 400kV overhead line Bramford -Twinstead • Reconductoring works

Evaluation criteria		Issues
Economy		• Estimated cost £650m
Cross if reason to park/discount		
Efficiency - system compliance		• Would be overstressed in fault level terms
Cross if reason to park/discount	X	
Efficiency - deliverability		• Extensive route length - solutions which do not require a third circuit are available
Cross if reason to park/discount		
Amenity		• Significant landscape and other impacts associated with three parallel 400kV OHLs between Sizewell and Bramford
Cross if reason to park/discount	x	

Recommendation :	Option to be discounted due to unacceptable landscape impacts and system compliance issues

OPTIONS EVALUATION PROFORMA

Scheme :	Sizewell
Option Reference and Title :	**Pre-Sanction Option 4 : Bramford to Twinstead Tee Overhead Line (Adopting DNO Route)**
Option Description :	• 20 bay 400kV GIS substation Sizewell • Two 400kV 3000 MVA reactors Sizewell • 22 bay 400kV GIS substation Bramford • Extend 400kV AIS substation Bramford • Modifications at Twinstead Tee • Modifications to Tilbury substation • c 28km 400kV overhead line Bramford -Twinstead • Reconductoring works • 8 bay 400kV AIS substation between Twinstead Tee and Thaxted. • Bramford to Twinstead to be undergrounded • Possible modification to DNO network

Evaluation criteria	**Issues**
Economy Cross if reason to park/discount	• Estimated cost £565m
Efficiency - system compliance Cross if reason to park/discount	• System compliant
Efficiency - deliverability Cross if reason to park/discount	• Deliverable but uncertain extent of DNO works pose risk to deliverability
Amenity Cross if reason to park/discount	• Potential impact on Dedham Vale AONB • Issues with protected species at Tilbury • Affects areas designated for their environmental and amenity value • Impacts associated with need to make changes to DNO system west of Twinstead

Recommendation :	Option to be investigated further

OPTIONS EVALUATION PROFORMA

Scheme :	Sizewell
Option Reference and Title :	**Pre-Sanction Option 5 : Sizewell to Bradwell AC undersea cable**
Option Description :	• offshore 400 KV AC cable Sizewell to Bradwell (c 80km)

Evaluation criteria		**Issues**
Economy		• Estimated cost £2970m
Cross if reason to park/discount	X	
Efficiency - system compliance		• Not compliant - untested technology
Cross if reason to park/discount	x	
Efficiency - deliverability		• Not technically feasible. Untested technology
Cross if reason to park/discount	x	
Amenity		• Not assessed - clear reasons for rejection on other grounds
Cross if reason to park/discount		

Recommendation :	Option to be discounted due to the high cost involved. In addition the length of AC cable would be well in excess of that considered technically feasible.

Appendix B

Options considered during the assessment process

OPTIONS EVALUATION PROFORMA

Scheme :	Sizewell
Option Reference and Title :	**Option S1 : Do nothing**
Option Description :	• No change to transmission system

Evaluation criteria		**Issues**
Economy		• No additional capital cost
Cross if reason to park/discount		
Efficiency - system compliance		• Non compliant • Current infrastructure unable to accommodate more generation without breaching thermal, quality of supply and stability constraints • Will not fulfil connection obligations
Cross if reason to park/discount	X	
Efficiency - deliverability		• No deliverability issue
Cross if reason to park/discount		
Amenity		• No impact on amenity
Cross if reason to park/discount		

Recommendation :	Option should now be discounted given that it would be a clear breach of National Grid's licence obligation to provide connections

OPTIONS EVALUATION PROFORMA

Scheme :	Sizewell
Option Reference and Title :	**Option S2 : Enhance Sizewell - Bramford**
Option Description :	• Reconductoring existing circuits Sizewell - Bramford

Evaluation criteria		Issues
Economy		• Estimated option cost £90m
Cross if reason to park/discount		
Efficiency - system compliance		• Non compliant • Current infrastructure beyond Bramford unable to accommodate more generation without breaching thermal, quality of supply and stability constraints • Will not fulfil connection obligations
Cross if reason to park/discount	X	
Efficiency - deliverability		• Deliverable
Cross if reason to park/discount		
Amenity		• Limited impact on amenity
Cross if reason to park/discount		

Recommendation :	Option should now be discounted given that it would be a clear breach of National Grid's licence obligation to provide connections

OPTIONS EVALUATION PROFORMA

Scheme :	Sizewell
Option Reference and Title :	**Option S3 : Generator action**
Option Description :	• Various options considered including fast valving and AC/DC/AC generation works

Evaluation criteria		**Issues**
Economy		• No cost implications for National Grid for some options
Cross if reason to park/discount		
Efficiency - system compliance		• Non - compliant • Use of unproven technology could cause system to become unstable in the event of a double circuit fault • Will not fulfil connection obligations of Grid Code.
Cross if reason to park/discount	X	
Efficiency - deliverability		• Outside National Grid control, so no guarantee of delivery
Cross if reason to park/discount		
Amenity		• Impact on amenity not determined • No additional overhead lines required
Cross if reason to park/discount		

Recommendation :	Option should now be discounted given that it would be non-compliant and outside National Grid's control

OPTIONS EVALUATION PROFORMA

Scheme :	Sizewell
Option Reference and Title :	**Option S4 : High Voltage Direct Current (HV DC) Subsea Cable Sizewell to Bradwell**
Option Description :	• 23 bay 400kV GIS substation at Sizewell • 3 x 1.5GW HVDC converter at Leiston • 3 x 1.5GW HVDC converter at Bradwell • 8 bay 400kV AIS substation at Bradwell • c 5km 400kV overhead line Sizewell to Leiston • c 38km 400kV overhead line Bradwell to Rayleigh • 4 80km HVDC cables between Bradwell and Sizewell

Evaluation criteria		Issues
Economy		• The estimated option cost is £1535m
Cross if reason to park/discount	X	
Efficiency - system compliance		• Would require very fast link operation to avoid damage from instability of Bradwell or Sizewell generation. • Requires 38km new OHL Bradwell to Rayleigh irrespective of Bradwell generation project. • OHL Rayleigh to Pelham or Warley required to manage subsequent Coryton generation project
Cross if reason to park/discount	X	
Efficiency - deliverability		• Very complicated operationally • Extensive works in sensitive areas would carry significant programme/delivery risks
Cross if reason to park/discount	X	
Amenity		• Involves works in environmentally sensitive areas with high level designations including European protected sites, SPA, SAC Ramsar, SSSI, AONB, Heritage Coast
Cross if reason to park/discount	x	

Recommendation :	Option should now be discounted given the very high cost, difficulties in ensuring delivery and compliance and potential impact on protected sites

OPTIONS EVALUATION PROFORMA

Scheme :	Sizewell
Option Reference and Title :	**Option S5 : Alternating Current (AC) Subsea Cable Sizewell to Bradwell**
Option Description :	• 23 bay 400kV GIS substation at Sizewell • 8 bay 400kV AIS substation at Bradwell • c 5km 400kV overhead line Sizewell to Leiston • c 38km 400kV overhead line Bradwell to Rayleigh • 4 80km AC cables between Bradwell and Sizewell [further consideration of Sanction Option 5]

Evaluation criteria		Issues
Economy		• The estimated option cost is £2970m
Cross if reason to park/discount	X	
Efficiency - system compliance		• Non compliant
Cross if reason to park/discount	X	
Efficiency - deliverability		• Not technically feasible. Requires use of unproven technology
Cross if reason to park/discount	X	
Amenity		• Involves works in environmentally sensitive areas with high level designations including European protects sites, SPA, SAC, Ramsar, SSI, ADNB, Heritage Coast
Cross if reason to park/discount		

Recommendation :	Option should now be discounted given that it is not technically feasible.

OPTIONS EVALUATION PROFORMA

Scheme :	Sizewell
Option Reference and Title :	**Option S6 : Bramford to Twinstead Tee Overhead Line (Not Adopting a DNO Route)**
Option Description :	• 20 bay 400kV GIS substation Sizewell • Two 400kV 3000 MVA reactors Sizewell • 16 bay 400kV GIS substation Bramford • Modifications at Twinstead Tee • Modifications to Tilbury substation • c 28km 400kV overhead line Bramford -Twinstead • Reconductoring works [further consideration of Sanction Option 2 revA]

Evaluation criteria	Issues
Economy Cross if reason to park/discount	• The estimated option cost is £530m
Efficiency - system compliance Cross if reason to park/discount	• System compliant
Efficiency - deliverability Cross if reason to park/discount	• Deliverable • Arrangement at Twinstead may lead to system access issues (outage planning)
Amenity Cross if reason to park/discount	• Potential impact on Dedham Vale AONB • Issues with protected species at Tilbury • Affects areas designated for their environmental and amenity value

Recommendation :	Option to be investigated further

OPTIONS EVALUATION PROFORMA

Scheme :	Sizewell
Option Reference and Title :	**Option S7 : Bramford to Twinstead Tee Overhead Line (Adopting DNO Route)**
Option Description :	• 20 bay 400kV GIS substation Sizewell • Two 400kV 3000 MVA reactors Sizewell • 16 bay 400kV GIS substation Bramford • Modifications at Twinstead Tee • Modifications to Tilbury substation • c 28km 400kV overhead line Bramford -Twinstead • Reconductoring works • 2 SGT AIS substation between Twinstead Tee and Thaxted • Possible DNO requirement for additional 132kV connections [further consideration of Sanction Option 4]

Evaluation criteria	Issues
Economy Cross if reason to park/discount	• The estimated option cost is £565m • Additional costs for DNO capital works and compensation
Efficiency - system compliance Cross if reason to park/discount	• System compliant
Efficiency - deliverability Cross if reason to park/discount	• Involvement of third party (DNO) affects programming and deliverability
Amenity Cross if reason to park/discount	• Potential impact on Dedham Vale AONB • Issues with protected species at Tilbury • Affects areas designated for their environmental and amenity value • Impacts associated with changes to DNO system west of Twinstead

Recommendation :	Option to be investigated further

OPTIONS EVALUATION PROFORMA

Scheme :	Sizewell
Option Reference and Title :	**Option S8 : Bramford to Burwell Overhead Line**
Option Description :	• 20 bay 400kV GIS substation at Sizewell • 22 bay 400kV GIS substation at Bramford • 20 bay 400kV AIS substation at Pelham • 12 bay 400kV AIS substation/GSP south of Bury St Edmunds • extension at Burwell substation • c 60km 400kV overhead line Bramford-Bury-Burwell

Evaluation criteria		Issues
Economy		• The estimated option cost is £890m , excluding Burwell - Wymondley line • Early asset write offs of £3m associated with works at Burwell
Cross if reason to park/discount	x	
Efficiency - system compliance		• Future Intergen projects SHP and THP will require a new Walpole-Spalding-Bainton line (38km) constructed ahead of connection; • Future offshore networks capacity beyond 1GW also requires a new Burwell-Wymondley line to be constructed • Does not significantly improve diversity of export out of East Anglia
Cross if reason to park/discount		
Efficiency - deliverability		• Significance scope of works at multiple sites and lengthy route poses risks to deliverability • The outages required to rebuild Pelham and Burwell cannot be programmed to fit with outages required to re conductor existing routes
Cross if reason to park/discount		
Amenity		• Need not pass across key designations but will affect sensitive area around Newmarket and scattered settlements/populations • Newmarket Heath SSSI, Breckland SPA and registered parks constrain route around Newmarket • Will contribute to wirescape north-west of Bramford • Substation at Burwell significant in scale. Other substations may be difficult to locate.
Cross if reason to park/discount	x	

Recommendation :	Option to be parked because of its cost and extensive impact on amenity when other shorter routes are available

OPTIONS EVALUATION PROFORMA

Scheme :	Sizewell
Option Reference and Title :	**Option S9 : Bramford to Burwell Overhead Line (Partly Using DNO Route)**
Option Description :	• removal of DNO circuits between Bramford and Bury St Edmunds (c 30km) • extensive undergrounding of DNO routes near Bury • 20 bay 400kV GIS substation at Sizewell • 22 bay 400kV GIS substation at Bramford • 20 bay 400kV AIS substation at Pelham • 12 bay 400kV AIS substation/GSP at Bury and Stowmarket • extension at Burwell substation • c 60km 400kV overhead line Bramford-Bury-Burwell

Evaluation criteria		Issues
Economy		• The estimated option cost is £930m excluding Burwell - Wymondley line • Early asset write offs of £3m associated with works at Burwell
Cross if reason to park/discount	x	
Efficiency - system compliance		• Future offshore networks capacity beyond 1GW also requires a new Burwell-Wymondley line to be constructed • Does not significantly improve diversity of export out of East Anglia
Cross if reason to park/discount		
Efficiency - deliverability		• Significance scope of works at multiple sites and lengthy route poses risks to deliverability • The outages required to rebuild Pelham and Burwell cannot be programmed to fit with outages required to re conductor existing routes • Involvement of third party (DNO) introduces a further risk
Cross if reason to park/discount		
Amenity		• Need not pass across key designations but will affect sensitive area around Newmarket and Bury St Edmunds and scattered settlements/populations • Newmarket Heath SSSI, Breckland SPA and registered parks constrain route around Newmarket • Ickworth House (National Trust) constrains route south of Bury St Edmunds • Substation at Burwell significant in scale. Other substations may be difficult to locate.
Cross if reason to park/discount	x	

Recommendation :	Option to be parked because of its cost and extensive impact on amenity when other shorter routes are available

OPTIONS EVALUATION PROFORMA

Scheme :	Sizewell
Option Reference and Title :	**Option S10 : Sizewell to Twinstead Overhead Line Avoiding Bramford**
Option Description :	• c 70km 400kV overhead line Sizewell - Twinstead, passing to the north of Bramford • 22 bay 400kV GIS substation Sizewell • 20 bay 400kV GIS substation Bramford • Two 400kV 3000 MVA reactors Sizewell • Modifications at Twinstead Tee • c 28km 400kV overhead line Bramford -Twinstead • Reconductoring works • Cross site connections at Bramford. [variant of Sanction Option 3 with less parallel running]

Evaluation criteria		Issues
Economy		• The estimated option cost is £650m
Cross if reason to park/discount	x	
Efficiency - system compliance		• System compliant • Would need to cross 4 YM route
Cross if reason to park/discount		
Efficiency - deliverability		• Route length and crossing of 4YM route increases risk to delivery
Cross if reason to park/discount		
Amenity		• Long route will affect scattered settlement/populations • Additional section of OHL in AONB/Heritage Coast
Cross if reason to park/discount	X	

Recommendation :	Option to be parked because of its cost and extensive impact on amenity when other shorter routes are available

OPTIONS EVALUATION PROFORMA

Scheme :	Sizewell
Option Reference and Title :	**Option S11 : Bramford to Braintree Overhead Line**
Option Description :	• c 45km 400kV overhead line between Bramford and Braintree • 8 bay 400kV substation at Twinstead • 12 bay 400kV substation at Braintree • 20 bay 400kV GIS substation Sizewell • Two 400kV 3000 MVA reactors Sizewell • 22 bay 400kV GIS substation Bramford • Modifications at Twinstead Tee • Removal of 22km 400kV overhead line Twinstead to Braintree • Modifications to Tilbury substation • Reconductoring works

Evaluation criteria		**Issues**
Economy		• The estimated option cost is £648m
Cross if reason to park/discount	x	
Efficiency - system compliance		• System compliant
Cross if reason to park/discount		
Efficiency - deliverability		• Longer route though environmentally sensitive area poses risk to delivery
Cross if reason to park/discount		
Amenity		• Route crosses Dedham Vale AONB • Could affect SSSI and Ramsar designations Stour and Orwell Estuaries SPA would constrain route • Substation at Twinstead could affect nature reserve • Long route will affect scattered settlements/populations and pass through dispersed development on outskirts of Colchester • Visual benefits associated with removal of Twinstead-Braintree
Cross if reason to park/discount	x	

Recommendation :	Option to be parked because of its cost and potential significant impact on AONB and other amenity issues

OPTIONS EVALUATION PROFORMA

Scheme :	Sizewell
Option Reference and Title :	**Option S12 : Bramford to Rayleigh Overhead Line (Using DNO Route)**
Option Description :	• c65km 400kV overhead line replacing existing 132kV DNO overhead line • 5 Grid Supply Points required - Lawford, Colchester, Abberton, Chelmsford, Coggleshall • 20 bay 400kV GIS substation Sizewell • Two 400kV 3000 MVA reactors Sizewell • 22 bay 400kV GIS substation Bramford • Modifications at Twinstead Tee • Removal of 22km 400kV overhead line Twinstead to Braintree • Modifications to Tilbury substation • Reconductoring works • possible sub-option to tee into ZT route between Bradwell and Rayleigh

Evaluation criteria		**Issues**
Economy		• The estimated option cost is £748m
Cross if reason to park/discount	X	
Efficiency - system compliance		• System compliant
Cross if reason to park/discount		
Efficiency - deliverability		• Deliverable but involvement of third party (DNO) carries risk to programme
Cross if reason to park/discount		
Amenity		• Crosses Dedham Vale AONB • Passes through Colchester built-up area • Visual benefits associated with removal of Twinstead-Braintree
Cross if reason to park/discount	X	

Recommendation :	Option to be parked because of its cost and potential significant impact on AONB and other amenity issues

OPTIONS EVALUATION PROFORMA

Scheme :	Sizewell
Option Reference and Title :	**Option S13 : Upgrade Bramford to Twinstead Tee Overhead Line**
Option Description :	• replace existing overhead line with 80m towers carrying four circuits • 20 bay 400kV GIS substation Sizewell • Two 400kV 3000 MVA reactors Sizewell • 20 bay 400kV GIS substation Bramford • Modifications at Twinstead Tee • Modifications to Tilbury substation • Reconductoring works

Evaluation criteria		**Issues**
Economy		• The estimated option cost is £590m
Cross if reason to park/discount		
Efficiency - system compliance		• Would not solve further system stability issues • Carries increased risk if four circuits lost
Cross if reason to park/discount	X	
Efficiency - deliverability		• Design not used in the UK to date. Need to secure type approval would delay delivery
Cross if reason to park/discount	x	
Amenity		• Would have a significant visual impact, including on AONB
Cross if reason to park/discount		

Recommendation :	Option should now be discounted given compliance and deliverability issues.

OPTIONS EVALUATION PROFORMA

Scheme :	Sizewell
Option Reference and Title :	**Option S14 : Upgrade Bramford to Pelham via Walpole – Ultra High Voltage**
Option Description :	• Upgrade c 230 km existing overhead lines to operate at UHV (800kV) would require new towers and substations • 800kV substations at Bramford, Walpole, Norwich, Burwell, Walpole and Pelham • 20 bay 400kV GIS substation Sizewell • Two 400kV 3000 MVA reactors Sizewell

Evaluation criteria		Issues
Economy		• The estimated option cost is £1280m , exclusive of 800kV substation costs, but difficult to estimate as specification of bespoke equipment not available
Cross if reason to park/discount	x	
Efficiency - system compliance		• System compliance would need to be established
Cross if reason to park/discount	X	
Efficiency - deliverability		• Technology untested in UK . Would require the development of a complete set of specifications for bespoke UHV equipment which could take 5-6 years
Cross if reason to park/discount	x	
Amenity		• The technology would use very high towers and affect very long sections of the existing network • Potential increases in current levels of EMF and operational noise
Cross if reason to park/discount		

Recommendation :	Option should now be discounted due to excessive cost and given that the technology is not currently available in the UK and could not be delivered in the required timescale

OPTIONS EVALUATION PROFORMA

Scheme :	Sizewell
Option Reference and Title :	**Option S15 : Bramford to Rayleigh via Lawford**
Option Description :	• 20 bay 400kV GIS substation at Sizewell • 22 bay 400kV GIS substation at Bramford • Two series reactors relocated to Pelham • c 65km 400kV overhead line Bramford-Rayleigh • modifications to DNO network between Lawford and Abberton • 12 bay Grid Supply Point at Lawford • c 18km 132kV DNO connection Braintree-Abberton

Evaluation criteria		Issues
Economy		• The estimated option cost, excluding DNO works, is £705m
Cross if reason to park/discount	X	
Efficiency - system compliance		• System compliant • Extensive reconfiguration of DNO network required
Cross if reason to park/discount		
Efficiency - deliverability		• Deliverable but involvement of third party (DNO) carries risk to programme
Cross if reason to park/discount		
Amenity		• Crosses Dedham Vale AONB • Passes through Colchester built-up area
Cross if reason to park/discount	X	

Recommendation :	Option to be parked because of its cost and potential significant impact on AONB and other amenity issues

OPTIONS EVALUATION PROFORMA

Scheme :	Sizewell
Option Reference and Title :	**Option S16 : Bramford to Rayleigh via Lawford and Bradwell**
Option Description :	• 20 bay 400kV GIS substation at Sizewell • 22 bay 400kV GIS substation at Bramford • Two series reactors relocated to Pelham • 8 bay 400kV AIS substation at Bradwell • c 20km 400kV overhead line Bramford to Colchester • c 12km 400kV AC subsea section Colchester to Bradwell • c 5km 400kV tunnel Colchester • c 38km 400kV overhead line Bradwell to Rayleigh • 12 bay Grid Supply Point at Lawford

Evaluation criteria	Issues
Economy Cross if reason to park/discount: x	• The estimated option cost is £1080m
Efficiency - system compliance Cross if reason to park/discount:	• System compliant, though risk of pre fault constraint up to 1300 MW if Bradwell connection proceeds • Extensive encroachment on DNO system
Efficiency - deliverability Cross if reason to park/discount: x	• Unlikely to meet current contracted dates due to significant scope of works at multiple sites • Health and safety issues related to tunnel sections • Buried cable in tidal zone poses risk to delivery
Amenity Cross if reason to park/discount: x	• Extensive overhead line network • Requires crossing of Dedham Vale AONB • Affects SSSI SPA SAC and Ramsar designations in Blackwater Estuary

Recommendation :	Option to be discounted because of its cost, delivery uncertainty and potential significant impact on AONB and other protected sites

OPTIONS EVALUATION PROFORMA

Scheme :	Sizewell
Option Reference and Title :	**Option S17 : Bramford to Pelham (not via Twinstead)**
Option Description :	• 20 bay 400kV GIS substation at Sizewell • 13 bay 400kV AIS substation at Twinstead • 22 bay 400kV AIS substation at Pelham • Two 400kV 3000 MVA reactors Sizewell • c 65km 400kV overhead line Bramford to Pelham • re-use of parts of existing DNO Belchamp-Twinstead-Bramford route would require construction of new GSP at Belchamp and possible new 132kV DNO route Braintree to Abberton • Reconductoring.

Evaluation criteria	**Issues**
Economy Cross if reason to park/discount: X	• The estimated option cost is £680m
Efficiency - system compliance Cross if reason to park/discount:	• System compliant
Efficiency - deliverability Cross if reason to park/discount:	• DNO precursor works likely to add one year to programme
Amenity Cross if reason to park/discount: X	• Extensive route length • Twinstead substation impact on landscape

Recommendation :	Option to be parked because of its cost and extensive impact on amenity when other shorter routes are available

OPTIONS EVALUATION PROFORMA

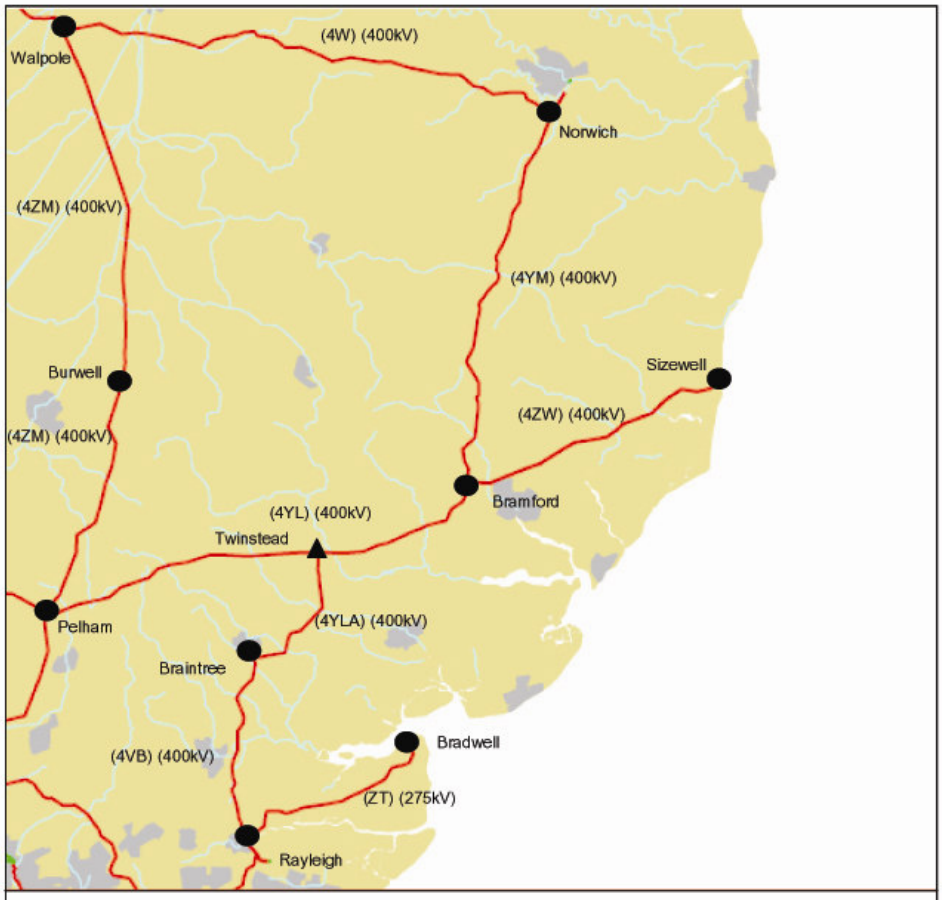
Scheme :	Sizewell
Option Reference and Title :	**Option S18 : Sizewell to Walpole via Norwich**
Option Description :	• c 127km 400kV overhead line between Sizewell and Walpole via Norwich • 22 bay 400kV GIS substation at Sizewell • 20 bay 400kV GIS substation at Bramford • Two 400kV 3000 MVA reactors Sizewell • additional SVCs at Sizewell • additional SVCs at Bramford • AIS substation at Walpole

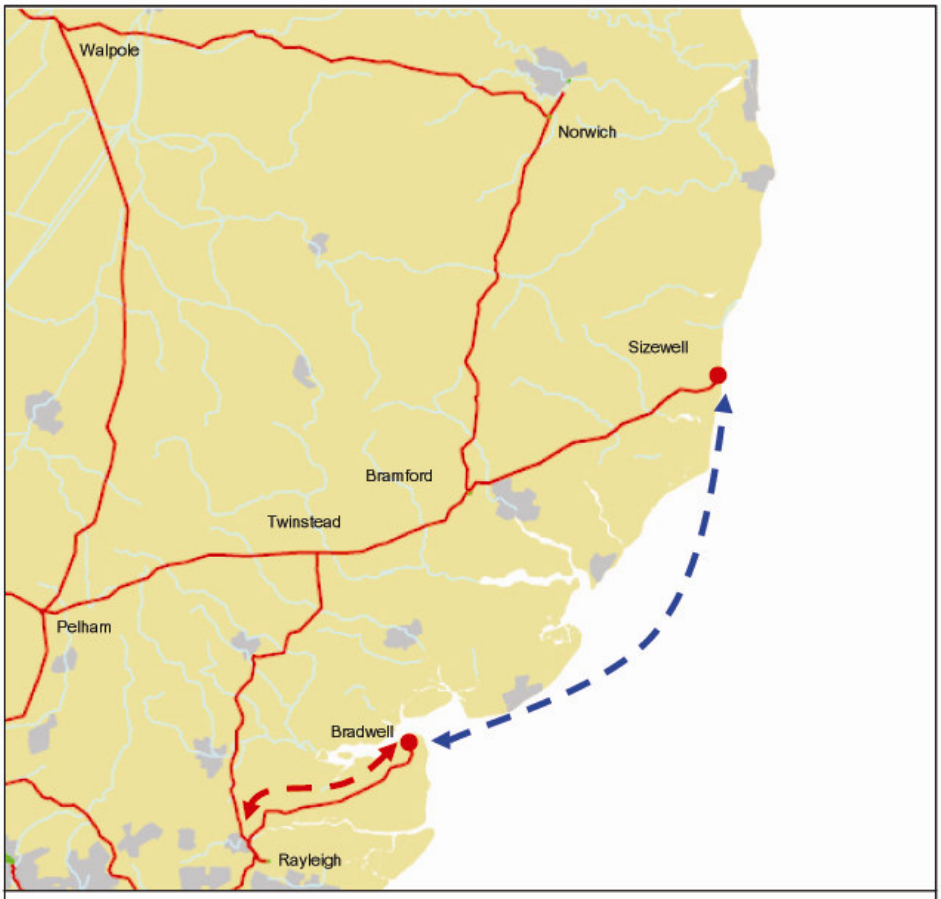
Evaluation criteria		Issues
Economy		• The estimated option cost is £690m
Cross if reason to park/discount	X	
Efficiency - system compliance		• System compliant • Would not solve issues of thermal capacity west of Bramford post 2020
Cross if reason to park/discount		
Efficiency - deliverability		• Length of route and interface with 4YM and 4VV routes pose risk to delivery
Cross if reason to park/discount		
Amenity		• Extensive route length with 79km parallel running between Norwich and Walpole • Would involve third overhead line in Suffolk Coast and Heaths AONB and Heritage Coast
Cross if reason to park/discount	x	

Recommendation :	Option to be parked because of its cost and extensive impact on amenity when other shorter routes are available. Wider system not compliant post 2020.

Appendix C

Existing transmission network and option diagrams


(4W) (400kV)
Walpole
Norwich
(4ZM) (400kV)
(4YM) (400kV)
Sizewell
Burwell
(4ZW) (400kV)
(4ZM) (400kV)
Bramford
(4YL) (400kV)
Twinstead
Pelham
(4YLA) (400kV)
Braintree
Bradwell
(4VB) (400kV)
(ZT) (275kV)
Rayleigh
Existing National Grid overhead line
Existing National Grid substation
Existing National Grid tee point
nationalgrid
Bramford - Twinstead Connection: Strategic Optioneering
Purpose
Information
Date
October 2009
Existing Transmission Network



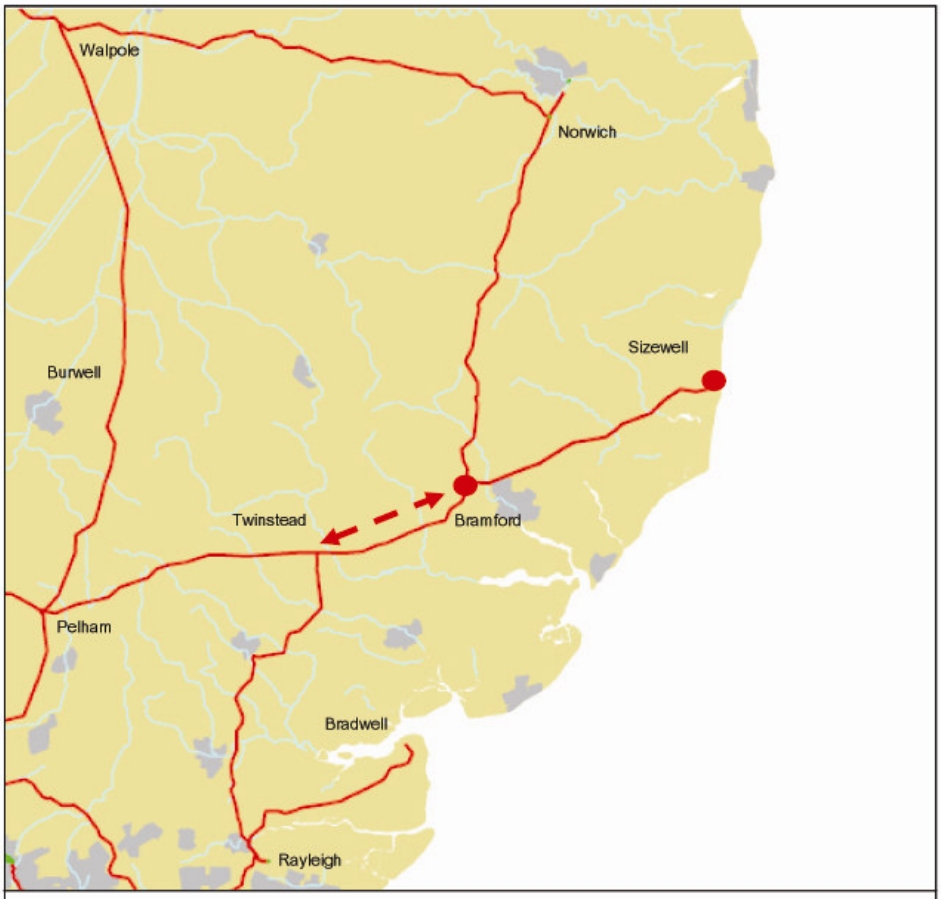
Existing National Grid overhead line
National Grid overhead line option
National Grid cable option
DNO overhead line route to be utilised
Overhead line to be removed
National Grid substation option
Grid supply point

nationalgrid

Bramford - Twinstead Connection: Strategic Optioneering

Purpose	Information
Date	October 2009

Option S4/S5: Sizewell - Bradwell Undersea Cable



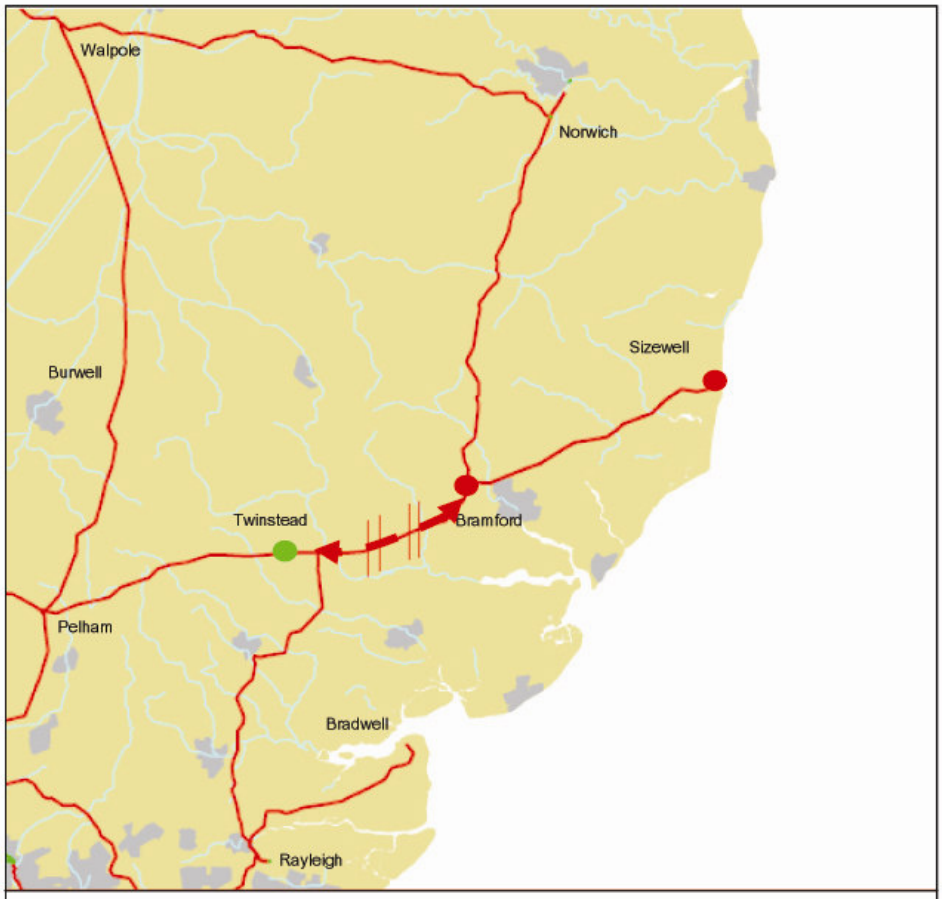
Existing National Grid overhead line
National Grid overhead line option
National Grid cable option
DNO overhead line route to be utilised
Overhead line to be removed
National Grid substation option
Grid supply point

nationalgrid

Bramford - Twinstead Connection: Strategic Optioneering

Purpose	Information
Date	October 2009

Option S6: Bramford - Twinstead



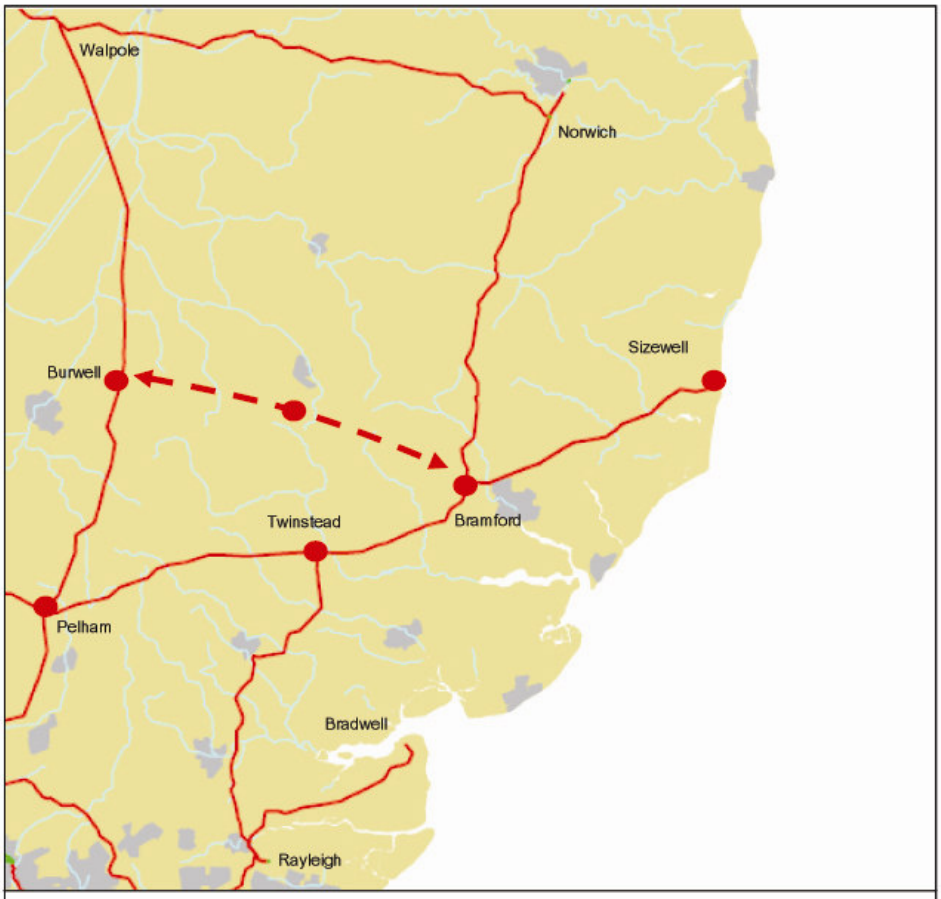
Existing National Grid overhead line
National Grid overhead line option
National Grid cable option
DNO overhead line route to be utilised
Overhead line to be removed
National Grid substation option
Grid supply point

nationalgrid

Bramford - Twinstead Connection: Strategic Optioneering

Purpose	Information
Date	October 2009

Option S7: Bramford – Twinstead (DNO Route)



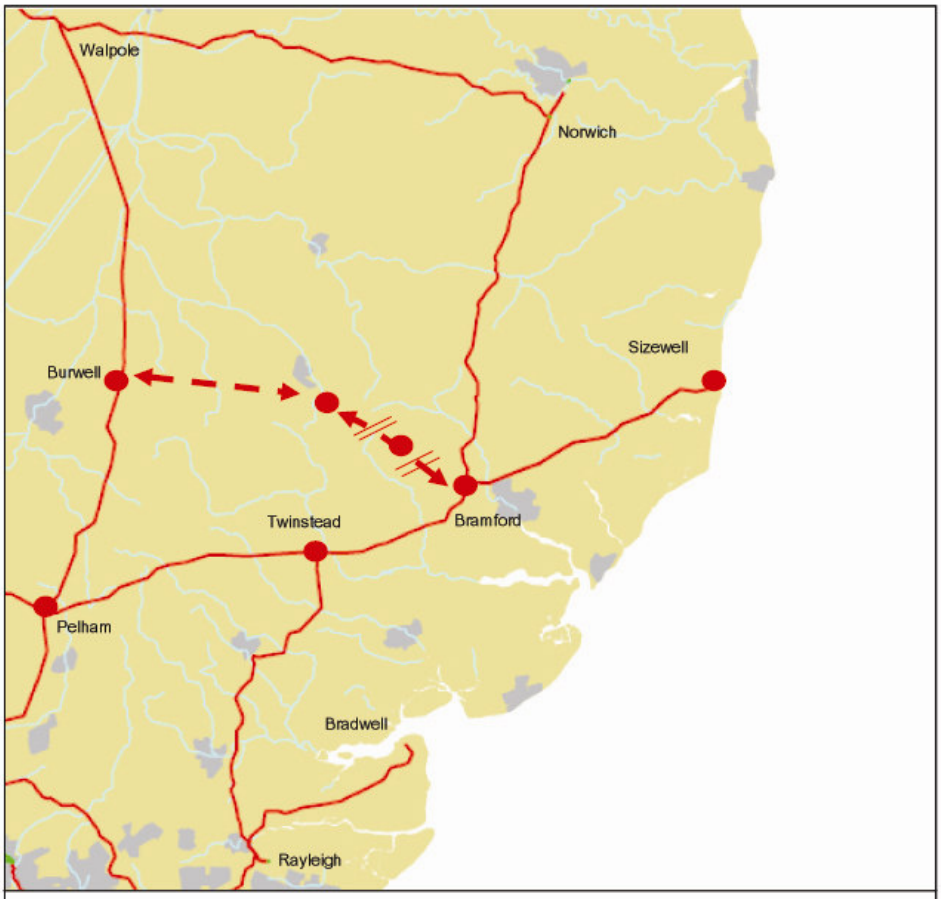
Existing National Grid overhead line
National Grid overhead line option
National Grid cable option
DNO overhead line route to be utilised
Overhead line to be removed
National Grid substation option
Grid supply point

nationalgrid

Bramford - Twinstead Connection: Strategic Optioneering

Purpose	Information
Date	October 2009

Option S8: Bramford - Burwell



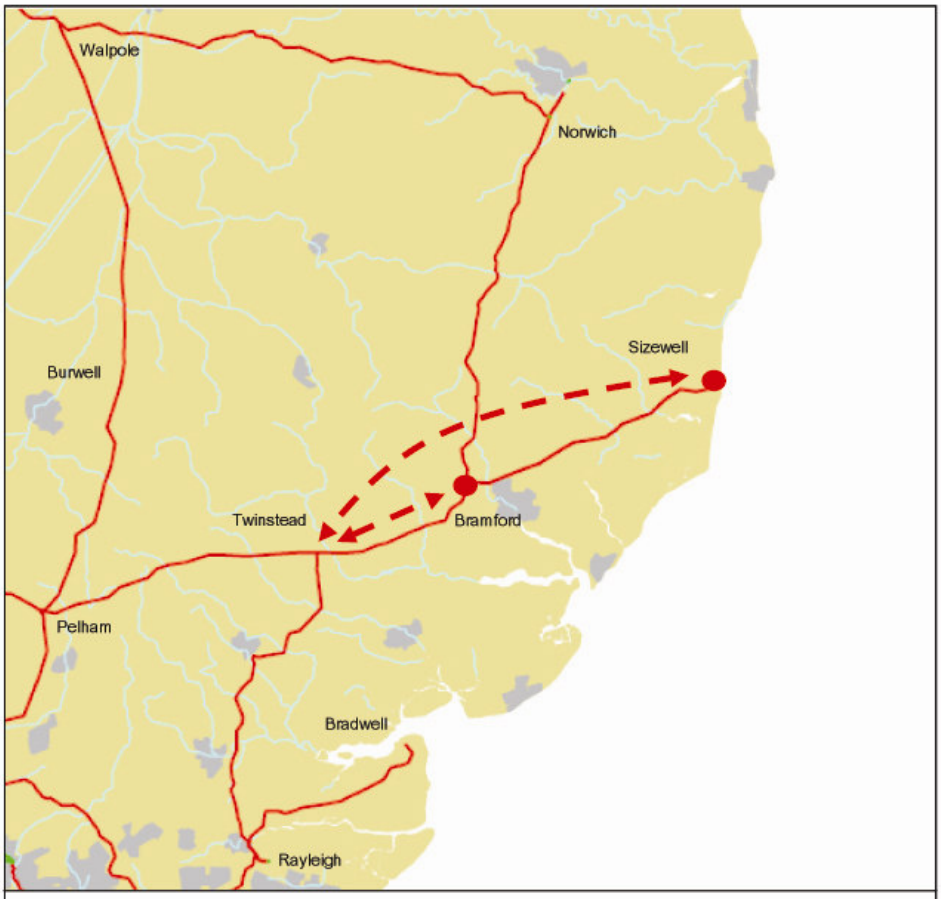
Existing National Grid overhead line
National Grid overhead line option
National Grid cable option
DNO overhead line route to be utilised
Overhead line to be removed
National Grid substation option
Grid supply point

nationalgrid

Bramford - Twinstead Connection: Strategic Optioneering

Purpose	Information
Date	October 2009

Option S9: Bramford - Burwell (DNO Route)



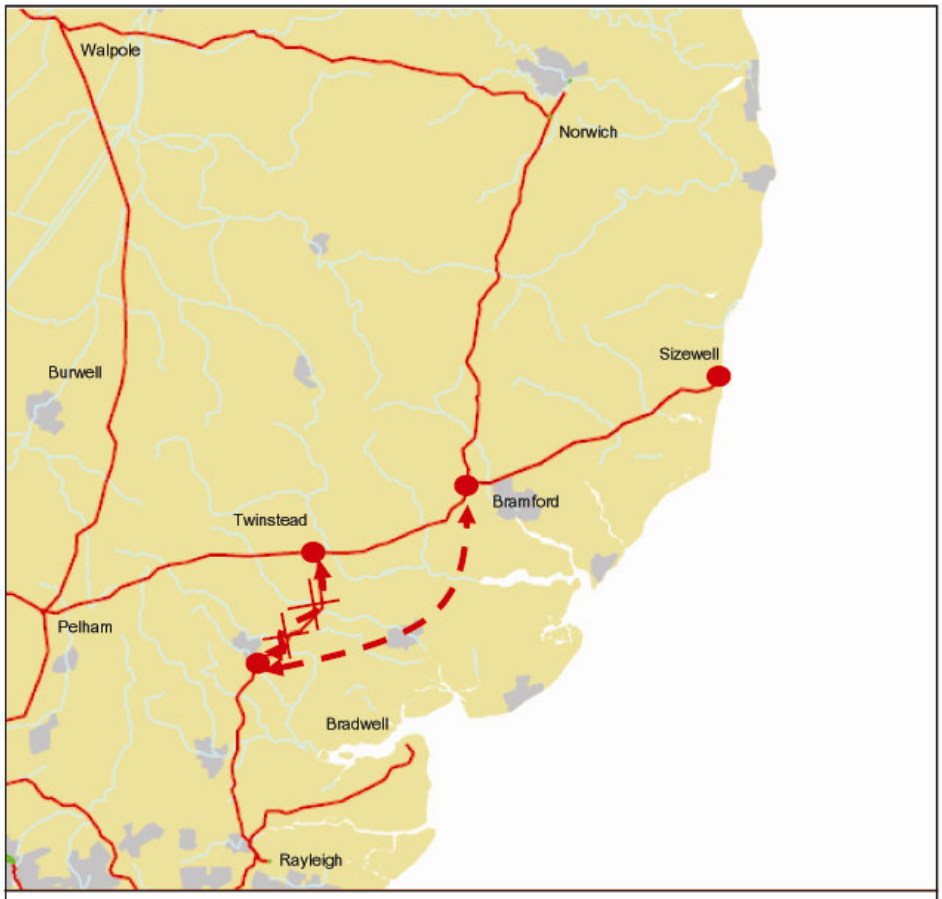
Existing National Grid overhead line
National Grid overhead line option
National Grid cable option
DNO overhead line route to be utilised
Overhead line to be removed
National Grid substation option
Grid supply point

nationalgrid

Bramford - Twinstead Connection: Strategic Optioneering

Purpose	Information
Date	October 2009

Option S10: Sizewell - Twinstead



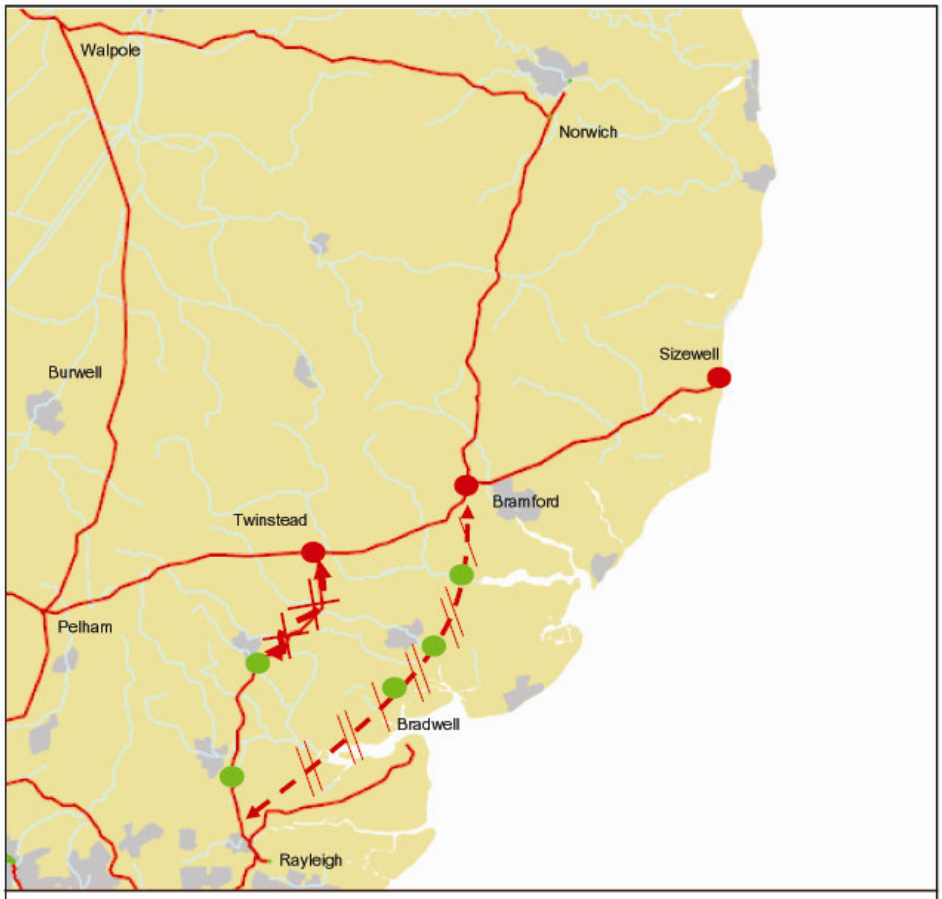
Existing National Grid overhead line
National Grid overhead line option
National Grid cable option
DNO overhead line route to be utilised
Overhead line to be removed
National Grid substation option
Grid supply point

nationalgrid

Bramford - Twinstead Connection: Strategic Optioneering

Purpose	Information
Date	October 2009

Option S11: Bramford – Braintree



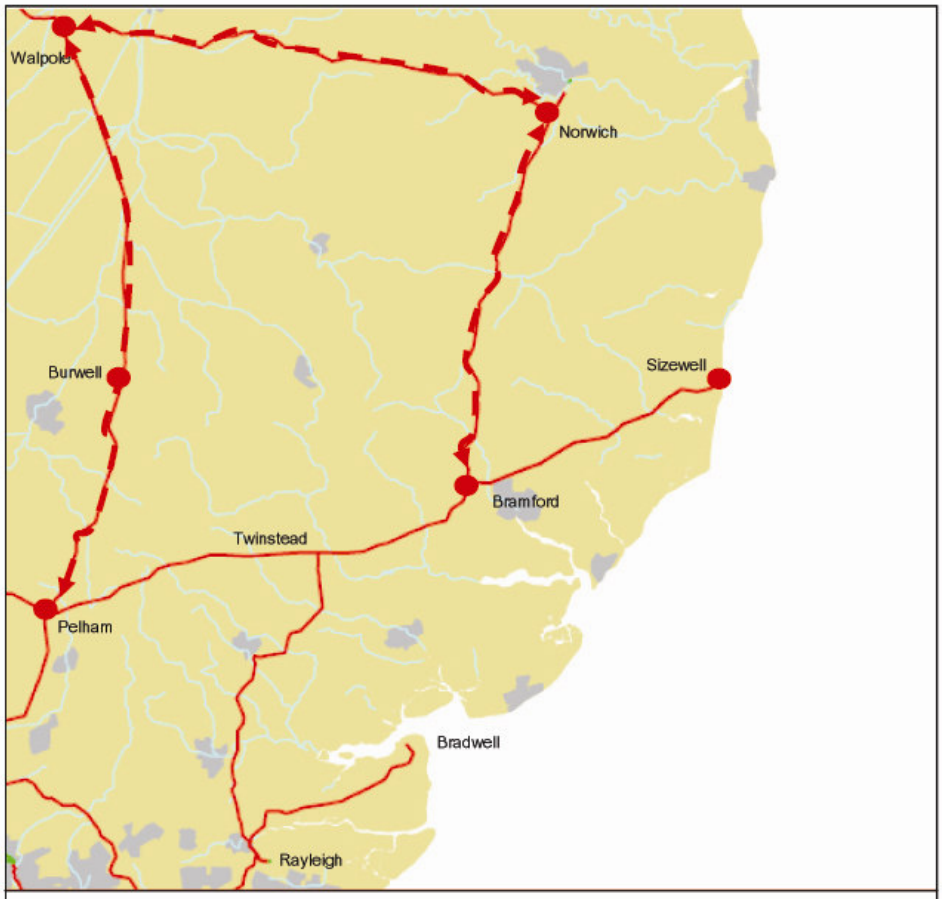
Existing National Grid overhead line
National Grid overhead line option
National Grid cable option
DNO overhead line route to be utilised
Overhead line to be removed
National Grid substation option
Grid supply point

nationalgrid

Bramford - Twinstead Connection: Strategic Optioneering

Purpose	Information
Date	October 2009

Option S12: Bramford –Rayleigh (DNO Route)



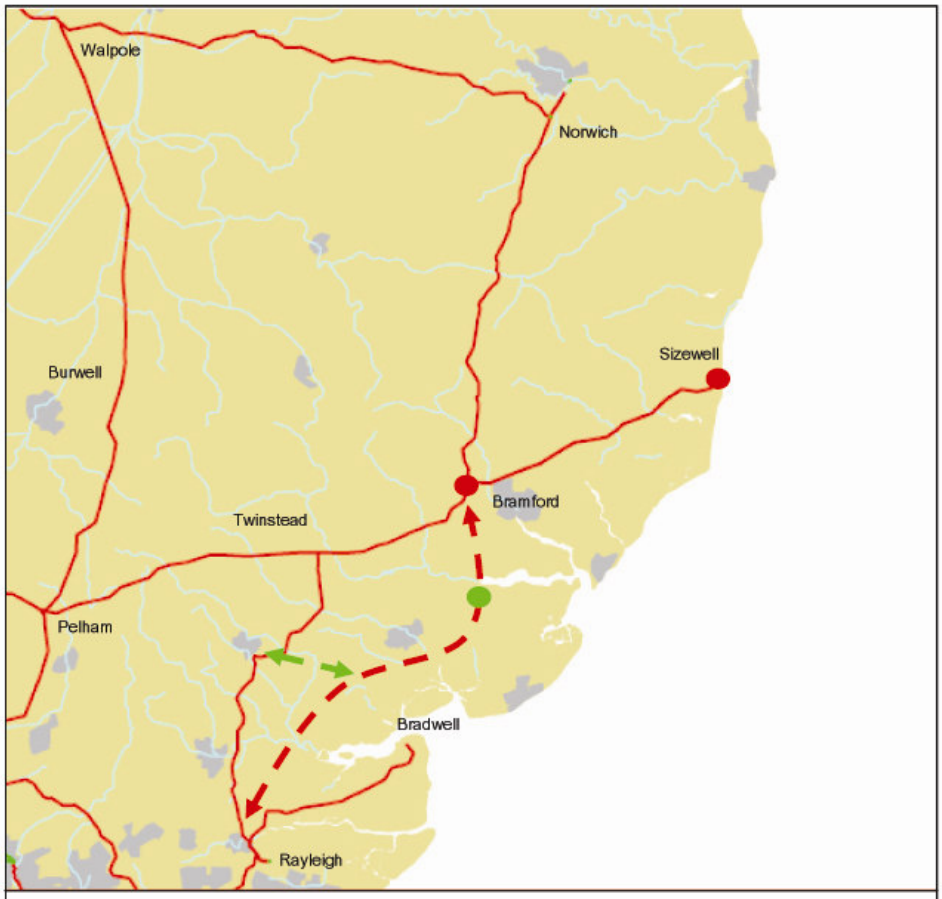
Existing National Grid overhead line
National Grid overhead line option
National Grid cable option
DNO overhead line route to be utilised
Overhead line to be removed
National Grid substation option
Grid supply point

nationalgrid

Bramford - Twinstead Connection: Strategic Optioneering

Purpose	Information
Date	October 2009

Option S14: Upgrade Bramford to Pelham Ultra High Voltage



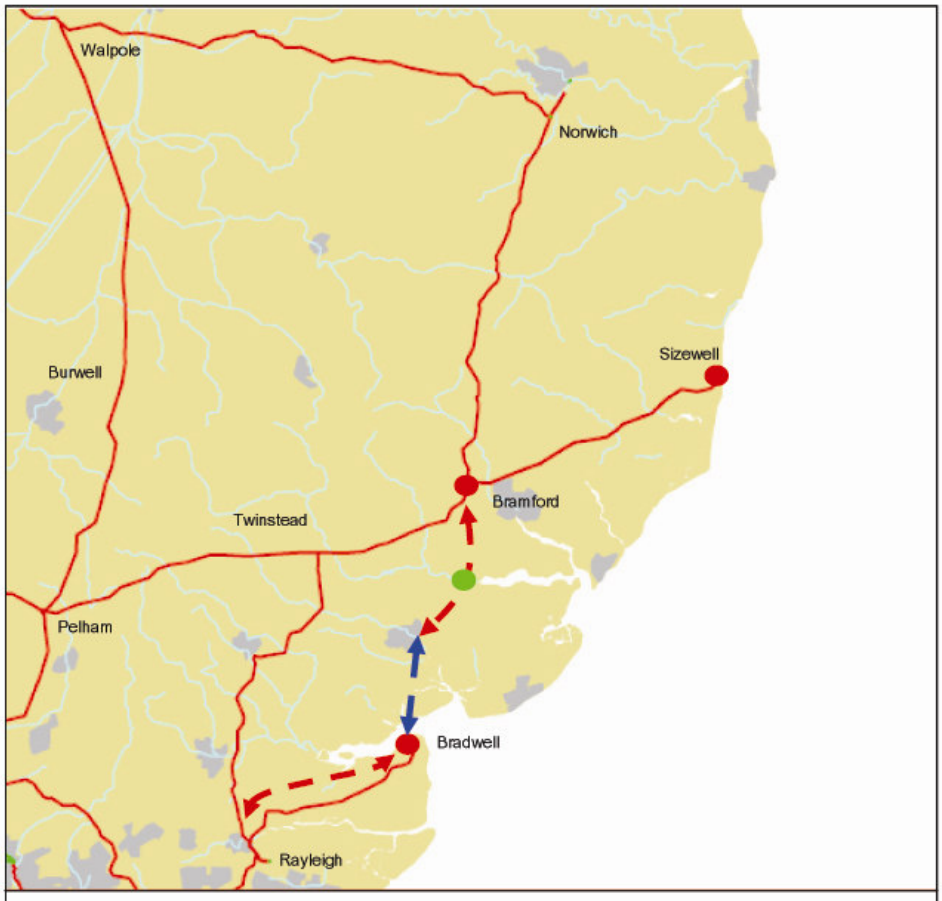
Existing National Grid overhead line
National Grid overhead line option
National Grid cable option
DNO overhead line route to be utilised
Overhead line to be removed
National Grid substation option
Grid supply point
DNO connection option

nationalgrid

Bramford - Twinstead Connection: Strategic Optioneering

Purpose	Information
Date	October 2009

Option S15: Bramford –Rayleigh via Lawford



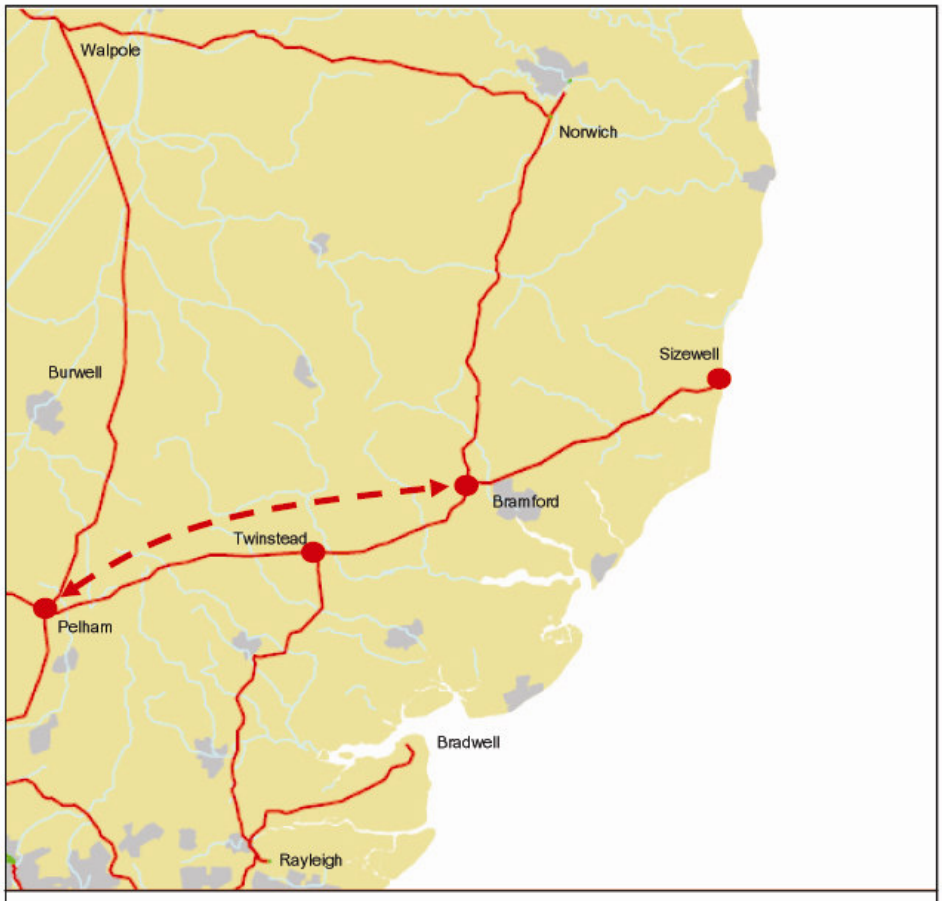
Existing National Grid overhead line
National Grid overhead line option
National Grid cable option
DNO overhead line route to be utilised
Overhead line to be removed
National Grid substation option
Grid supply point

nationalgrid

Bramford - Twinstead Connection: Strategic Optioneering

Purpose	Information
Date	October 2009

Option S16: Bramford –Rayleigh via Bradwell



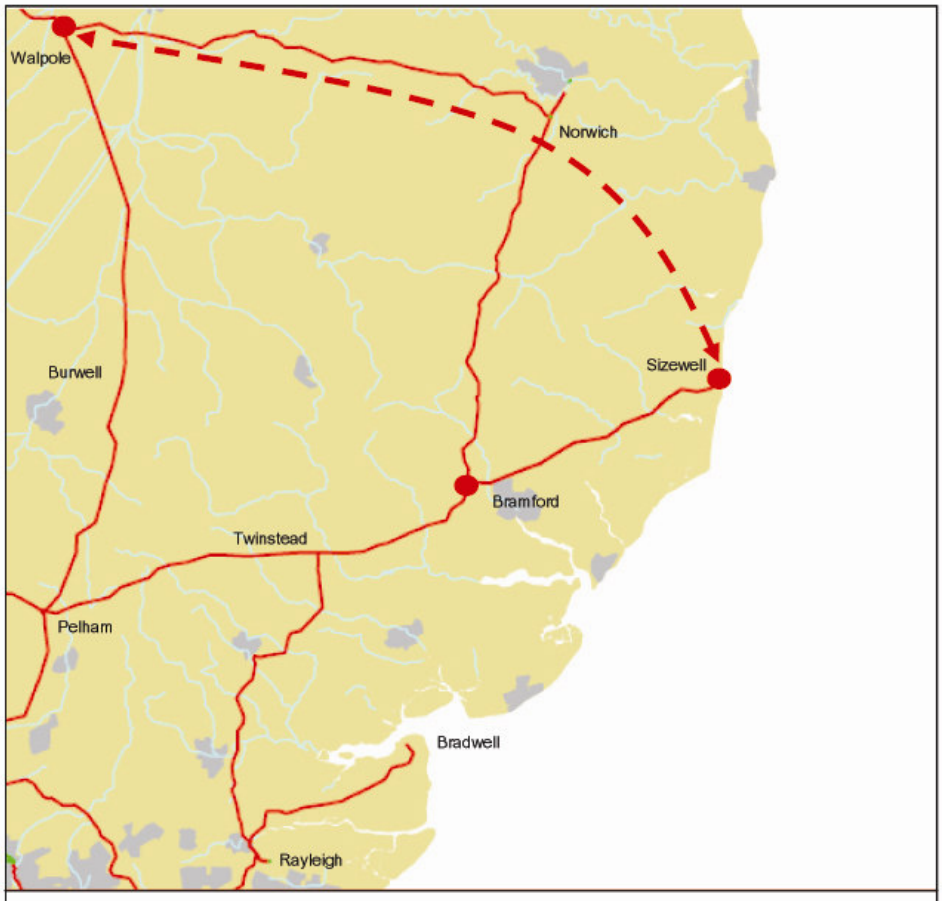
Existing National Grid overhead line
National Grid overhead line option
National Grid cable option
DNO overhead line route to be utilised
Overhead line to be removed
National Grid substation option
Grid supply point

nationalgrid

Bramford - Twinstead Connection: Strategic Optioneering

Purpose	Information
Date	October 2009

Option S17: Bramford – Pelham



Existing National Grid overhead line
National Grid overhead line option
National Grid cable option
DNO overhead line route to be utilised
Overhead line to be removed
National Grid substation option
Grid supply point

nationalgrid

Bramford - Twinstead Connection: Strategic Optioneering

Purpose	Information
Date	October 2009

Option S18: Sizewell – Walpole