Integrated Offshore Transmission Project (East)

Appendix 3

Cost Benefit Analysis Work-Stream Report

Contents

1 Introduction

NOTE: Since completion of this work-stream report the assumptions around credible connection dates and volumes of offshore wind generation have changed in response to current market conditions. As stated in the original conclusions if the spread of generation between the three zones considered was to vary then the case for integration could be weakened. Latest market intelligence suggests that the build-up of offshore wind generation is likely to be slower than previously forecast and has potential to deliver volumes below the 10GW lower limit assessed in this analysis. Therefore the conclusions stated in this work-stream report are no longer considered valid. The current view on the least worst regret assessment of integrated designs is given in the main project summary report. While the analysis presented here was correct at the time of assessment, all conclusions are now superseded.

1.1 Context

The Integrated Offshore Transmission Project (East) (IOTP(E)) was set up to identify, develop and examine a range of credible network solutions for the connection of three East Coast Round Three offshore wind farms in the most economic and efficient manner. The development may provide additional transmission capacity to the wider and local system boundaries and improve offshore transmission reliability, depending on the design.

The three projects, referred to as Dogger Bank, Hornsea and East Anglia are managed by different development companies, namely:

Dogger Bank - Forewind

Hornsea - Smart Wind

East Anglia - East Anglia Offshore Wind

Whilst the analysis has been undertaken by National Grid, this project has been coordinated through a joint working group comprised of all major stakeholders including representatives from the parties listed above. The network design options considered in this assessment cover a range of configurations from base radial connection solutions (with and without onshore reinforcements) to various integrated offshore network configurations.

As part of this work, National Grid has undertaken a Cost Benefit Assessment (CBA) using established economic assessment rationale to assess the range of network designs against future scenarios. In simple terms, the objective is to consider the value of any benefits offered by each design, against the additional investment associated with that design. The benefits include both forecast savings in constraint payments made to onshore generation, and the welfare benefit of obtaining higher levels of renewable energy from the three wind farms.

The onshore constraint cost forecasts are produced using a network modelling tool. The welfare benefits are represented as constraint costs on the offshore generation, and are also calculated by the network modelling tool. The investment costs have been calculated using the unit prices provided by the technology work stream. The modelling of the welfare benefit and constraints is described more fully in chapter 4 of this report.

Within this context, this document presents the details of the CBA undertaken by National Grid, as shared with the working group, to provide a vision of the overall economic benefits that could exist.

1.2 Economic Objectives of the Project

The current transmission network capabilities coupled with the range of generation projected to connect/disconnect over the next 20 years will impact on operational costs. These operational costs will increase in the absence of any reinforcements because the network design has evolved to best meet the current generation disposition.

Given that National Grid has an obligation to connect generation in accordance with agreed contracted dates, the key economic objectives of this project are twofold:

- Ensure value for money for the consumers by delivering cost effective reinforcements to ensure economically efficient design and operation of the network.
- Timely delivery of necessary reinforcement(s) to minimise any cost exposure for consumers to either early investment or delayed implementation.

1.3 Study Objectives and Scope

The context outlined above drives the CBA objectives and scope of National Grid Electricity Transmission (NGET) work. Furthermore, consistent with the **Guidance on Strategic Wider Works arrangements in the electricity transmission price control, RIIO – T1,** the objectives of this CBA are:

- To be consistent with our Licence obligations, National Electricity Transmission System (NETS) Security and Quality of Supply Standards (SQSS), the analysis promotes economic and efficient investment.
- To present economic justification for the preferred designs and an explanation of how they compare with the alternative counterfactual case.
- To present evidence on expected long-term value for money for consumers considering a range of sensitivities, and

- To present evidence on optimal timing of the preferred reinforcement option.

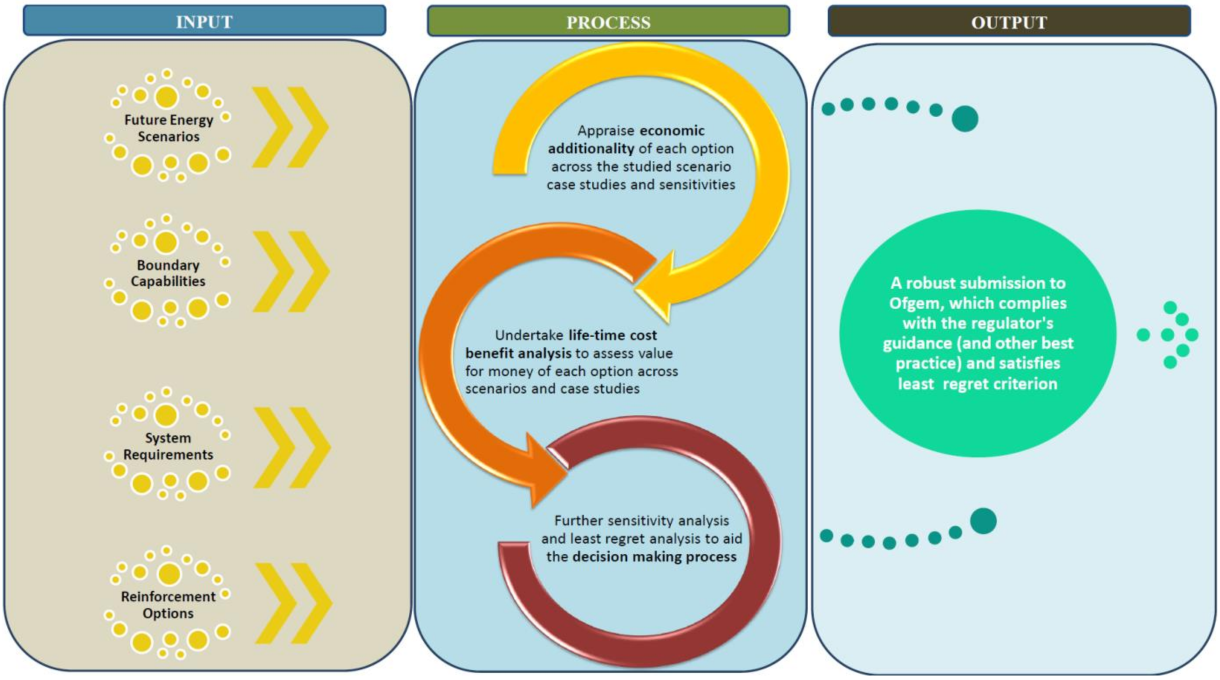
Driven by these objectives the scope of the CBA is outlined below:

- To establish the reference case position in terms of constraint costs forecasts associated with the 'do minimum' network state, across two generation background scenarios.
- To model the economic impact, measured as constraint cost savings, for a range of designs, across a range of scenarios.
- To undertake a CBA by:
    - Appraising the economic case of the options by adopting the Spackman[1] approach and determining respective Net Present Values (NPVs) across the studied generation scenarios and sensitivities.
    - Establishing worst regrets associated with each design/technology appraised.
    - Identifying the Least Worst Regret option overall.
    - Assessing the impact of key sensitivities: increase in capital expenditure, and delays in delivery timeframes.
- Make recommendations for the preferred option i.e. the Least Worst Regret solution, taking into consideration the impact of sensitivities.

This CBA process is summarised in Figure 1-1 below.

Figure 1-1: National Grid's Cost Benefit Assessment Process

[1] The Joint Regulators Group on behalf of UK's economic and competition regulators recommend a discounting approach that discounts all costs (including financing costs as calculated based on a Weighted Average Cost of Capital or WACC) and benefits at the Social Time Preference Rate (STPR). This is known as the Spackman approach. Further details of our assumptions regarding WACC and STPR are presented later in this document.



Source: Electricity Ten Year Statement 2013, National Grid

1.4 Structure of the Document

The structure of this CBA document is outlined below:

- **Chapter 1 Introduction** outlines the aims and objectives of the study.
- **Chapter 2 Background** presents boundary capabilities, offshore wind capacity assumptions, wind generation characteristics and offshore network fault rate assumptions.
- **Chapter 3 Options for Economic Appraisal** summarises details of the designs and their costs considered in the CBA.
- **Chapter 4 Counterfactual and Economic Impact of Options** focusses on constraint costs forecasts for the counterfactual case and other designs considered in the CBA
- **Chapter 5 Cost Benefit Assessment** brings together the analysis presented in the earlier chapters using the Spackman approach to develop NPVs, and performs regret analysis to determine the most economic option overall based on minimising regrets across the scenarios.
- **Chapter 6 Sensitivity Analysis** presents the impact of key sensitivities on the analysis presented in Chapter 5. This covers delays on investment and investment cost increase.
- **Chapter 7 Conclusions and Recommendations**.

2 Background

2.1 Introduction

Three large offshore wind generation projects proposing connection along the east coast of Britain from 2020/21 to 2030/31 will impact on the power flows and supply patterns across the transmission system.

Transmission network boundaries B6, B7, B7a, B8, B9 will be impacted primarily by Dogger Bank and Hornsea wind developments, whilst boundary EC5 will be impacted by East Anglia developments. Additionally, local boundaries EC1, EC3, and EC7 may pose a restriction. The potential scale of these developments will also lead to changes of power flow and constraint conditions on the transmission network, particularly when high generation levels are achieved.

Due to the huge array of incremental offshore generation and network build up scenarios, it has not been practical to model development/construction years. Construction is assumed to cover a 10 year period from 2020/21 to 2030/31. No constraint costs (or benefits from partial integration) are assumed during the construction period, but capital costs associated with integration *are* captured and assumed to follow a common annual profile.

The modelling has focussed on the year 2030/31 in which all designs could be fully commissioned and stable. This particular year is assumed representative for the entire asset life. The subsea cables and associated equipment has an assumed life of 40 years. Whilst it could be argued that the network is likely to undergo further changes during a 40 year horizon from 2030/31, it is particularly difficult to forecast the state of the network so far into the future with any sense of accuracy. Consequently, we do not account for speculative projections beyond 2030/31 and simply adopt this year as representative throughout the asset life.

Constraint cost results are taken as the average of 120 discrete model runs for 2030/31, to capture the random nature of fault outages. This ensures a representative inclusion of generation lost as a result of offshore faults, or secured through a secondary (integrated) route to market. This number of simulations has been necessary due to the low fault rates of some of the equipment. Fault rates are assumed constant across the life time of the assets.

The average annual constraint costs derived across the 120 iterative studies are assumed to apply from 2030 for each year of a forty year asset life, and are discounted using the Spackman methodology.

The rest of this chapter discusses the forecast network capabilities, an overview of Future Energy Scenarios 2013 (FES

2013), offshore network fault rate assumptions, wind generation capacity assumptions and generation characteristics.

2.2 *Network Capabilities*

In order to accommodate new transmission connected generation between now and 2030/31, some network developments will be necessary, irrespective of these offshore wind projects. The extent of these developments is driven by the generation background scenarios of Gone Green and Slow Progression.

Consequently, future transmission boundary capability forecasts have been adopted from National Grid's Electricity Ten Year Statement (ETYS) to form the basis of the onshore network capability. ETYS presents a view by scenario of the likely state of boundary capabilities, based on commissioning dates of new generation.

Where an IOTP(E) design provides additional transmission capability across boundaries, this capability is included in the model assumptions. Where there is no additional capacity associated with the design studied, then the ETYS assumptions remain unaltered.

The network capabilities by boundary for each of the IOTP(E) designs studied can be seen in Appendix 2. Note that the more complex designs have a more complex set of boundary definitions. It is important to note that any boundary capability is sensitive to the demand/generation background used to calculate the capability, and so any change in these can result in network capability changes.

The boundary capabilities (by generation background and by design), also reflect the fact that some transmission assets have a seasonal rating driven primarily by ambient temperatures. The seasons are defined as ***Winter*** (December, January and February) ***Spring/Autumn*** (March, April, May, September, October November) and ***Summer*** (June, July and August).

Subsea cables associated with the IOTP(E) designs do not have seasonal ratings because sea temperatures at depth do not vary much, and water has a much higher thermal mass than air. Consequently, the cable ratings are taken from the design work stream and apply all year.

However, the subsea cables do have statistical fault outage conditions applied in the modelling. Fault outage conditions are an important consideration because even though they are rare, they can impose a significant financial impact if they occur, since the generation may be lost to the wider community. A fault event can lead to increased costs to consumers if the remaining network capability is insufficient for the available generation.

Integrated network designs may mitigate the effect of fault outages by creating secondary transmission routes for generation to reach the market. These characteristics are captured in the modelling in line with fault rate assumptions, boundary capability and wind output levels.

The assumptions for ‘per unit’ fault rates and Mean Time To Repair (MTTR) for AC and DC primary network components are shown in table 2-1 below: -

Table 2-1 Offshore Fault Rates

	Component	Failure Rate /day	Failure Rate /year	Failure Rate over 40 years	MTTR (days)
DC	Converter	0.0000178	0.0065	0.260	60
DC	Conv. Transformer	0.0001096	0.0400	1.600	60
DC	Cable (1km)	0.0000019	0.0007	0.028	60

	Component	Failure Rate /day	Failure Rate /year	Failure Rate over 40 years	MTTR (days)
AC	Transformer	0.000018	0.006600	0.2640	60
AC	Cable (1km)	0.000002	0.000705	0.0282	60

Source: Cigre Studies and National Grid

The corresponding MTTR period of 60 days is assumed across all equipment types and is regarded as a central view. Faults will in all likelihood be of different durations depending on; their nature, the time of occurrence and ease of access/repair. However, it is difficult to forecast this variance hence a common assumption of sixty days is adopted.

These fault rates are coupled with the corresponding number of units and kilometres of cable for each of the design components, to reflect the total fault rate for each electrical path in each design. The modelling uses random sampling to reflect fault events based on these statistics. The cable distance assumptions from platform-to-shore and platform-to-platform are shown in table 2-2 below: -

Table 2-2 Offshore Distances

DOGGER BANK	Offshore Cable Distance (km)
P1	212.5
P2	261.0
P3	222.8
P4	215.1
P5	210.6
P6	246.3
P1-P2	72.9
P1-P3	28.2
P1-P4	30.6
P2-P3	41.2
P2-P4	95.3
P2-P6	49.4
P3-P4	35.3
P3-P5	34.1
P4-P5	31.8
P5-P6	36.5

HORNSEA	Offshore Cable Distance (km)
P1	150
P2	125
P3	125
P4	138
P1-P3	64
P2-P3	38
P1-P4	29
P2-P4	56
P1-P2	27
P3-P4	38

EAST ANGLIA	Offshore Cable Distance (km)
P1	73
P2	43
P3	140
P4	160
P5	24
P6	68

In addition, three other general cable distance assumptions have been adopted: -

- Where not specified, an integrating High Voltage Direct Current (HVDC) platform to any connecting offshore windfarm HVDC platform on the same zone is 30km
- The distance between Dogger Bank and Hornsea is 120km and the distance between Hornsea and East Anglia is 100km
- The distance from Scotland (Bootstrap) to EC7, EC1 and EC3 local boundary areas are assumed to be 150km, 250km and 350km respectively.

2.3 Future Energy Scenarios 2013

The Future Energy Scenarios[2] (FES) are prepared by National Grid in consultation with key industry stakeholders including the transmission system owners, DECC, and the Electricity Networks Strategy Group (ENSG). The FES outputs are each built on a set of central axioms to represent a credible scenario. Collectively, they are designed to represent a range of possible outcomes, which may be used to examine future network requirements.

FES 2013 comprised two main background scenarios, namely Slow Progression (SP) and Gone Green (GG)

An overview of the key axioms and principles of the Slow Progression and Gone Green background scenarios are:

- **Slow Progression:** Developments in renewable and low carbon energy are comparatively slow and the renewable energy target for 2020 is not met until sometime between 2020 and 2025. The carbon reduction target for 2020 is achieved but not the target for 2030.
- **Gone Green:** Assumes a balanced approach with contributions from different generation sectors in order to meet the environmental targets. GG sees the renewable target for 2020 and the emissions targets for 2020 and 2030 all met.

As described in Chapter 1, these background scenarios, with two assumed levels of offshore wind development at Dogger Bank, Hornsea and East Anglia form the basis of the analysis.

The remainder of this chapter outlines the wind generation capacities and load factor characteristics studied to appraise the efficiency of the investment options.

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[2] FES 2013 document can be sourced from http://www2.nationalgrid.com/Media/UK-Press-releases/2013/National-Grid-s-UK-Future-Energy-Scenarios-2013/.

2.4 *Offshore Wind*

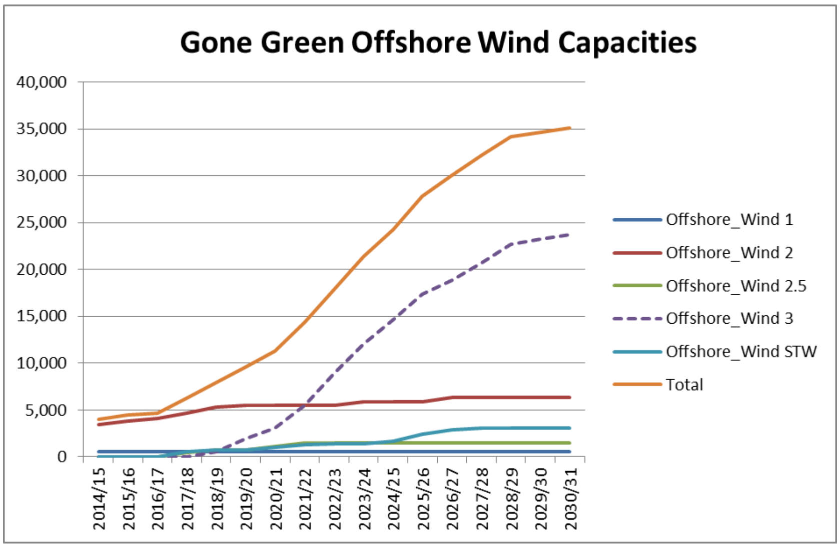
There are two offshore wind generation capacity cases under consideration which are intended to capture a credible range of development outcomes. These two studies are referred to as: -

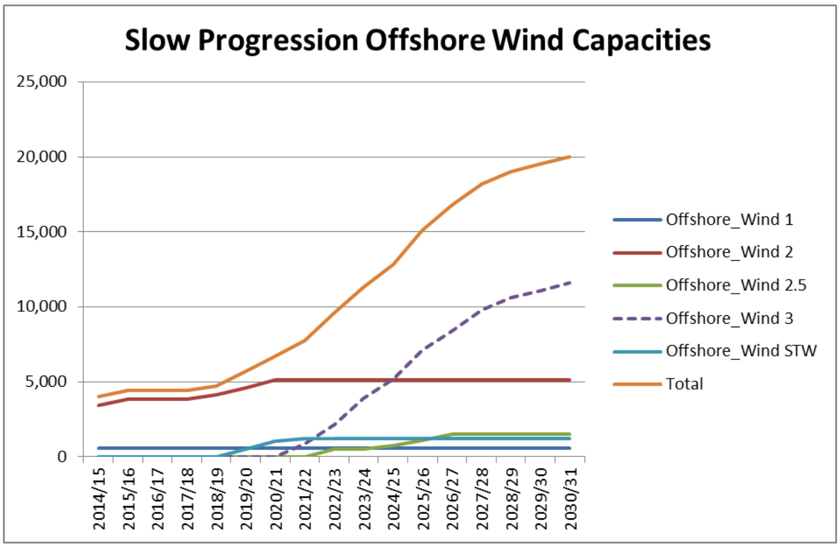
1. Scenario 1 - with a total of 10GW of IOTPE wind capacity
2. Scenario 2 - with a total of 17.2GW of IOTPE wind capacity

Scenario 1 represents the largest wind capacity development across the three wind generation projects based on contracted positions, whilst Scenario 2 was agreed by the working group to reflect a less aggressive overall build programme.

The FES 2013 provides assumptions on the total capacity of offshore wind development based on stakeholder engagement and the agreed scenario axioms. Both the GG and SP scenarios are consistent with IOTP(E) wind capacities. i.e. the modelled wind development capacities of 10.0GW and 17.2GW shown above are within the corresponding offshore wind capacities by FES scenario. The 2030/31 offshore wind capacity assumptions along with the build-up for offshore wind capacity under both FES scenarios are shown in table 2-3 below: -

Table 2-3 Total Wind Capacities by Round





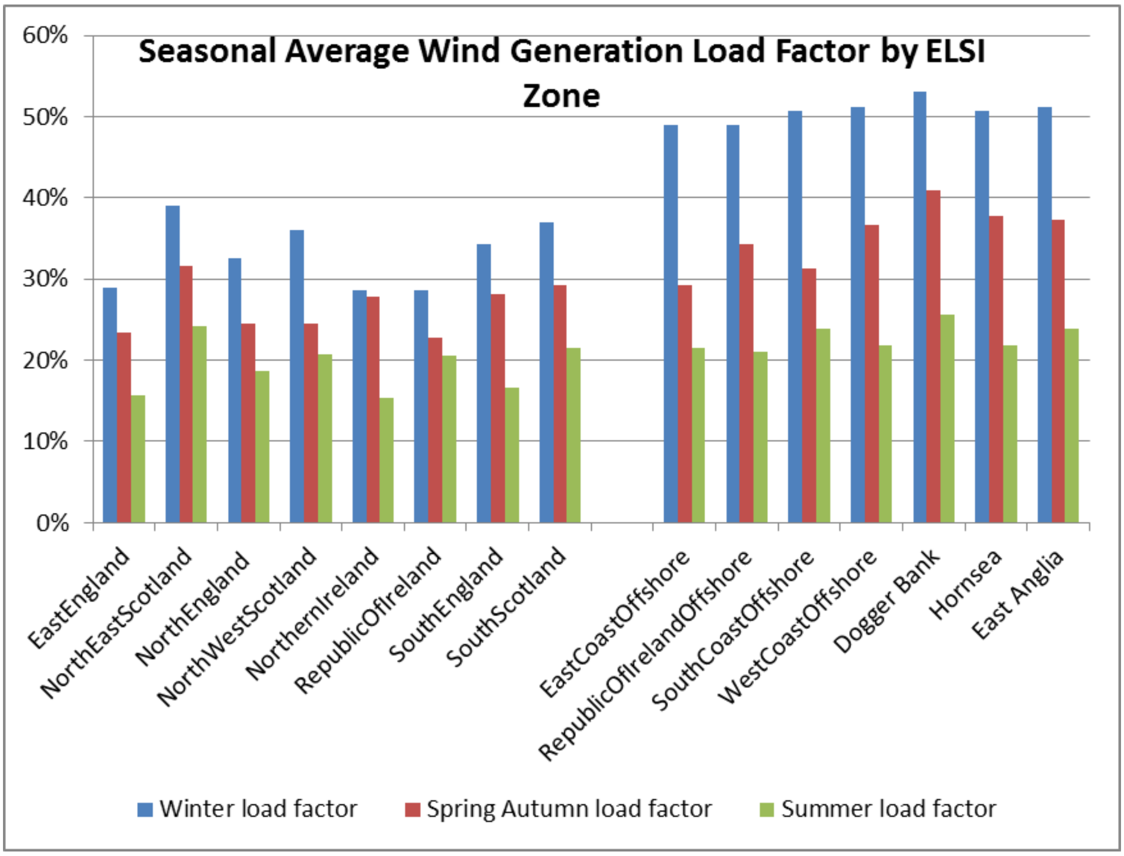
2.5 *Wind Generation Load Factors and Characteristics*

The Electricity Scenario illustrator (ELSI) modelling process samples a ten year historical data set to represent wind generation load levels. The model selects a day from the season under study, and reads the corresponding load factors for each wind zone, for each period of that day. The original source data from which these tables have been derived is from the Meteorological Office. The ten years' worth of data is broken up into 15 geographical zones reflecting locational spread. Consequently, each data sample respects seasonality, time of day effects and locational correlation.

Having this data selection method, means that the full range of credible load factors and zonal correlations is captured in the analyses and the results reflect seasonal and time of day effects.

The seasonal average wind generation load factors by ELSI zone are shown in table 2-4 below: -

Table 2-4 Seasonal Average Wind Load Factors by model Zone



The annual average wind load factors for the three projects Dogger Bank, Hornsea, East Anglia are 40.1%, 37.1% and 37.4% respectively. Evidence suggests this is representative of other offshore wind generation studies.

It can be seen that the offshore zones have better load factors (driven by higher wind speeds) than onshore zones. Similarly, northerly zones (such as Scotland) also benefit from stronger wind speeds. In all zones, load factors are highest in winter and lowest in summer.

Zonal Correlation of ELSI Wind Zones

Zonal correlation of wind generation is an important consideration since this could have a significant impact on power flows and corresponding constraint costs. The correlation matrix between the three key zones Dogger Bank, Hornsea and East Anglia reflects the relative distances between the zones. i.e. neighbouring zones have a higher correlation than more distant zones of Dogger Bank and East Anglia, as shown in table 2-5 matrix below.

Table 2-5 Wind Generation Correlation matrix for IOTP(E) Zones

ELSI Wind Generation Correlation Matrix - New Zones	DoggerBank	Hornsea	East Anglia
DoggerBank		0.85	0.49
Hornsea			0.64
East Anglia			

The wider zonal pattern of correlation for the other ELSI zones exhibit similar trends. Once again, it can be seen that zones in close proximity have higher correlation values than more distant zones. The remaining ELSI zone correlation matrix is shown in table 2-6 below highlighting the highest and lowest correlation values: -

Table 2-6 Wind Generation Correlation matrix for other Zones

ELSI Wind Generation Correlation Matrix	EastEngland	NorthEastScotland	NorthEngland	NorthWestScotland	NorthernIreland	RepublicOfIreland	SouthEngland	SouthScotland	EastCoastOffshore	RepublicOfIrelandOffshore	SouthCoastOffshore	WestCoastOffshore
EastEngland		0.47	0.78	0.39	0.52	0.55	0.69	0.55	0.79	0.59	0.65	0.71
NorthEastScotland			0.65	0.80	0.56	0.49	0.31	0.71	0.49	0.50	0.27	0.49
NorthEngland				0.53	0.68	0.66	0.62	0.77	0.75	0.69	0.56	0.81
NorthWestScotland					0.58	0.51	0.27	0.68	0.36	0.46	0.22	0.43
NorthernIreland						0.91	0.50	0.76	0.48	0.69	0.40	0.69
RepublicOfIreland							0.60	0.73	0.49	0.72	0.47	0.75
SouthEngland								0.44	0.67	0.56	0.85	0.78
SouthScotland									0.50	0.66	0.34	0.67
EastCoastOffshore										***0.62***	***0.70***	***0.74***
RepublicOfIrelandOffshore											0.55	0.82
SouthCoastOffshore												0.75
WestCoastOffshore												

The combination of representative seasonal and time of day load factors, along with representative correlation between zones, provides a reasonable basis to assess the impact on transmission system power flows associated with new wind generation developments.

It should be noted that the ten year wind data set used in ELSI does include a range of stronger and weaker wind characteristics, and as such captures some natural variance. However, this does not eliminate the chance of experiencing unusual weather patterns following commissioning.

3 Options for Economic Appraisal

3.1 Introduction

A key objective of the project, as outlined in Chapter 2, is to deliver efficient network capability to meet future system requirements. In order to meet these requirements, a range of network designs were prepared by the working group, to be taken into the CBA. The CBA appraises these designs against the counterfactual position.

This chapter presents further details of these options.

3.2 Design Options

Fourteen original designs were selected by the working group for CBA from a much wider set of design alternatives. They were chosen to represent the broad range of technology alternatives and include various size links to shore, two bootstrap designs, and various integrated configurations. Some designs are broadly comparable despite the need to accommodate different wind capacities. This allows the results to be grouped by design/technology such that broad comparisons can be made.

Diagrams of all the designs can be found in Appendix 1 which shows the layout and rating of each major asset. The diagrams are illustrative and not to scale.

There are a total of eight network designs associated with the 10GW offshore wind capacity. In summary, the designs have the following labels and key design characteristics: -

The Base Case (Radial Design) – Predominantly 1GW links from offshore hubs to onshore.
Design 2a – Predominantly 1GW links from offshore hubs to onshore, with a 2.5GW near-shore link (Scotland to Walpole) crossing transmission boundaries B6, B7, B7a, B8 and B9.
Design 2c – A mix of 1GW and 2GW links from offshore hubs to onshore, with a 2.5GW near-shore link (Scotland to Walpole) crossing transmission boundaries B6, B7, B7a, B8 and B9.
Design 3a - Predominantly 1GW links from offshore hubs to onshore, with a 2.5GW near-shore link (Scotland to Killingholme) crossing transmission boundaries B6, B7 and B7a.
Design 4a – Same as 3a except for some within zone links between offshore hubs.
Design 5a (Optimised) - Predominantly 1GW links from offshore hubs to shore with a 1GW offshore links between zones.
Design 5b – Larger 1.8GW, 2.0GW and 2.2GW links to shore with 1GW offshore inter-zonal links.

The model results for these seven designs were presented to the Working Group in September and led to significant debate on the economic benefits associated with fewer larger capacity links to shore. Concern was expressed that insufficient analysis had been undertaken to give a representative view of the relative merit of such designs. Consequently, an additional design (5b anticipatory) utilising the largest capacity links to shore, was added to the suite of options to help inform the analysis.

Design 5b (Anticipatory) – Similar to 5a (which was a favoured design initially), but with even larger links than design 5b from Hornsea and East Anglia offshore platforms to shore, and larger 1.2GW offshore inter-zonal links.

Importantly, the suite of designs was chosen to collectively cover a range of cable technologies and configurations, since it is not practical to consider every possible design permutation.

There are a further seven designs associated with the larger 17.2GW offshore wind capacity assumption. These can be summarised as: -

The Base Case (Radial Design) – Predominantly 1GW links from offshore hubs to onshore, sufficient to cater for the larger 17.2GW of wind capacity.
Design 10a - Predominantly 1GW links from offshore hubs to onshore, with a 2.5GW near-shore link (Scotland to Killingholme) crossing transmission boundaries B6, B7 and B7a.
Design 10c - 1GW, 1.2GW, 1.8GW and 2GW links from offshore hubs to onshore, with a 2.5GW near-shore link (Scotland to Killingholme) crossing transmission boundaries B6, B7 and B7a.
Design 13a – Same as 10a, but includes some within zone links between some Dogger Bank platforms and Hornsea platforms.
Design 13c – Same as 10c, but includes more within zone links between Dogger Bank platforms.
Design 15a (Optimised) - Predominantly 1GW and 1.8GW links from offshore hubs to shore with a 1GW offshore mesh between zones.
Design 15c (Optimised) – Similar to 15a with 1GW offshore links between zones, but with some larger capacity links from offshore hubs to shore.

Designs 5a, 15a and 15c are labelled as having been Optimised, which means that their designs were reviewed and improved early in the process.

Some of the 10GW wind capacity designs broadly correspond to the 17.2GW capacity designs. This is a useful feature in that they can be grouped together for regret analysis.

3.3 Option Costs

The capital cost estimates for the designs are presented in table 3-1 below and have been calculated using data provided by the

Technology work stream. These estimates are broad engineering figures and do not have any specific allowance for contingencies or professional fees. A sensitivity increasing costs by 20% is considered in Chapter 6.

The portion of the total design cost attributable to the integration elements is reported separately. The cost portion associated with a radial connection design represents the least cost connection and is the radial counterfactual case against which other designs are assessed.

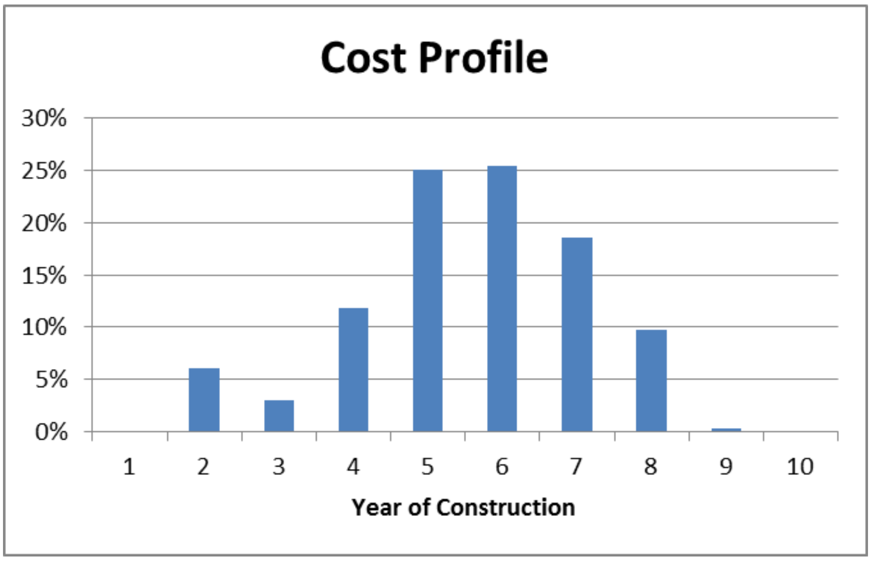
Table 3-1 Capital Cost Forecasts

	IOTP DESIGNS	Radial Cost (£Billion)	Reinforcement Cost (£Billion)	Total Cost (Radial + Reinforcement) (£Billion)
10GW Capacity Designs	Base Case (Radial)	6.33	0.00	6.33
	2a Bootstrap to Walpole and 1GW links	6.33	0.92	7.25
	2c Bootstrap to Walpole and 2GW links	5.54	1.04	6.58
	3a Bootstrap to KILS with 1GW links	6.33	1.10	7.43
	4a Hybrid Bootstrap with 1GW links	6.33	1.05	7.38
	5a Offshore 1GW HVDC (optimised)	6.94	1.40	8.34
	5b Offshore 2GW HVDC (optimised)	5.54	1.26	6.80
	5b (Anticipatory) Offshore 2.2GW	5.44	1.15	6.59
	Base Case (Radial) with onshore reinforcement	6.33	0.87	7.20
17.2GW Capacity Designs	Base Case (Radial)	10.29	0.00	10.29
	10a Onshore Design with 1GW links	10.29	1.43	11.72
	10c Onshore Design with 1GW links	9.64	1.44	11.08
	13a Hybrid offshore and Bootstrap with 1GW links	10.33	1.26	11.59
	13c Hybrid offshore and Bootstrap with 2GW links	9.60	1.05	10.65
	15a Offshore HVDC 1GW (optimised)	10.33	1.81	12.14
	15c Offshore HVDC 2GW (optimised)	10.05	1.53	11.58
	Base Case (Radial) with onshore reinforcement	10.29	0.87	11.16

Source: National Grid

It has not been possible to establish the precise profile of capital cost expenditure for each design at this stage. Therefore, a generic profile has been adopted based on the Western HVDC link project, as shown in diagram 3-2 below. The profile spans a ten year period from 2020/21 to 2030/31 and is thought broadly reflective of large subsea cable projects, in that the majority of the costs fall in the central period of the construction phase.

Table 3-2 Capital Cost Profile



Source: National Grid

The cost of design integration is limited to the additional cost associated with the reinforcement components and does not extend to the underlying radial configuration. Therefore, only the costs associated with integration have been used to calculate the Present Value (PV) of costs for integrated designs. This means we have isolated the additional spend against which any corresponding constraint savings can be compared. The constraint savings are similarly measured relative to the underlying radial configuration.

Appendix 4 shows an alternative method based on minimising the combined investment cost and constraint cost overall, which leads to the same conclusions.

The PV calculation process follows the 'Spackman' methodology which is the accepted approach for large infrastructure projects under regulatory supervision. These cost estimates include the following assumptions:

- A **Weighted Average Cost of Capital or WACC**, which is currently estimated at **4.55% p.a**., and
- A **Social Time Preference Rate or STPR**, which is estimated at **3.5% p.a.** by HM Treasury.

Further details of the Spackman approach and other elements of the CBA are presented in Chapter 5. Chapter 4 outlines the forecast of economic impacts measured in terms of constraint cost savings for designs appraised in this CBA. These forecasts also form part of the CBA presented in Chapter 5.

4 Counterfactual and Economic Impact of Options

4.1 *Introduction*

The **Guidance on the Strategic Wider Works arrangements in the electricity transmission price control, RIIO-T1** states that a reinforcement option is economic when the cost of the project is less than the benefit to consumers.

Within this context, this section outlines the forecasts of constraint costs and lost welfare benefits likely to be incurred by consumers in two counterfactual cases (10GW and 17.2GW total IOTP(E) offshore wind capacity) across the two generation backgrounds (Gone Green and Slow Progress). Furthermore, the chapter also presents the PV of constraint costs and lost benefits for each design considered, and subsequent Net Present Values accounting for PV of integration investment costs.

4.2 *Modelling of Constraint Costs and Welfare benefit*

Constraint costs are incurred when the desired power transfer across a transmission system boundary exceeds the maximum operational capability of that boundary. When this occurs, it is necessary to pay generation behind that boundary to reduce production (constrain their output) and replace this energy with generation located in an unconstrained area of the network to balance the system.

Under current arrangements, constraint payments are made to onshore Generators, but not to offshore generators. ROCs / cfd's are not paid when Generators are not delivering energy. Consequently the consumer will pay less when offshore wind generation is constrained, as the reduced ROC/cfd payments outweigh the cost of bringing on onshore generation. However, established practice in cost benefit assessment of offshore wind is to assume that higher availability brings consumer benefit through its contribution to meeting renewable energy targets, and its potential to offset the need to develop further offshore generation to ensure that targets are met. In the analysis described in this report this benefit is represented by applying constraint costs to offshore generation. The applied constraint cost includes the value of ROCs / cfds that would be paid if the energy was provided.

ELSI is National Grid's in-house model to prepare medium to long term constraint forecasts on the transmission network. The model is our preferred tool to inform long term investment decisions. ELSI studies have previously been used to demonstrate the economic impact of our RIIO Capex Programme spanning 2010-2030. Equally, it performs a similar role for our Network Development Plan (NDP) analysis and production of the Electricity Ten Year Statement (ETYS), one of our key licence obligations.

ELSI is a Microsoft Excel based model which utilises Visual Basic linear programming to perform optimisations. Additionally, unlike most tools, ELSI adopts a transparent modelling approach, where all input assumptions and algorithms are accessible to the user.

ELSI represents the GB electricity market, in which the energy market is assumed to be perfectly competitive; i.e. there is perfect information for all parties, sufficient competition so that suppliers contract with the cheapest generation first, and that there are no barriers to entry and exit.

The electricity transmission system is represented in ELSI by a series of zones separated by boundaries. The total level of generation and demand is modelled such that each zone contains specific generation capacity by fuel type (CCGT, Coal, Nuclear etc.) and a percentage of overall demand.

Zonal interconnectivity is defined in ELSI to reflect existing and future boundary capabilities. The boundaries, which represent the transmission circuits facilitating this connectivity, have a maximum capability that restricts the amount of power which can be securely transferred across them.

ELSI models the electricity market in two main steps:

- The first step looks at the short run marginal cost (SRMC[3]) of each fuel type and dispatches available generation from the cheapest through to the most expensive, until the total level of GB demand is met. This is referred to as the 'unconstrained dispatch'. The network is assumed to have infinite capacity and so does not impinge on the unconstrained dispatch.
- The second step takes the unconstrained dispatch of generation and looks at the resulting power transfers across the boundaries. ELSI compares the power transfers with the actual boundary capabilities and re-dispatches generation where necessary to relieve any instances where power transfer exceeds capability (i.e. a constraint has occurred). This re-dispatch is referred to as the 'constrained dispatch' of generation.

The algorithm within ELSI will relieve the constraints in the most economic and cost effective way by using the SRMC of each fuel type. The cost associated with moving away from the most economic dispatch of generation (unconstrained dispatch), to one which ensures the transmission network remains within its limits (constrained dispatch) is known as the operational constraint cost and is calculated using the bid and offer price associated with each action.

Like industry benchmark tools for constraint cost forecasts, ELSI includes various input data including:

- Transmission Network

[3] Note that ELSI models SRMC (£/MWh) = Production (£/MWh) + Carbon emissions (£/MWh) + zonal adjuster (£/MWh)

- Boundary capability assumptions
- Seasonal ratings
- Annual outage plan for each boundary

- Economic Assumptions
  - Fuel costs and price of carbon forecasts
  - Thermal efficiency assumptions by fuel type
  - Bid and Offer price assumptions by fuel type based on historical data
  - Seasonal plant availability by fuel type based on historical data
  - Renewable subsidies
  - Forecasts for base load energy price in Europe and Ireland
  - Forecast SRMCs by fuel type, which defines the merit order
  - Zonal SRMC adjuster
- Generation scenarios and sensitivities
- Demand
  - Demand profile or load duration curve
  - Zonal distribution of peak demand
  - Forecast annual peak demand based on two energy scenarios
- Wind generation
  - Represented by sampling ten years of historical daily wind speed data. Each day studied is defined by season and is divided up into four periods within the day.
  - ELSI model disaggregates the wind data into fifteen zones, with Dogger Bank, Hornsea and East Anglia separately represented. This allows for temporal and locational wind diversity in ELSI
- Reinforcements
  - Onshore reinforcements anticipated in ETYS for both generation backgrounds that are delivered by 2030/31.
  - The offshore integrated capability across each boundary provided by each design from 2030/31.

4.3 Forecasts of Constraint Costs: Counterfactual

Best practice when undertaking ex-ante economic appraisals requires a clear definition of the counterfactual for comparison purposes. In particular, the counterfactual involves an assumption about the future state of the network in the absence of other proposals.

For the purpose of this CBA, the counterfactual network state is:

- Radial HVDC links from offshore hubs to onshore connection points utilising 1GW cable technology for the Dogger Bank and Hornsea zones. East Anglia zone utilises a range of cable technologies and includes some within zone links. This offers some redundancy within the zone.
- Limited onshore reinforcements necessary to ensure NETS SQSS compliance. This is based on the wider GB network investment projections identified in the ETYS 2013 out until 2030, and reflects each generation background.

The remainder of this section presents forecasts of constraint costs across the two generation backgrounds and offshore designs. These are compared to the corresponding counterfactual case to establish annual constraint savings.

It is worth noting that all forecasts are modelled and reported for the entire GB network. Furthermore, the forecasts are focussed on 2030/31 since this is considered the earliest date by which the completed system is considered feasible. This year is then adopted over the rest of the asset life.

Table 4-1 presents annual constraint cost forecasts for the counterfactual case and related designs, for the wind capacity scenario totalling 10GW, spread across the three zones.

Table 4-1: Constraint Cost Forecasts for the 10GW Wind Capacity Scenario

10GW IOTP(E) Offshore Wind Capacity Designs	Gone Green Average Annual Constraint Costs (in £m)	Slow Progression Average Annual Constraint Costs (in £m)
Base Case (Radial Design)	952	730
Design 2a	328	260
Design 2c	408	208
Design 3a	441	423
Design 4a	386	300
Design 5a (Optimised)	293	273
Design 5b (Optimised)	407	217
Design 5b (Anticipatory)	371	194
Base Case plus onshore reinforcement	488	362

Source: National Grid

A corresponding table of annual constraint cost forecasts based on the larger 17.2GW wind capacity assumption is shown in Table 4-2 below.

Table 4-2: Constraint Cost Forecasts for 17.2GW Wind Capacity Scenario

17.2GW IOTP(E) Offshore Wind Capacity Designs	Gone Green Average Annual Constraint Costs (in £m)	Slow Progression Average Annual Constraint Costs (in £m)
Base Case (Radial Design)	1,091	1,000
Design 10a	923	634
Design 10c	434	345
Design 13a	425	587
Design 13c	386	451
Design 15a (Optimised)	306	307
Design 15c (Optimised)	336	289
Base Case plus onshore reinforcement	606	494

Source: National Grid

It can be seen that for the radial connection designs the annual constraint costs tend to be larger where greater offshore wind capacity is developed.

4.4 Economic Impact

This section presents the forecast of economic impact for the designs appraised in this CBA across both generation backgrounds.

The economic impact is defined as the constraint cost savings as described in Chapter 1 relative to the counterfactual case (radial links to shore), versus the additional cost of integration.

The annual value for constraint savings in 2030/31 for each study is assumed across the entire 40 year asset life and depreciated at the Social time Preference Rate (STPR) of 3.5%.

Constraint savings that may occur as a result of a partial network during the construction phase are ignored, as it is not possible to appraise the wide range of permutations. In this sense the savings could be regarded as pessimistic since some additional savings through a partially built network could offer additional benefit during construction.

Relative to the counterfactual case, each of the related designs offers an annual constraint cost saving. These annual savings are shown below in table 4-3 for the 10GW offshore wind capacity study.

Table 4-3: Central 2030 Constraint Savings

10GW IOTP(E) Offshore Wind Capacity Designs	Gone Green Annual Constraint savings against Base Case (£m)	Slow Progression Annual Constraint savings against Base Case (£m)
Design 2a	624	471
Design 2c	544	522
Design 3a	511	307
Design 4a	566	430
Design 5a (Optimised)	659	458
Design 5b (Optimised)	545	513
Design 5b (Anticipatory)	581	537
Base Case plus onshore reinforcement	464	369

Source: National Grid

Similarly, the annual constraint savings offered by the larger 17.2GW offshore wind capacity studies are shown in table 4-4 below. In some cases, as the scale of design integration increases, the savings in constraint costs relative to the counterfactual case increase.

Table 4-4: TEC 2030 Constraint Savings

17.2GW IOTP(E) Offshore Wind Capacity Designs	Gone Green Annual Constraint Cost Savings against Counterfactual (£m)	Slow Progression Annual Constraint Cost Savings against Counterfactual (£m)
Design 10a	168	366
Design 10c	657	655
Design 13a	667	413
Design 13c	705	550
Design 15a (Optimised)	786	694
Design 15c (Optimised)	756	711
Base Case plus onshore reinforcement	485	507

Source: National Grid

5 Cost Benefit Assessment

5.1 Introduction

At its simplest level, the assessment compares the PV of integration costs with the PV of forecast constraint cost savings. Where the constraint cost savings exceed the integration investment cost, then the investment is considered economic. In order to help develop robust conclusions a range of generation backgrounds, designs and sensitivities have been considered.

This chapter brings together the analysis presented earlier of investment costs and constraint savings to establish an overall Net Present Value (NPV) for each of the different designs. Further details of the methodology along with relevant assumptions used to perform different elements of CBA are presented later in this chapter.

All future values are discounted on an annual basis to account for the time-value of money. The discounting method follows the 'Spackman' methodology, widely recognised and endorsed by utility Regulatory bodies.

The design NPVs are used to perform Regret analysis, and subsequently to determine the most economic option based on a Least Worst Regret (LWR) approach.

5.2 Net Present Value of the Design Options

In order satisfy the Spackman methodology, the future costs associated with integrated design components and constraints savings both have to be represented by a PV. To achieve this for the investment costs, two steps are undertaken: -

- The annual investment costs across the construction phase are 'mortgaged' at a post-tax WACC of 4.5% over the asset life.
- Future payments on investments are discounted at HM Treasury's STPR of 3.5%

Similarly, the PV figures for corresponding constraint cost savings are discounted: -

- This is achieved with the same STPR discount rate of 3.5%. The base year for this is 2014 and the construction runs from 2020/21 to 2030/31, hence the savings do not commence until 2030/31 on completion of the build, and then run for 40 years.

Table 5-1 below presents a matrix summary of the constraint saving PVs and additional integration cost PVs for each design. The table distinguishes the results by Gone Green and Slow Progression backgrounds.

In order to make a comparison between the designs, the investment PV is deducted from the constraint savings PV to give a relative Net Present Value (NPV) for each design. This provides a comparative measure of the value of the scheme with both costs and benefits accounted for.

Table 5-1:PVs and NPVs of the options considered (in £m)

		Gone Green			Slow Progression		
	Design	PV of constraint savings	PV of additional cost of Integration	NPV: Constraints minus Additional costs	PV of constraint savings	PV of additional cost of Integration	NPV: Constraints minus Additional costs
10GW Offshore Wind Capacity	Design 2a	£7,685	£778	£6,907	£5,799	£778	£5,020
	Design 2c	£6,705	£876	£5,829	£6,434	£876	£5,558
	Design 3a	£6,290	£926	£5,363	£3,785	£926	£2,859
	Design 4a	£6,977	£1,043	£5,933	£5,302	£1,043	£4,258
	Design 5a (Optimised)	£8,111	£1,179	£6,932	£5,638	£1,179	£4,459
	Design 5b (Optimised)	£6,716	£1,061	£5,655	£6,323	£1,061	£5,261
	Base Case plus onshore reinforcement	£5,721	£736	£4,985	£4,543	£736	£3,807
	Design 5b (Anticipatory)	£7,159	£968	£6,190	£6,607	£968	£5,639
17.2GW Offshore Wind Capacity	Design 10a	£2,066	£1,204	£861	£4,508	£1,204	£3,303
	Design 10c	£8,095	£1,213	£6,882	£8,067	£1,213	£6,854
	Design 13a	£8,208	£1,061	£7,147	£5,086	£1,061	£4,025
	Design 13c	£8,681	£884	£7,797	£6,772	£884	£5,888
	Design 15a (Optimised)	£9,675	£1,524	£8,150	£8,545	£1,524	£7,021
	Design 15c (Optimised)	£9,305	£1,288	£8,017	£8,758	£1,288	£7,469
	Base Case plus onshore reinforcement	£5,976	£736	£5,239	£6,239	£736	£5,503

Source: National Grid

The analysis confirms that relative to the counterfactual radial link designs, all design alternatives have a positive economic case. This is evident in the positive NPVs which are driven by having greater constraint savings then integration investment costs.

However, values of the designs differ considerably depending on the scale of offshore wind capacity assumption and the generation background. The largest NPVs are attributable to designs for the largest 17.2GW offshore wind capacity coupled with the Gone Green generation background.

Summarising the NPVs for each design gives the table 5-2 below:-

Table 5-2: NPVs Summary

NPVs of each Design £m	Gone Green		Slow Progression	
	10GW	17.2GW	10GW	17.2GW
Base Case plus onshore reinforcement	4,985	-	3,807	-
Design 2a	6,907	-	5,020	-
Design 2c	5,829	-	5,558	-
Design 3a	5,363	-	2,859	-
Design 4a	5,933	-	4,258	-
Design 5a (Optimised)	6,932	-	4,459	-
Design 5b (Optimised)	5,655	-	5,261	-
Design 5b (Anticipatory)	6,190	-	5,639	-
Base Case plus onshore reinforcement	-	5,239	-	5,503
Design 10a	-	861	-	3,303
Design 10c	-	6,882	-	6,854
Design 13a	-	7,147	-	4,025
Design 13c	-	7,797	-	5,888
Design 15a (Optimised)	-	8,150	-	7,021
Design 15c (Optimised)	-	8,017	-	7,469
Max	*6,932*	*8,150*	*5,639*	*7,469*

Given that the analysis must be robust against the uncertainty of generation background and eventual wind capacity, Regret analysis is now considered as it is the acknowledged assessment mechanism for uncertainty of this type.

5.3 Regret Analysis

Regret analysis is designed to identify solutions from a range of possibilities which are least likely to be wrong. It is not designed to pick options that may offer the largest benefit, although this could occur coincidentally. This provides a more robust decision against the range of uncertainties, and minimises the chance of an adverse result impacting consumers.

In this analysis, the regret is defined as the difference in the NPV between 'the option being considered' and 'the best possible option for that scenario', i.e. all options are considered against the option which provides the maximum NPV (taking into account the investment and operational costs). It follows that the best alternative has zero regret against which all other options are compared.

This analysis is repeated for all scenarios and importantly, different options could be identified as the zero regret (best) alternative in different scenarios. The resulting regret measures are shown in table 5-3 below: -

Table 5-3: Regret Summary

Regrets	Gone Green		Slow Progression		
	10GW Offshore Capacity (£m)	17.2GW Offshore Capacity (£m)	10GW Offshore Capacity (£m)	17.2GW Offshore Capacity (£m)	Worst Regret (£m)
Base Case plus onshore reinforcement	1,947	-	1,833	-	1,947
Design 2a	25	-	619	-	619
Design 2c	1,102	-	81	-	1,102
Design 3a	1,568	-	2,780	-	2,780
Design 4a	999	-	1,381	-	1,381
Design 5a (Optimised)	0	-	1,180	-	1,180
Design 5b (Optimised)	1,276	-	378	-	1,276
Design 5b (Anticipatory)	741	-	0	-	741
Base Case plus onshore reinforcement	-	2,911	-	1,966	2,911
Design 10a	-	7,289	-	4,166	7,289
Design 10c	-	1,268	-	615	1,268
Design 13a	-	1,003	-	3,444	3,444
Design 13c	-	353	-	1,581	1,581
Design 15a (Optimised)	-	0	-	448	448
Design 15c (Optimised)	-	134	-	0	134

The integrated design 15c is the least worst regret option overall with £134m of regret.

Grouping the NPVs presented in Table 5-2 into comparable design technologies, wind capacities and generation background provides the basis for regret analysis. The grouping of the designs follows this approach:

- Whilst seeking to retain the major design philosophy (offshore integration, near-shore bootstrap, radial etc.), grouping by cable technology/size.

Therefore, where some 2/2.2GW cables are included in a design this may be grouped with other related designs that also part utilise this technology. The groupings are shown in table 5-4 below: -

Table 5-4: Grouping Summary

Grouping by Design, Technology and by Scenarios:	Designs	
	10GW Offshore Capacity	17.2GW Offshore Capacity
Base Case plus onshore	Base Case plus onshore	Base Case plus onshore
Bootstrap 1 GW	2a and 3a	10a
Hybrid bootstrap 2 GW	2c	10c
Hybrid offshore 1 GW	4a	13a
Hybrid offshore 2 GW	none	13c
Integrated 1 GW	5a (Optimised)	15a (Optimised)
Integrated 2 GW	5b (Opt.) and 5b (Ant.)	15c (Optimised)

Based on these groupings, the condensed NPV table 5-5 is shown below.

Table 5-5: Grouping NPVs

NPVs of Designs (grouped by Technology) £m	Gone Green		Slow Progression	
	10GW Offshore Capacity (£m)	17.2GW Offshore Capacity (£m)	10GW Offshore Capacity (£m)	17.2GW Offshore Capacity (£m)
Base Case plus onshore	4,985	5,239	3,807	5,503
Bootstrap 1 GW	6,907	861	5,020	3,303
Hybrid bootstrap 2 GW	5,829	6,882	5,558	6,854
Hybrid offshore 1 GW	5,933	7,147	4,258	4,025
Hybrid offshore 2 GW	NA	7,797	NA	5,888
Integrated 1 GW	6,932	8,150	4,459	7,021
Integrated 2 GW	6,190	8,017	5,639	7,469
Max £m	*6,932*	*8,150*	*5,639*	*7,469*

Source: National Grid

For each of the four study combinations the design with the greatest NPV is shaded. In the absence of any uncertainty of outcome, these designs and technologies would offer greatest value.

In all studies, an economic advantage exists relative to the equivalent radial design, demonstrated by the positive NPVs. There is no model result in which a counterfactual radial link design offers an economic benefit relative to the other designs. This will not necessarily hold true for offshore wind capacities below the modelled 10GW level.

Least Worst Regret

The Least Worst Regret (LWR) methodology requires that design preference is based on the option that is least likely to result in an adverse outcome overall. The underlying philosophy is that it is advantageous to pick the solution that has the least chance of being wrong across the range of eventualities, given the uncertainties in forecasts and other assumptions. This approach ensures that unfavourable combinations are avoided. It assumes that all eventualities are seen as credible outcomes at the investment decision.

The measure of regret for each combination of design and scenario is defined as the difference in NPVs between the design in question and the best possible alternative in that scenario. This is derived by taking the difference between the best (largest) NPV in each column and the NPV for each related design. Comparable designs and technologies have been grouped together by row such that the worst regret for each design/technology can be established.

The Worst Regret column is the highest regret value across the four conditions. The resulting regret values are shown in Grouped Regrets table 5-6 below: -

Table 5-6: Grouped Regret Analysis

Design & Technology by Scenarios: Regrets in (£m)	Gone Green		Slow Progression		
	10GW	17.2GW	10GW	17.2GW	Worst Regret
Base Case plus onshore	1947	2911	1833	1966	2911
Bootstrap 1 GW	25	7289	619	4166	7289
Hybrid bootstrap 2 GW	1102	1268	81	615	1268
Hybrid offshore 1 GW	999	1003	1381	3444	3444
Hybrid offshore 2 GW	N/A	353	N/A	1581	1581
Integrated 1 GW	**0**	**0**	1180	448	1180
Integrated 2 GW	741	134	0	0	741

Source: National Grid

This analysis forecasts the regret associated with a design approach for the range of eventualities. The analysis indicates that the Least Worst Regret overall, is an integrated design based on larger 2GW and/or 2.2GW links. This is identified by the lowest value in the Worst Regrets column (£741m worth of regret). This result is driven by design 15c and design 5b anticipatory both of which entail significant offshore integration with some large capacity HVDC links to shore.

However, whilst integration offers economic value with the assumed total wind capacities of 10GW or more, smaller developments may not necessarily have the economies of scale to sustain this result. Similarly, if the spread of wind capacity between the three zones was materially different, or if one zone did not develop, then this would influence this result.

Designs based on 1GW links to shore and a 2.5GW bootstrap from Scotland to England (3a, 10a and 13a) perform poorly with higher levels of regret. There are two reasons for this:

- There is no sharing of transmission assets between the three zones
- The designs offer less network reinforcement across some transmission boundaries.

However, the results are sensitive to both wind capacity and generation background assumptions.

5.4 Conclusions

The analysis presented in this Chapter illustrates that across our range of studies, economic value is offered by all designs relative to the counterfactual designs based on radial links to shore.

Based on this analysis, a design approach with offshore integration and inter-zonal offshore links (designs 5a, 5b anticipatory, 15a and 15c) offers greatest economic value and also reduces the levels of regret.

The LWR analysis identifies offshore integration with some larger capacity links (designs 5b anticipatory and 15c) as the preferred design approach overall, accounting for the wind capacity and generation background uncertainty.

Whilst one of the favoured designs (15c) has a 2GW link between Hornsea platform 3 to Walpole substation, there may be an opportunity to refine this (and other) designs and reduce the number of links to shore. This proved attractive with the '5b anticipatory' design.

If the assumptions on IOTP(E) wind capacities, or the spread between the three zones was to differ significantly, then the case for integration could be weakened. We cannot deduce from this study work the precise tipping point for this, but it must lie below the 10GW level captured in these studies. Since the 10GW and 17.2GW capacity assumptions are both considered credible at this stage, this forms a reasonable vision for investment decisions.

Equally, if the wind capacity assumptions increased above the 17.2GW assumption, then it would, in all likelihood, strengthen the case for integration due to economies of scale.

Under the Slow Progression generation background the designs identified by the LWR (5b anticipatory and 15c) are also the best design options with the highest NPVs.

NOTE: Since completion of this work-stream report the assumptions around credible connection dates and volumes of offshore wind generation have changed in response to current market conditions. As stated in the original conclusions if the spread of generation between the three zones considered was to vary then the case for integration could be weakened. Latest market intelligence suggests that the build-up of offshore wind generation is likely to be slower than previously forecast and has potential to deliver volumes below the 10GW lower limit assessed in this analysis. Therefore the conclusions stated in this work-stream report are no longer considered valid. The current view on the least worst regret assessment of integrated designs is given in the main project summary report. While the analysis presented here was correct at the time of assessment, all conclusions are now superseded.

6 Sensitivity Analysis

6.1 Introduction

The focus of this chapter is to present sensitivity analysis to confirm the robustness of the conclusions of Chapter 5. The sensitivities assessed in this chapter are:

- The impact of delays from the earliest service delivery date of 2030/31 for all designs (as requested by the Work Group).
- The impact of a 20% increase in capital costs.

6.2 *Impact of Delays*

This section presents the NPVs of the designs for both generation backgrounds and wind capacity assumptions where delays of up to 9 years occur. This reflects a situation where both constraint savings and investment costs are delayed and discounted into the future No investment costs or constraint savings accrue during the delay period. Discounting follows the same methods and assumptions as detailed in section 5.2, but extends the timeframe to retain the same 40 year asset life.

This test is looking at whether delaying investment would be economically justified i.e. if the savings in investment costs realised in early years exceed the constraint savings foregone.

The results are presented in Tables 6-1 (17.2GW designs) and 6-2 (10GW designs) below. The shaded years identify the year with the greatest NPV hence are the most cost effective timing.

Table 6-1: NPV of options from earliest delivery date and delays of up to 9 years

Net Present Values (£m)	17.2GW Wind Capacity and Gone Green NPVs Offshore network and wind capacity is built to commission for: -									
Design	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/5**	**2035/6**	**2036/7**	**2037/8**	**2039/40**	**2040/41**
Design 10a	861	936	908	878	848	819	792	765	739	714
Design 10c	6,882	6,754	6,529	6,309	6,095	5,889	5,690	5,498	5,312	5,132
Design 13a	7,147	6,997	6,764	6,535	6,314	6,101	5,895	5,695	5,503	5,317
Design 13c	7,797	7,610	7,355	7,106	6,866	6,634	6,410	6,193	5,983	5,781
Design 15a (Optimised)	8,150	8,006	7,740	7,479	7,226	6,982	6,746	6,517	6,297	6,084
Design 15c (Optimised)	8,017	7,857	7,595	7,339	7,090	6,851	6,619	6,395	6,179	5,970
Base Case Design plus onshore	5,239	5,126	4,955	4,787	4,625	4,469	4,318	4,172	4,031	3,895

Net Present Values (£m)	17.2GW Wind Capacity and Slow Progress NPVs Offshore network and wind capacity is built to commission for: -									
Design	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/5**	**2035/6**	**2036/7**	**2037/8**	**2039/40**	**2040/41**
Design 10a	3,303	3,296	3,188	3,080	2,976	2,876	2,778	2,684	2,594	2,506
Design 10c	6,854	6,727	6,503	6,284	6,071	5,866	5,668	5,476	5,291	5,112
Design 13a	4,025	3,981	3,849	3,720	3,594	3,472	3,355	3,241	3,132	3,026
Design 13c	5,888	5,765	5,573	5,385	5,203	5,027	4,857	4,692	4,534	4,380
Design 15a (Optimised)	7,021	6,915	6,686	6,460	6,242	6,031	5,827	5,630	5,439	5,255
Design 15c (Optimised)	7,469	7,328	7,084	6,845	6,613	6,390	6,174	5,965	5,763	5,568
Base Case Design plus onshore	5,503	5,380	5,201	5,025	4,855	4,691	4,532	4,379	4,231	4,088

Source: National Grid

Table 6-2: NPV of options from earliest delivery date and delays of up to 9 years

Net Present Values (£m)	10GW Offshore Wind Capacity and Gone Green NPVs Offshore network and wind capacity is built to commission for: -									
Design	2030/31	2031/32	2032/33	2033/34	2034/5	2035/6	2036/7	2037/8	2039/40	2040/41
Design 2a	6907	6740	6515	6295	6082	5876	5677	5485	5300	5121
Design 2c	5829	5708	5517	5165	5151	4977	4808	4646	4489	4337
Design 3a	5363	5262	5087	4915	4749	4588	4433	4283	4138	3998
Design 4a	5933	5803	5604	5410	5221	5039	4864	4694	4530	4371
Design 5a (Optimised)	6932	6799	6573	6351	6136	5929	5728	5534	5347	5166
Design 5b (Optimised)	5655	5556	5371	5190	5014	4845	4681	4522	4370	4222
Base Case Design plus onshore	4985	4880	4717	4557	4403	4254	4111	3972	3837	3708
Design 5b (Anticipatory)	6190	6065	5863	5665	5473	5288	5109	4936	4769	4608

Net Present Values (£m)	10GW Offshore Wind Capacity and Slow Progress NPVs Offshore network and wind capacity is built to commission for: -									
Design	2030/31	2031/32	2032/33	2033/34	2034/5	2035/6	2036/7	2037/8	2039/40	2040/41
Option 2a	5020	4918	4754	4593	4438	4288	4143	4003	3867	3737
Option 2c	5558	5445	5264	4920	4914	4748	4587	4432	4282	4138
Option 3a	2859	2842	2749	2656	2567	2480	2396	2315	2237	2161
Option 4a	4258	4185	4041	3899	3762	3629	3501	3377	3258	3142
Option 5a (Optimised)	4459	4410	4265	4121	3982	3847	3717	3591	3470	3352
Option 5b (Optimised)	5261	5175	5003	4834	4671	4513	4360	4213	4071	3933
Base Case Design plus onshore	3807	3741	3617	3495	3377	3263	3152	3046	2943	2843
Design 5b (Anticipatory)	5639	5532	5348	5167	4992	4824	4661	4503	4351	4204

Source: National Grid

The NPVs for all except one case (Design 10a, Gone Green, 17.2GW wind capacity) are greatest with no delay in investment.

The designs identified in Chapter 5 by the Least Worst Regret analysis (5b anticipatory and 15c) do not benefit from a delay.

The analysis confirms that, in general, optimal timing for investment occurs when wind capacity and transmission capacity are matched, and delays in investment are not justified by the value realised through discounting investment into future years.

6.3 The impact of Investment Cost increases

This sensitivity examines the effect of a 20% increase in the investment costs. The previous analysis is repeated with higher investment cost profiles.

This reflects the chance that investment cost forecasts used in Chapter 5 increase with future market movements. The possibility that investment costs could reduce has not been considered, although such an eventuality would in all likelihood, strengthen the case for investment.

Consequently, a sensitivity based on a 20% increase across the designs has been considered. Whilst the increase is attributable to all design components, it is only the costs associated with integration components that are captured for comparison. This treatment of investment costs is identical to analysis in Chapter 5, and hence offers a like-for-like comparison.

The annual constraint cost savings and their corresponding PV do not change from the Chapter 5 analysis. Only the PV of investment cost is affected. Updating the NPV tables by design and scenario gives the results in table 6-3 below: -

Table 6-3 Net Present Values by Design with 20% Investment Increase

	CAPEX 120%	Gone Green			Slow Progression		
	Design	PV of constraint savings (£m)	PV of additional cost of Integration (£m)	NPV: Constraints minus Additional costs (£m)	PV of constraint savings (£m)	PV of additional cost of Integration (£m)	NPV: Constraints minus Additional costs (£m)
10GW Offshore Wind Capacity	Design 2a	£7,685	£934	£6,751	£5,799	£934	£4,865
	Design 2c	£6,705	£1,051	£5,654	£6,434	£1,051	£5,383
	Design 3a	£6,290	£1,112	£5,178	£3,785	£1,112	£2,674
	Design 4a	£6,977	£1,061	£5,915	£5,302	£1,061	£4,241
	Design 5a (Optimised)	£8,111	£1,415	£6,696	£5,638	£1,415	£4,224
	Design 5b (Optimised)	£6,716	£1,273	£5,443	£6,323	£1,273	£5,049
	Base Case plus onshore	£5,721	£883	£4,837	£4,543	£883	£3,659
	Design 5b (Anticipatory)	£7,159	£1,162	£5,997	£6,607	£1,162	£5,445
17.2GW Offshore Wind Capacity	Design 10a	£2,066	£1,674	£391	£4,508	£1,674	£2,833
	Design 10c	£8,095	£1,455	£6,639	£8,067	£1,455	£6,612
	Design 13a	£8,208	£1,273	£6,935	£5,086	£1,273	£3,813
	Design 13c	£8,681	£1,061	£7,620	£6,772	£1,061	£5,711
	Design 15a (Optimised)	£9,675	£1,829	£7,845	£8,545	£1,829	£6,716
	Design 15c (Optimised)	£9,305	£1,546	£7,759	£8,758	£1,546	£7,211
	Base Case plus onshore	£5,976	£883	£5,092	£6,239	£883	£5,356

The NPVs of each design has reduced due to the increase in investment cost.

Repeating the NPV and Regrets analysis of Chapter 5 using data from table 6-3 above provides a comparable view with the 20% cost increase. This is shown in table 6-4 and 6-5 below.

Table 6-4 NPVs Grouped by Design/Technology with 20% investment Cost Increase

NPVs grouped by Design/Technology £m	Gone Green		Slow Progression	
	10GW Offshore Capacity (£m)	17.2GW Offshore Capacity (£m)	10GW Offshore Capacity (£m)	17.2GW Offshore Capacity (£m)
Base Case plus onshore	4,837	5,092	3,659	5,356
Bootstrap 1 GW	6,751	391	4,865	2,833
Hybrid bootstrap 2 GW	5,654	6,639	5,383	6,612
Hybrid offshore 1 GW	5,915	6,935	4,241	3,813
Hybrid offshore 2 GW	NA	7,620	NA	5,711
Integrated 1 GW	6,696	7,845	4,224	6,716
Integrated 2 GW	5,997	7,759	5,445	7,211
Max £m	*6,751*	*7,845*	*5,445*	*7,211*

Table 6-5 Regret Analysis with 20% Investment Cost Increase

Design & Technology by Scenarios: Regrets in (£m)	Gone Green 10GW Offshore Capacity (£m)	Gone Green 17.2GW Offshore Capacity (£m)	Slow Progression 10GW Offshore Capacity (£m)	Slow Progression 17.2GW Offshore Capacity (£m)	Worst Regret (£m)
Base Case plus onshore	1914	2753	1786	1856	2753
Bootstrap 1 GW	0	7454	581	4378	7454
Hybrid bootstrap 2 GW	1097	1206	63	600	1206
Hybrid offshore 1 GW	836	910	1205	3398	3398
Hybrid offshore 2 GW	N/A	225	N/A	1500	1500
Integrated 1 GW	55	0	1222	496	1222
Integrated 2 GW	754	87	0	0	754

Whilst the Regret values have changed the LWR result remains consistent.

This demonstrates that the designs identified by the LWR analysis in Chapter 5 remains the LWR irrespective of the investment cost increase. This implies that the previous results are robust against cost increases up to and including this 20% bound.

6.4 The impact of Cost Increases and Delays

The impact on the NPV for this 20% investment cost increase, coupled with investment delays for each design has also been considered. This follows the same methodology as previously adopted and described in Chapter 5.

Table 6-6 below shows results of this calculation for each study scenario and wind capacity assumption.

Table 6-6 Delay Analysis with 20% Investment Cost Increase

Net Present Values with +20% CAPEX (£m)	17.2GW Wind Capacity and Gone Green NPVs — Offshore network and wind capacity is built to commission for: -									
Design	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/5**	**2035/6**	**2036/7**	**2037/8**	**2039/40**	**2040/41**
Design 10a	391	495	475	451	428	406	385	364	344	325
Design 10c	6,639	6,541	6,324	6,110	5,904	5,704	5,511	5,325	5,145	4,971
Design 13a	6,935	6,810	6,584	6,362	6,147	5,939	5,738	5,544	5,356	5,175
Design 13c	7,620	7,454	7,205	6,962	6,726	6,499	6,279	6,067	5,862	5,663
Design 15a (Optimised)	7,845	7,738	7,482	7,229	6,985	6,749	6,521	6,300	6,087	5,881
Design 15c (Optimised)	7,759	7,630	7,377	7,128	6,887	6,654	6,429	6,211	6,001	5,798
Base Case plus onshore	5,092	4,996	4,830	4,667	4,509	4,357	4,209	4,067	3,929	3,797

Net Present Values with +20% CAPEX (£m)	17.2GW Wind Capacity and Slow Progress NPVs — Offshore network and wind capacity is built to commission for: -									
Design	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/5**	**2035/6**	**2036/7**	**2037/8**	**2039/40**	**2040/41**
Design 10a	2,833	2,854	2,754	2,654	2,556	2,462	2,371	2,283	2,198	2,116
Design 10c	6,612	6,514	6,298	6,085	5,880	5,681	5,489	5,303	5,124	4,950
Design 13a	3,813	3,794	3,670	3,546	3,426	3,310	3,198	3,090	2,986	2,885
Design 13c	5,711	5,609	5,423	5,240	5,063	4,892	4,726	4,566	4,412	4,263
Design 15a (Optimised)	6,716	6,647	6,427	6,211	6,001	5,798	5,602	5,412	5,229	5,052
Design 15c Optimised)	7,211	7,101	6,866	6,634	6,410	6,193	5,983	5,781	5,586	5,397
Base Case plus onshore	5,356	5,251	5,076	4,905	4,739	4,579	4,424	4,274	4,130	3,990

Net Present Values with +20% CAPEX (£m)	10GW Offshore Wind Capacity and Gone Green NPVs Offshore network and wind capacity is built to commission for: -									
Design	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/5**	**2035/6**	**2036/7**	**2037/8**	**2039/40**	**2040/41**
Design 2a	6751	6603	6383	6167	5959	5757	5563	5374	5193	5017
Design 2c	5654	5554	5369	5179	5012	4843	4679	4521	4368	4220
Design 3a	5178	5099	4930	4764	4602	4447	4296	4151	4011	3875
Design 4a	5915	5807	5614	5424	5241	5064	4892	4727	4567	4413
Design 5a (Optimised)	6696	6592	6373	6158	5950	5748	5554	5366	5185	5009
Design 5b (Optimised)	5443	5369	5191	5016	4846	4683	4524	4371	4223	4081
Base Case plus onshore	4837	4750	4592	4437	4287	4142	4002	3867	3736	3610
Design 5b (Anticipatory)	5997	5894	5698	5506	5320	5140	4966	4798	4636	4479

Net Present Values with +20% CAPEX (£m)	10GW Offshore Wind Capacity and Slow Progress NPVs Offshore network and wind capacity is built to commission for: -									
Design	**2030/31**	**2031/32**	**2032/33**	**2033/34**	**2034/5**	**2035/6**	**2036/7**	**2037/8**	**2039/40**	**2040/41**
Option 2a	4865	4781	4622	4466	4315	4169	4028	3892	3760	3633
Option 2c	5383	5291	5115	4935	4776	4614	4458	4307	4162	4021
Option 3a	2674	2679	2592	2505	2420	2338	2259	2183	2109	2038
Option 4a	4241	4189	4050	3914	3781	3654	3530	3411	3295	3184
Option 5a (Optimised)	4224	4203	4065	3928	3795	3667	3543	3423	3307	3195
Option 5b (Optimised)	5049	4988	4824	4661	4503	4351	4204	4062	3924	3792
Base Case plus onshore	3659	3612	3492	3374	3260	3150	3044	2941	2841	2745
Design 5b (Anticipatory)	5445	5362	5184	5009	4839	4676	4518	4365	4217	4075

These results show that design 10a continues to have a higher NPV with a 1 year delay (discounted). Whilst some minor benefits to optimal investment timing are evident with these results compared to the earlier results, the changes occur on less favourable designs and do not extend beyond one year duration.

The overarching conclusion from this analysis is that delaying investment costs for the more favourable designs will not enhance the Net Present Value of the scheme. It follows that the best economic advantage is gained where network investment is managed to deliver transmission capacity in line with the commissioning of the wind generation.

7 Conclusions and Recommendations

NOTE: Since completion of this work-stream report the assumptions around credible connection dates and volumes of offshore wind generation have changed in response to current market conditions. As stated in the original conclusions if the spread of generation between the three zones considered was to vary then the case for integration could be weakened. Latest market intelligence suggests that the build-up of offshore wind generation is likely to be slower than previously forecast and has potential to deliver volumes below the 10GW lower limit assessed in this analysis. Therefore the conclusions stated in this work-stream report are no longer considered valid. The current view on the least worst regret assessment of integrated designs is given in the main project summary report. While the analysis presented here was correct at the time of assessment, all conclusions are now superseded.

7.1 Conclusions

The **Guidance on the Strategic Wider Works arrangements in the electricity transmission price control, RIIO-T1** states that a reinforcement option is economic when the cost of the project is less than the cost consumers would otherwise pay under the counterfactual case.

Given the range of uncertainty presented by various designs, scenarios and sensitivities studied, this CBA has been carried out to illustrate the opportunity to optimise the design of offshore connections to reduce the impact of network constraints borne by the wider community.

The analysis presented in this document demonstrates that integrated designs offer both greater scheme Net Present Values and also represent Least Worst Regret solutions overall. In no circumstance does the Radial connection design offer economic advantage, even when coupled with a £870m onshore reinforcement package. Where IOTP(E) wind capacities of 10GW or more exist these results look stable. Lower wind capacities may not offer the same value.

One key driver for these findings is the value derived in terms of constraint cost mitigation associated with linking the three offshore zones electrically. This enables the sharing of transmission capacity between a much wider set of generation assets. In the analysis undertaken, the offshore constraint costs represent the welfare benefit of obtaining more energy from the wind farms considered, based on established practice that this presents an opportunity to avoid additional renewable generation investment to achieve the same result.

Furthermore, the analysis demonstrates that efficient investment timing is best achieved where transmission capacity becomes available as wind capacity is developed.

The sensitivity analysis with 20% higher investment costs demonstrates that the key findings are robust against this level of cost escalation. Any investment cost savings that may be achievable through market price reductions have been ignored.

7.2 Recommendations

The wider value to consumers in terms of constraint cost savings and welfare benefit over the asset life offered by an integrated network design is significant. None of the modelling studies yield a negative NPV, hence all forms of development (above radial connections) offer savings and economic improvement. The best solutions are wind capacity and generation background sensitive. Accounting for these uncertainties with LWR analysis suggests that integration with inter-zonal links offers the LWR design approach.

The limited number of our studies relative to the huge range of possible combinations and eventualities means that these results can only provide a ***vision*** of where value exists. It is not possible to determine a precise solution due to the near limitless range of variables.

Scope may exist to move from a radial connection design to a more integrated design at a later date. However, this may only be practical if the first development steps make provision for this expansion. Consequently, investment decisions will need to be made early enough if this optionality is to be retained. Given the value attributable to integration where significant wind capacity is developed, it is recommended that this optionality is sought in early developmental steps.

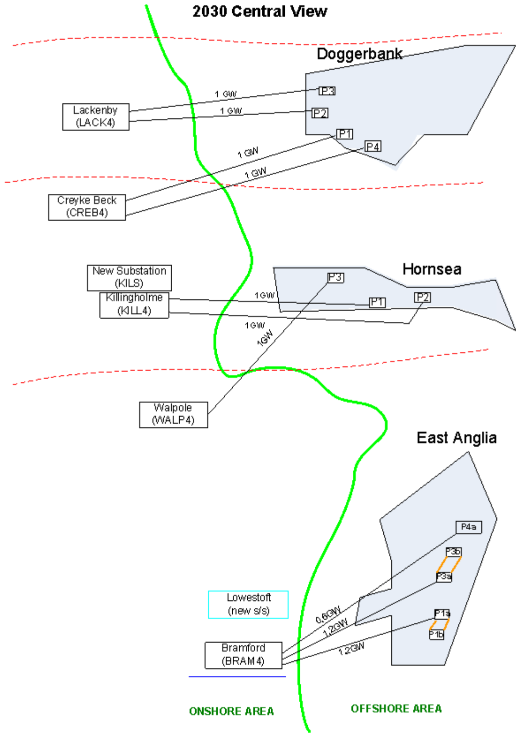
The cost associated with retaining integration optionality is currently unclear. In order to make sound economic judgements this will need costing. Additionally, development of more complex designs could present risk of commissioning delay. If so, it would be appropriate to capture such costs in the analysis.

In order to minimise the chance of stranded assets, investment options should be considered on a step-by-step basis in response to a Needs Case document, following the Strategic Wider Works arrangements detailed in the electricity transmission price control RIIO-T1.

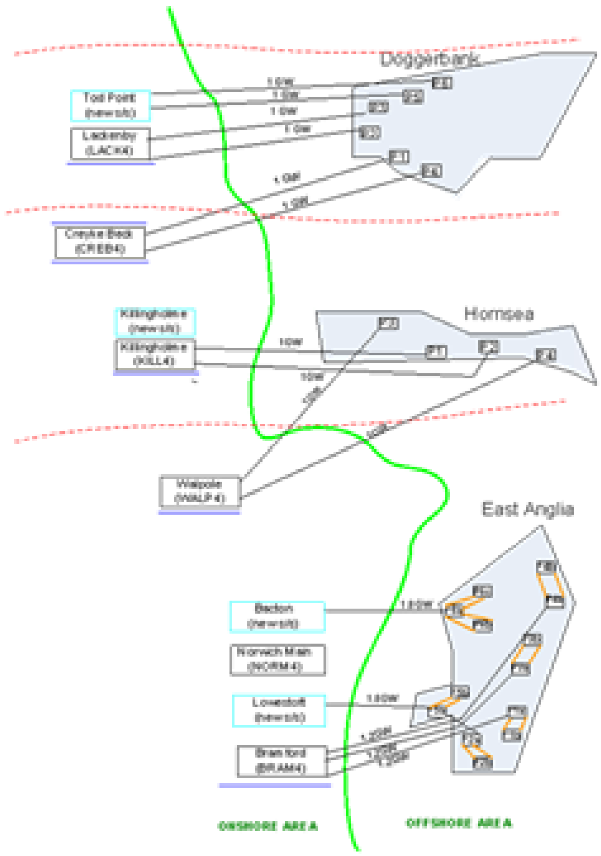
To best ensure value for money for GB consumers, clarity on the likely wind capacity for each of the three zones is a key driver. The wind capacities modelled in this work are sufficient to economically justify a level of integration. Smaller overall wind capacities, or a significantly different spread of the capacity between the three zones would influence the results.

Appendix 1 – Network designs

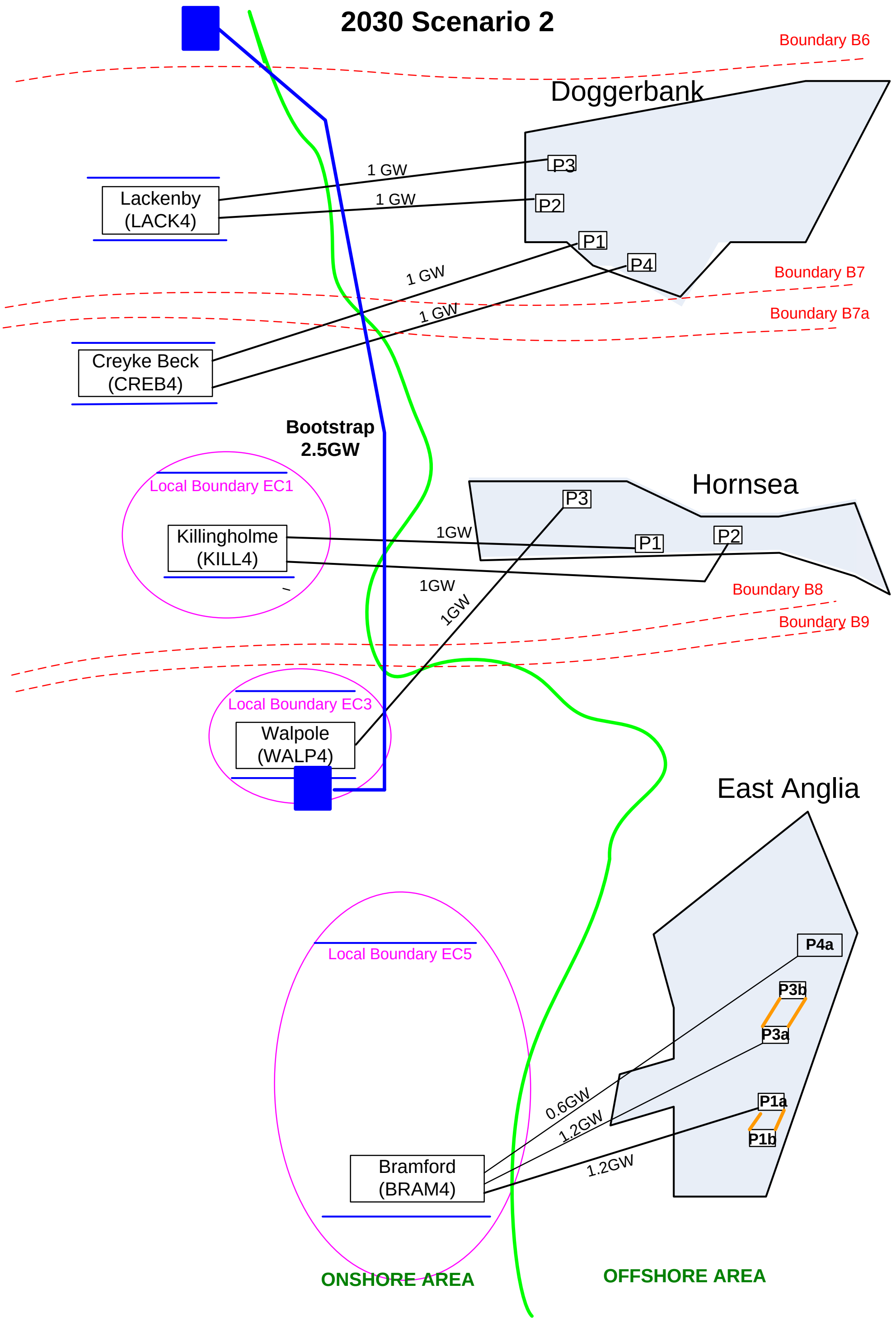
The Base Case Design (Counterfactual) for 10GW Wind Capacities – Radial Links to Shore



The Base Case Design (Counterfactual) for 17.2GW wind capacity – Radial Links to Shore



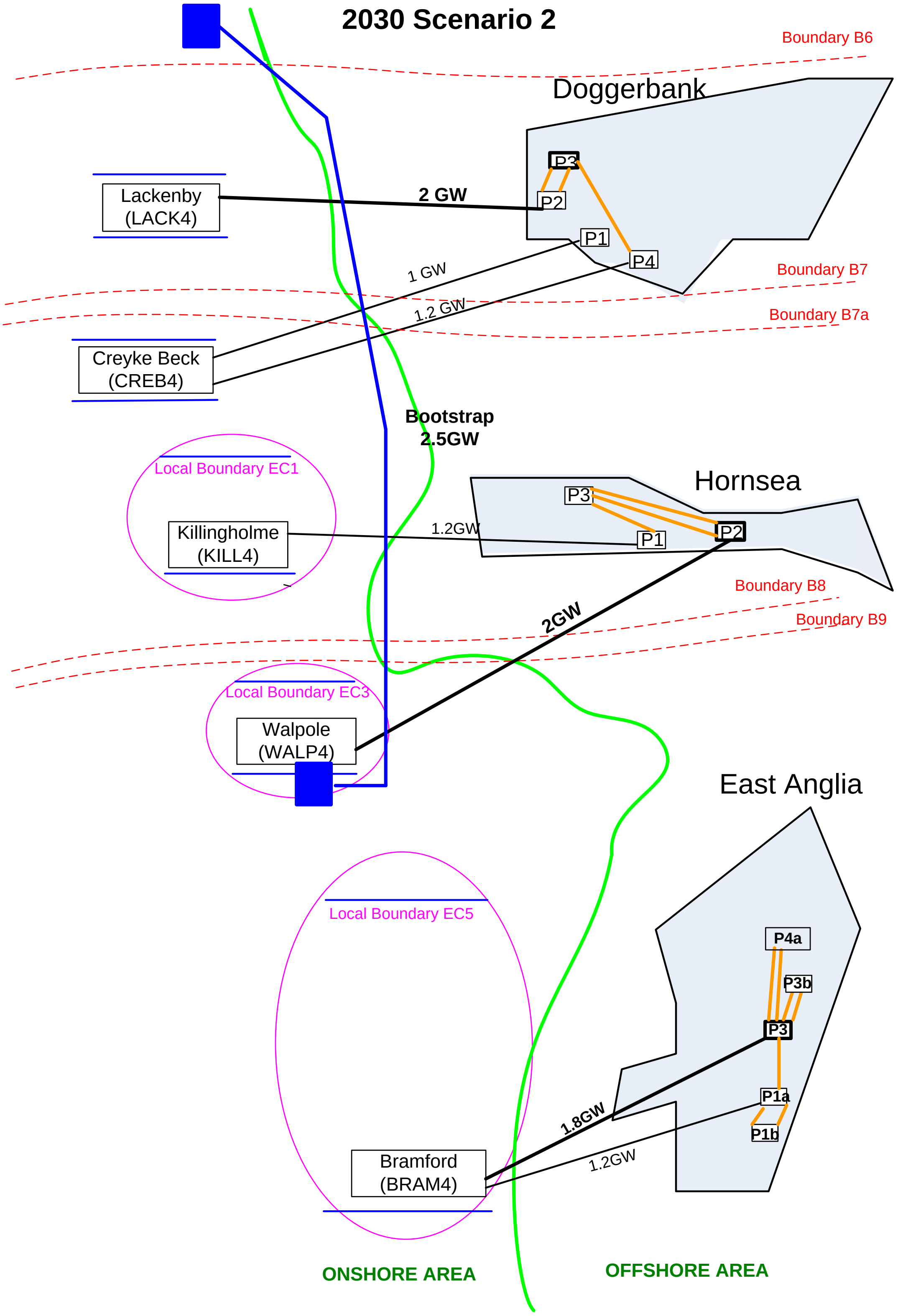
Design 2a - A 2.5GW Bootstrap across B6, B7, B7a, B8 and B9 boundaries and 1GW links to Shore.



Design 2a - Cost Breakdown

	Radial Cost (£m)	Reinforcement / Integration Cost (£m)	TOTAL
Dogger Bank			
HVDC 1GW radial link at a distance of 212.5km between P1 and CREB4 including cable installation cost and 1GW onshore VSC Converter	700.15		
HVDC 1GW radial link at a distance of 261km between P2 and LACK4 including cable installation cost and 1GW onshore VSC Converter	768.10		
HVDC 1GW radial link at a distance of 222.8km between P3 and LACK4 including cable installation cost and 1GW onshore VSC Converter	714.58		
HVDC 1GW radial link at a distance of 215.1km between P4 and CREB4 including cable installation cost and 1GW onshore VSC Converter	703.80		
Hornsea			
HVDC 1GW radial link at a distance of 150km between P1 and KILL4 including cable installation cost and 1GW onshore VSC Converter	612.59		
HVDC 1GW radial link at a distance of 125km between P2 and KILL4 including cable installation cost and 1GW onshore VSC Converter	577.57		
HVDC 1GW radial link at a distance of 125km between P1 and WALP4 including cable installation cost and 1GW onshore VSC Converter	577.57		
East Anglia			
HVDC 1.2GW radial link at a distance of 73km between P1 and BRAM4 including cable installation cost and 1.2GW onshore VSC Converter	559.17		
HVDC 1GW radial link at a distance of 43km between P2(600MW) and BRAM4 including cable installation cost and 1GW onshore VSC Converter	462.68		
HVDC 1.2GW radial link at a distance of 140km between P3 and BRAM4 including cable installation cost and 1.2GW onshore VSC Converter	654.78		
Bootstrap (Intra Grid Link)			
2.5GW HVDC link at a distance of 350km from Scotland to Walpole(EC3) including cable installation cost, two 2.5GW onshore VSC Converters and cost of required reinforcement at point of connection in Scotland and Walpole(EC3)		924.24	
TOTAL	**6330.09**	**924.24**	**7254.23**

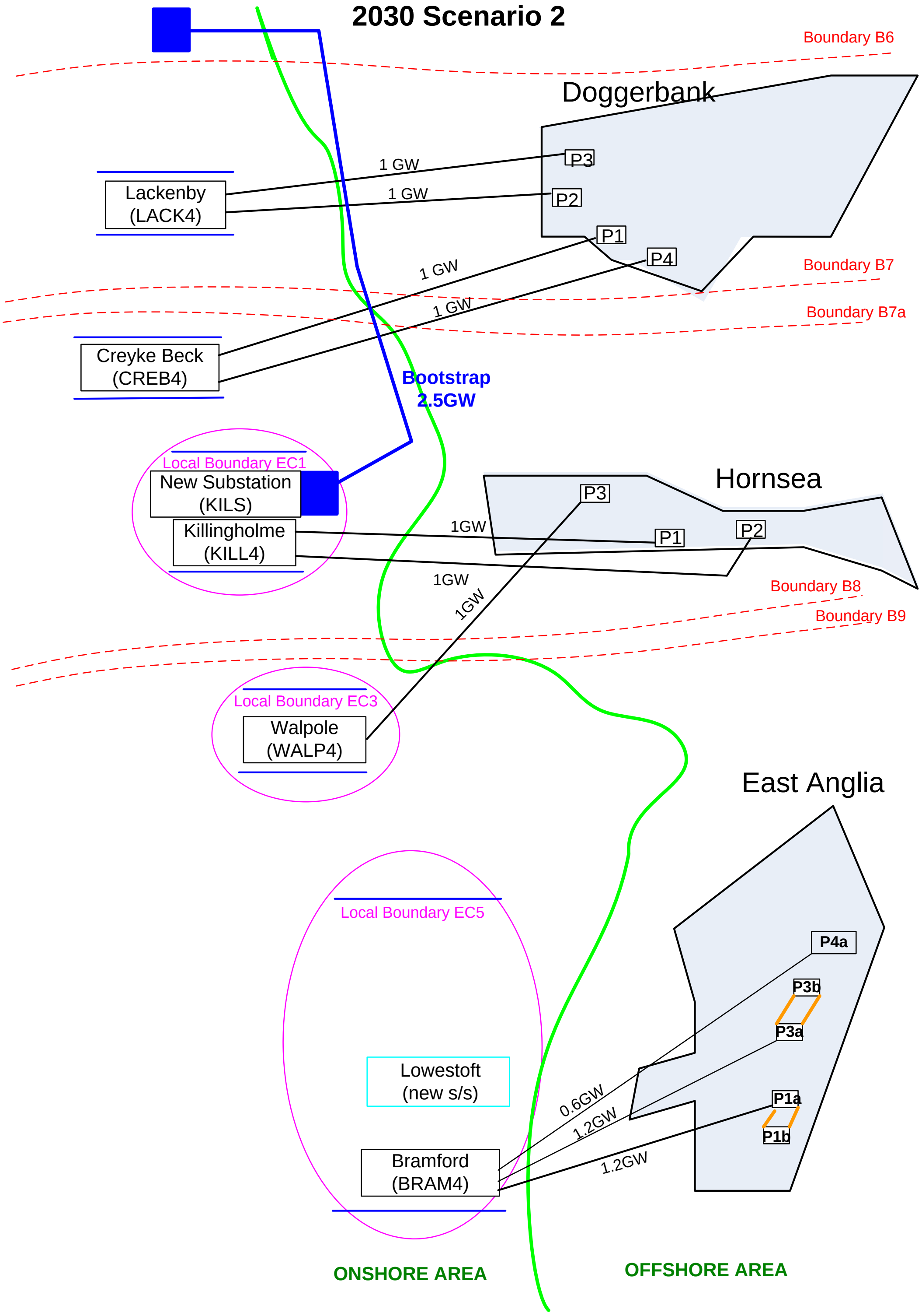
Design 2c - A 2.5GW Bootstrap across B6, B7, B7a, B8 and B9 boundaries and 2GW links to Shore.



Design 2c Cost Breakdown

	Radial Cost (£m)	Reinforcement / Integration Cost (£m)	TOTAL
Dogger Bank			
HVDC 1GW radial link at a distance of 212.5km between P1 and CREB4 including cable installation cost and 1GW onshore VSC Converter	700.15		
HVDC 2GW radial link at a distance of 261km between P2 and LACK4 including cable installation cost and 2GW onshore VSC Converter	1044.55		
HVDC 1.2GW radial link at a distance of 215.1km between P4 and CREB4 including cable installation cost and 1.2GW onshore VSC Converter	761.95		
Two 500MW HVAC Cables at a distance of 41.2km from P3 to P2 including cable installation cost	64.83		
Integration HVAC link at a distance of 35.3km from P4 to P3 including cable installation cost		38.90	
Hornsea			
HVDC 1.2GW radial link at a distance of 150km between P1 and KILL4 including cable installation cost and 1.2GW onshore VSC Converter	612.59		
HVDC 2GW radial link at a distance of 125km between P2 and WALP4 including cable installation cost and 2GW onshore VSC Converter	829.06		
Two 500MW HVAC Cables at a distance of 38km from P3 to P2 including cable installation cost	59.79		
Integration HVAC link at a distance of 64km from P1 to P3 including cable installation cost		73.89	
East Anglia			
HVDC 1.2GW radial link at a distance of 73km between P1 and BRAM4 including cable installation cost and 1.2GW onshore VSC Converter	559.17		
HVDC 1.8GW radial link at a distance of 140km between P3(1.2GW) and BRAM4 including cable installation cost and 1.8GW onshore VSC Converter	838.13		
Two 300MW HVAC Cables at a distance of 30km from P4a to P3 including cable installation cost	69.27		
Bootstrap (Intra Grid Link)			
2.5GW HVDC link at a distance of 350km from Scotland to Walpole(EC3) including cable installation cost, two 2.5GW onshore VSC Converters and cost of required reinforcement at point of connection in Scotland and Walpole(EC3)		924.24	
TOTAL	**5539.50**	**1037.03**	**6576.53**

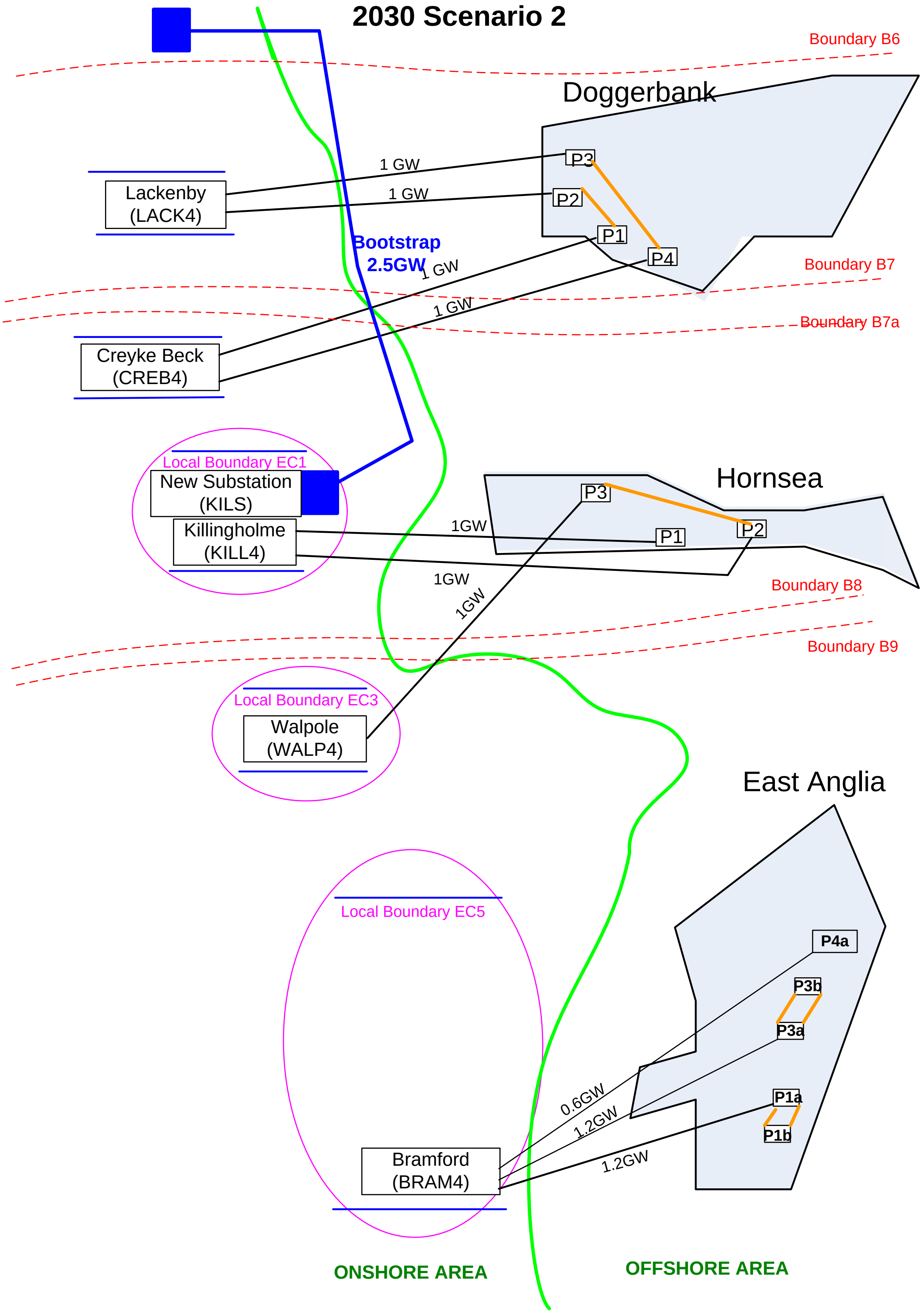
Design 3a – Hybrid 2.5GW Bootstrap



Design 3a – Cost Breakdown

	Radial Cost (£m)	Reinforcement / Integration Cost (£m)	TOTAL
Dogger Bank			
HVDC 1GW radial link at a distance of 212.5km between P1 and CREB4 including cable installation cost and 1GW onshore VSC Converter	700.15		
HVDC 1GW radial link at a distance of 261km between P2 and LACK4 including cable installation cost and 1GW onshore VSC Converter	768.10		
HVDC 1GW radial link at a distance of 222.8km between P3 and LACK4 including cable installation cost and 1GW onshore VSC Converter	714.58		
HVDC 1GW radial link at a distance of 215.1km between P4 and CREB4 including cable installation cost and 1GW onshore VSC Converter	703.80		
Hornsea			
HVDC 1GW radial link at a distance of 150km between P1 and KILL4 including cable installation cost and 1GW onshore VSC Converter	612.59		
HVDC 1GW radial link at a distance of 125km between P2 and KILL4 including cable installation cost and 1GW onshore VSC Converter	577.57		
HVDC 1GW radial link at a distance of 125km between P1 and WALP4 including cable installation cost and 1GW onshore VSC Converter	577.57		
East Anglia			
HVDC 1.2GW radial link at a distance of 73km between P1 and BRAM4 including cable installation cost and 1.2GW onshore VSC Converter	559.17		
HVDC 1GW radial link at a distance of 43km between P2(600MW) and BRAM4 including cable installation cost and 1GW onshore VSC Converter	462.68		
HVDC 1.2GW radial link at a distance of 140km between P3 and BRAM4 including cable installation cost and 1.2GW onshore VSC Converter	654.78		
Bootstrap (Intra Grid Link)			
2.5GW HVDC link at a distance of 250km from Scotland to proposed New Killingholme South substation(EC1) including cable installation cost, two 2.5GW onshore VSC Converters and cost of required reinforcement at point of connection in Scotland and New Killingholme South substation(EC1)		880.84	
Onshore Reinforcement			
Cost of proposed new Substation(New Killingholme South KILS4) and cost of KILS4-WBUR4 new double OHL		220	
TOTAL	**6330.09**	**1100.84**	**7431.83**

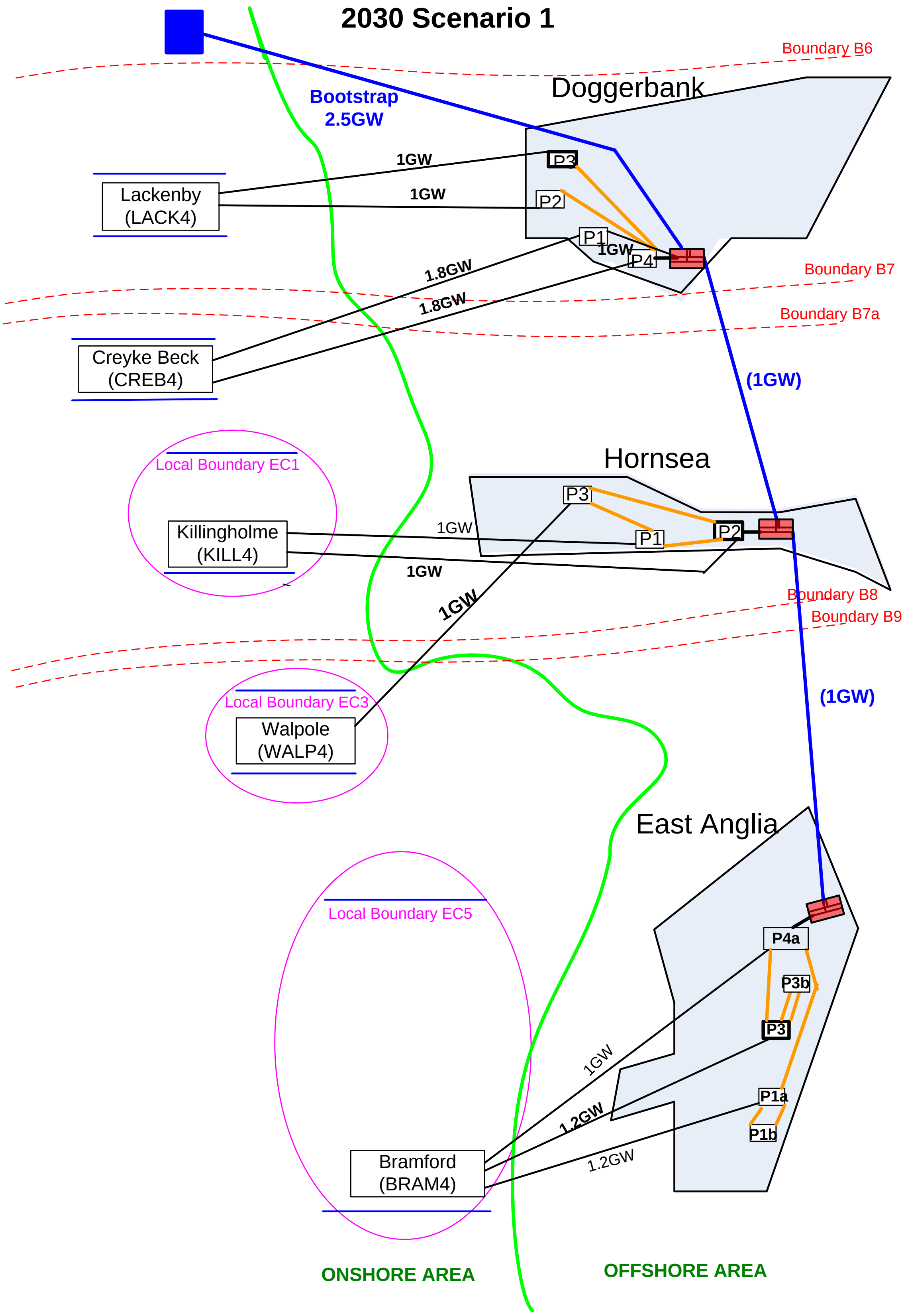
Design 4a - Hybrid 2.5GW Bootstrap with internal links



Design 4a – Cost Breakdown

	Radial Cost (£m)	Reinforcement / Integration Cost (£m)	TOTAL
Dogger Bank			
HVDC 1GW radial link at a distance of 212.5km between P1 and CREB4 including cable installation cost and 1GW onshore VSC Converter	700.15		
HVDC 1GW radial link at a distance of 261km between P2 and LACK4 including cable installation cost and 1GW onshore VSC Converter	768.10		
HVDC 1GW radial link at a distance of 222.8km between P3 and LACK4 including cable installation cost and 1GW onshore VSC Converter	714.58		
HVDC 1GW radial link at a distance of 215.1km between P4 and CREB4 including cable installation cost and 1GW onshore VSC Converter	703.80		
300MW HVAC link at a distance of 72.9km from P2 to P1 including installation cost		84.16	
300MW HVAC link at a distance of 35.3km from P4 to P3 including installation cost		40.75	
Hornsea			
HVDC 1GW radial link at a distance of 150km between P1 and KILL4 including cable installation cost and 1GW onshore VSC Converter	612.59		
HVDC 1GW radial link at a distance of 125km between P2 and KILL4 including cable installation cost and 1GW onshore VSC Converter	577.57		
HVDC 1GW radial link at a distance of 125km between P1 and WALP4 including cable installation cost and 1GW onshore VSC Converter	577.57		
300MW HVAC link at a distance of 38km from P3 to P2 including installation cost		43.87	
East Anglia			
HVDC 1.2GW radial link at a distance of 73km between P1 and BRAM4 including cable installation cost and 1.2GW onshore VSC Converter	559.17		
HVDC 1GW radial link at a distance of 43km between P2(600MW) and BRAM4 including cable installation cost and 1GW onshore VSC Converter	462.68		
HVDC 1.2GW radial link at a distance of 140km between P3 and BRAM4 including cable installation cost and 1.2GW onshore VSC Converter	654.78		
Bootstrap (Intra Grid Link)			
2.5GW HVDC link at a distance of 250km from Scotland to proposed New Killingholme South substation(EC1) including cable installation cost, two 2.5GW onshore VSC Converters and cost of required reinforcement at point of connection in Scotland and New Killingholme South substation(EC1)		880.84	
TOTAL	**6330.99**	**1049.63**	**7380.62**

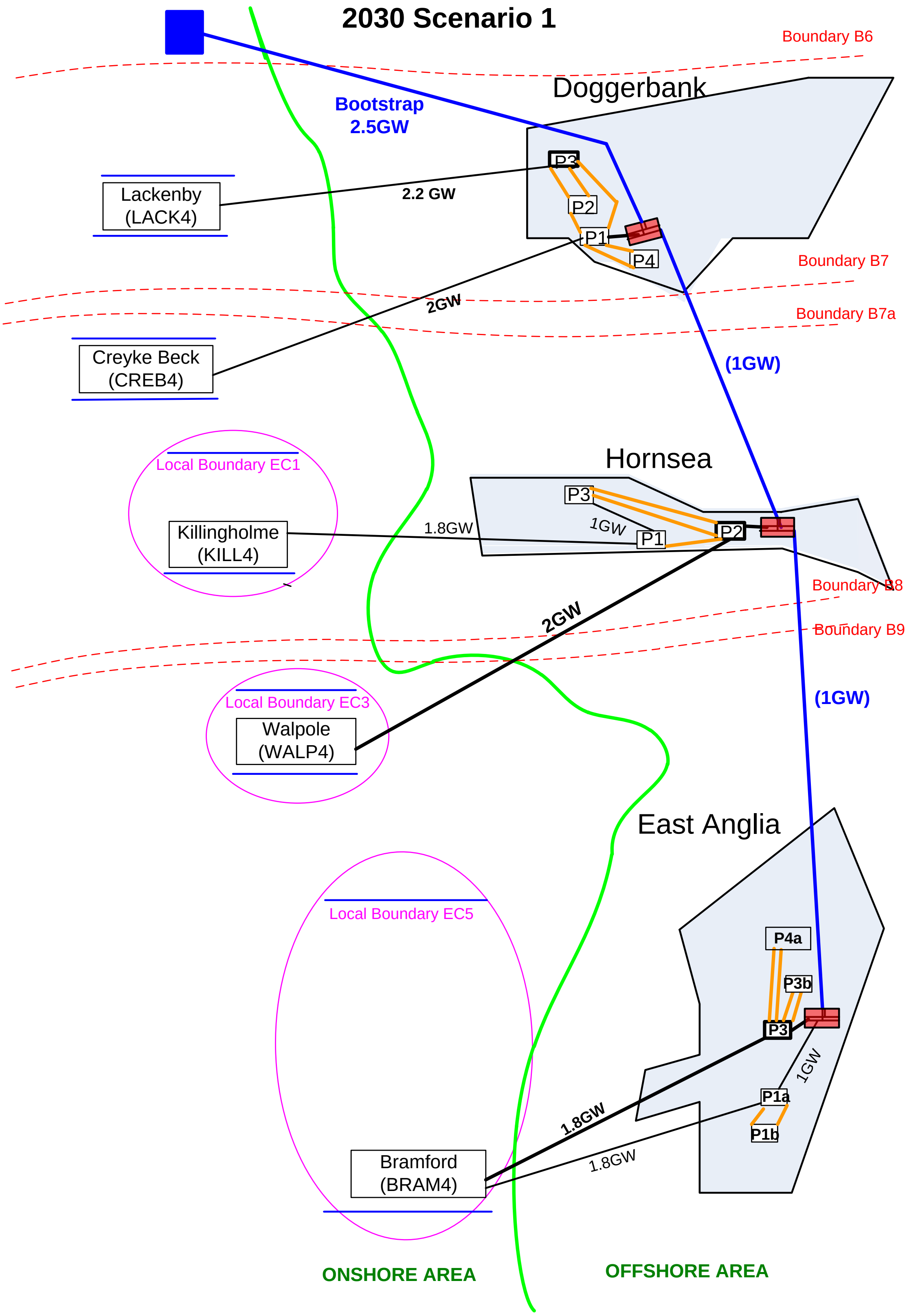
5a (Optimised) – Offshore 1GW Mesh with 1GW links to Shore



5a (Optimised) – Cost Breakdown

	Radial Cost (£m)	Reinforcement / Integration Cost (£m)	TOTAL
Dogger Bank			
HVDC 1.8GW radial link at a distance of 212.5km between P1 and CREB4 including cable installation cost and 1.8GW onshore VSC Converter	945.39		
HVDC 1GW radial link at a distance of 261km between P2 and LACK4 including cable installation cost and 1GW onshore VSC Converter	768.10		
HVDC 1GW radial link at a distance of 222.8km between P3 and LACK4 including cable installation cost and 1GW onshore VSC Converter	714.58		
HVDC 1.8GW radial link at a distance of 215.1km between P4 and CREB4 including cable installation cost and 1.8GW onshore VSC Converter	949.24		
HVDC 1GW Integrating T-Platform located at Dogger Bank		50	
HVDC 1GW at a distance of 120km from Dogger Bank to Hornsea including cable installation cost		168.12	
HVDC 1GW at a distance of 30.6km from P1 to HVDC integration T-platform including installation cost		42.87	
HVAC 300MW at a distance of 95.3km from P2 to HVDC integration T-platform including installation cost		110.02	
HVAC 300MW at a distance of 35.3km from P3 to HVDC integration T-platform including installation cost		40.75	
2.5GW VSC Converter located in Scotland		176.17	
2.5GW HVDC Cable from Scottish Transmission Network to Dogger Bank at a distance of 200km		322.80	
Hornsea			
HVDC 1GW radial link at a distance of 150km between P1 and KILL4 including cable installation cost and 1GW onshore VSC Converter	612.59		
HVDC 1GW radial link at a distance of 125km between P2 and KILL4 including cable installation cost and 1GW onshore VSC Converter	577.57		
HVDC 1GW radial link at a distance of 125km between P1 and WALP4 including cable installation cost and 1GW onshore VSC Converter	577.57		
300MW HVAC link at a distance of 64km from P3 to P2 including installation cost		73.89	
HVDC 1GW Integrating T-Platform located at Hornsea		50	
HVDC 1GW at a distance of 120km from East Anglia to Hornsea including cable installation cost		168.12	
HVAC 300MW at a distance of 27km from P1 to HVDC integration T-platform including installation cost		31.17	
HVAC 300MW at a distance of 38km from P3 to HVDC integration T-platform including installation cost		43.87	
East Anglia			
HVDC 1.2GW radial link at a distance of 73km between P1 and BRAM4 including cable installation cost and 1.2GW onshore VSC Converter	559.17		
HVDC 1GW radial link at a distance of 43km between P2(600MW) and BRAM4 including cable installation cost and 1GW onshore VSC Converter	462.68		
HVDC 1.2GW radial link at a distance of 140km between P3 and BRAM4 including cable installation cost and 1.2GW onshore VSC Converter	654.78		
HVDC 1GW Integrating T-Platform located at East Anglia		50	
HVAC 300MW at a distance of 30km from P1 to HVDC integration T-platform including installation cost		34.64	
HVAC 300MW at a distance of 30km from P3 to HVDC integration T-platform including installation cost		34.64	
Onshore Reinforcement			
Additional Enabling Works at CREB4	113.9		
TOTAL	**6935.57**	**1397.06**	**8332.63**

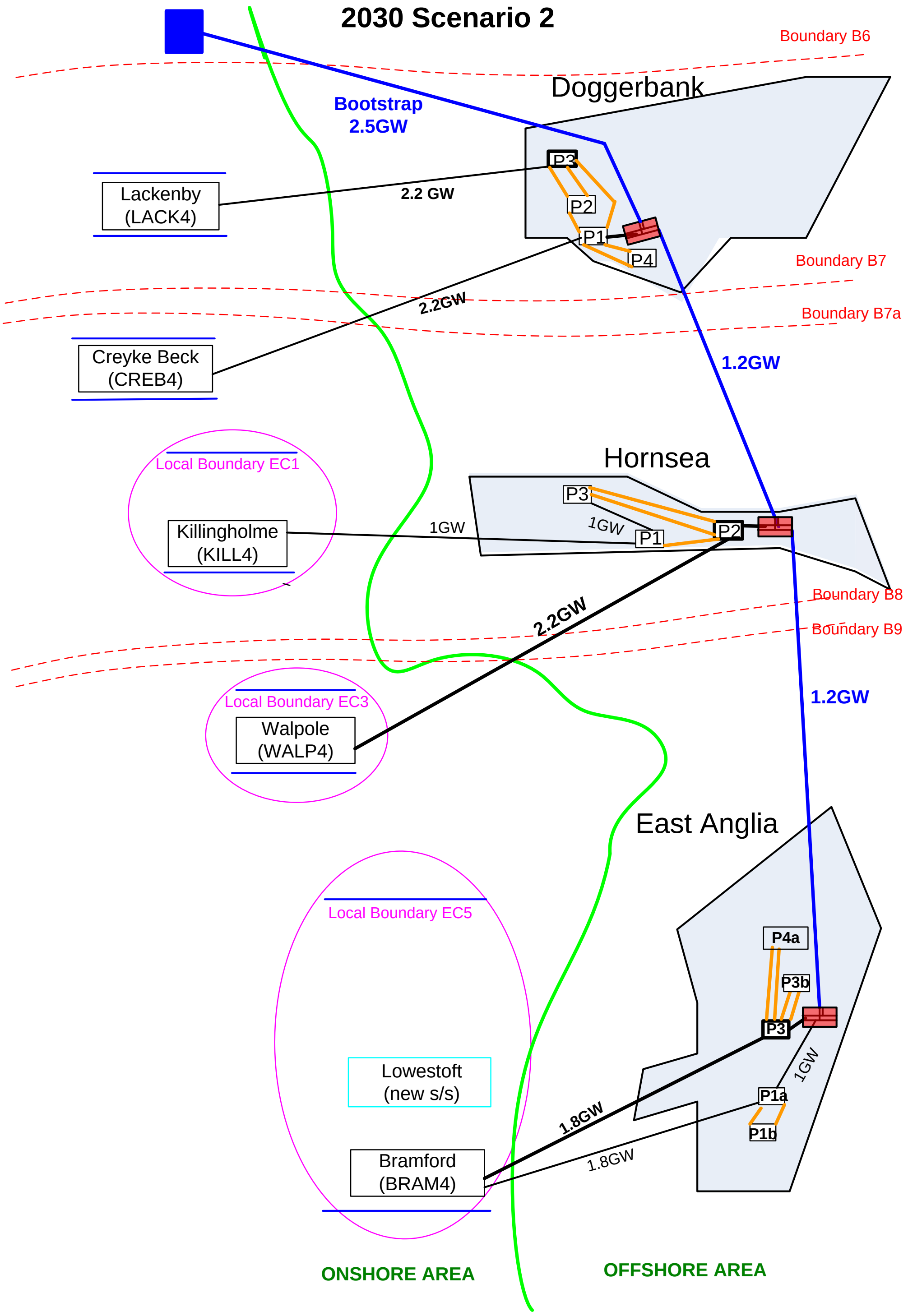
Design 5b – Offshore 1GW Mesh with 2GW links to Shore



Design 5b – Cost Breakdown

	Radial Cost (£m)	Reinforcement / Integration Cost (£m)	TOTAL
Dogger Bank			
HVDC 2GW radial link at a distance of 212.5km between P1 and CREB4 including cable installation cost and 2GW onshore VSC Converter	967.71		
HVDC 2.2GW radial link at a distance of 222.80km between P3 and LACK4 including cable installation cost and 2.2GW onshore VSC Converter	1069.77		
Two 500MW HVAC Cables at a distance of 41.2km from P3 to P2 including cable installation cost	64.83		
Two 500MW HVAC Cables at a distance of 30.6km from P4 to P1 including cable installation cost	48.15		
300MW HVAC link at a distance of 72.9km from P2 to P1 including installation cost		84.16	
300MW HVAC link at a distance of 28.2km from P1 to P3 including installation cost		32.56	
HVDC 1GW Integrating T-Platform located at Dogger Bank		50	
HVDC 1.2GW at a distance of 120km from Dogger Bank to Hornsea including cable installation cost		171.24	
2.5GW VSC Converter located in Scotland		176.17	
2.5GW HVDC Cable from Scottish Transmission Network to Dogger Bank at a distance of 200km		322.80	
Hornsea			
HVDC 1.8GW radial link at a distance of 150km between P1 and KILL4 including cable installation cost and 1.8GW onshore VSC Converter	852.93		
HVDC 2GW radial link at a distance of 125km between P2 and WALP4 including cable installation cost and 2GW onshore VSC Converter	829.06		
Two 500MW HVAC Cables at a distance of 38km from P3 to P2 including cable installation cost	59.79		
Integration HVDC link at a distance of 64km from P1 to P3 including cable installation cost		89.66	
HVDC 1GW Integrating T-Platform located at Hornsea		50	
HVDC 1.2GW at a distance of 120km from Hornsea to East Anglia including installation cost		168.12	
HVAC 300MWlink at a distance of 27km from P1 to HVDC Integration T-Platform located at P2		31.17	
East Anglia			
HVDC 1.8GW radial link at a distance of 73km between P1(1.2GW) and BRAM4 including cable installation cost and 1.8GW onshore VSC Converter	739		
HVDC 1.8GW radial link at a distance of 140km between P3(1.2GW) and BRAM4 including cable installation cost and 1.8GW onshore VSC Converter	838.13		
Two 300MW HVAC Cables at a distance of 30km from P4a to P3 including cable installation cost	69.27		
HVDC 1GW Integrating T-Platform located at East Anglia		50	
HVDC 1GW link at a distance of 30km from P1 to HVDC Integration T-Platform located at P3		42.03	
TOTAL	**5538.64**	**1258.90**	**6797.53**

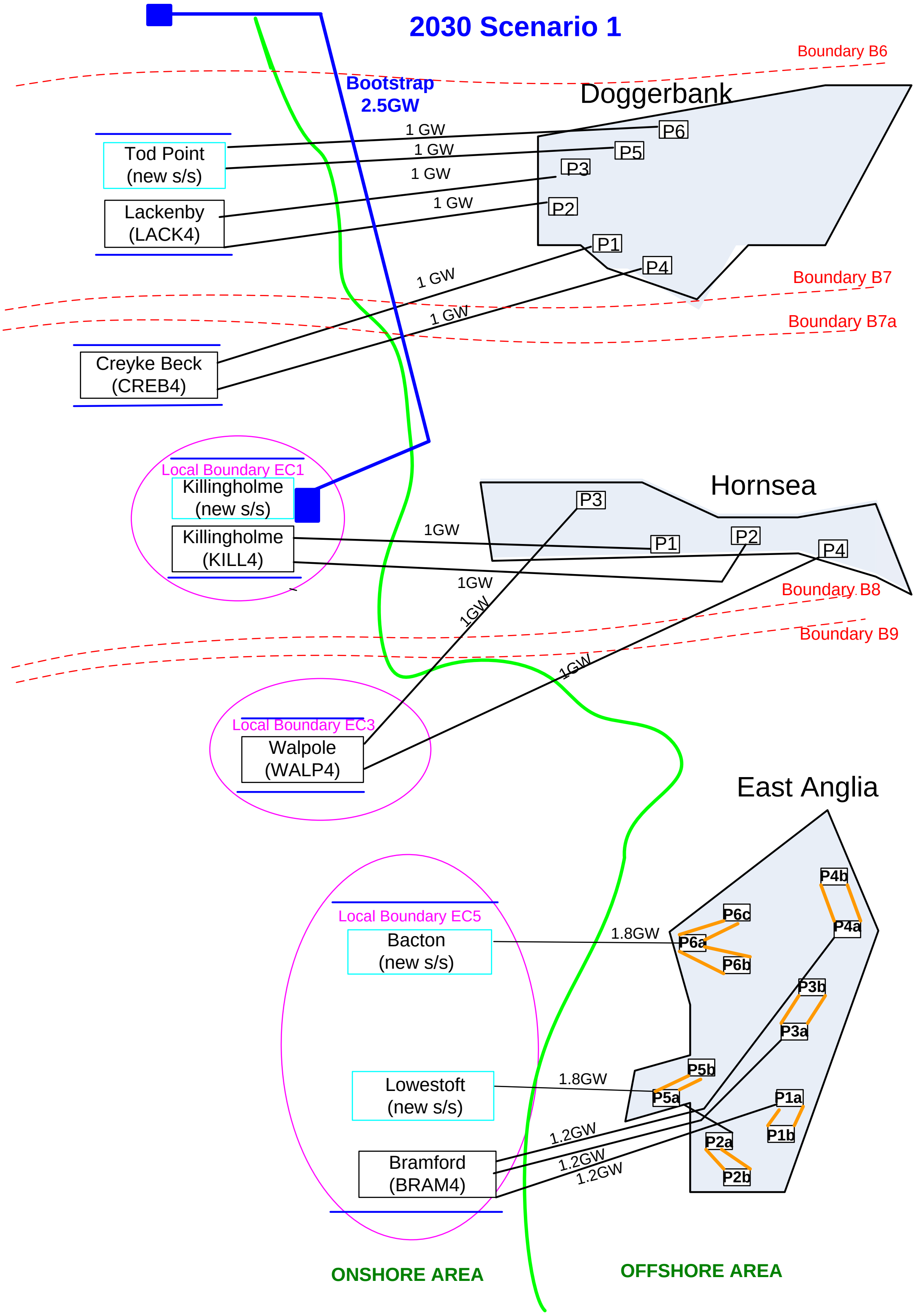
5b Anticipatory 2.2GW links to shore and 1.2GW links between zones



5b Anticipatory – Cost Breakdown

	Radial Cost (£m)	Reinforcement / Integration Cost (£m)	TOTAL
Dogger Bank			
HVDC 2.2GW radial link at a distance of 212.5km between P1 and CREB4 including cable installation cost and 2.2GW onshore VSC Converter	1025.21		
HVDC 2.2GW radial link at a distance of 222.80km between P3 and LACK4 including cable installation cost and 2.2GW onshore VSC Converter	1069.77		
Two 500MW HVAC Cables at a distance of 41.2km from P3 to P2 including cable installation cost	64.83		
Two 500MW HVAC Cables at a distance of 30.6km from P4 to P1 including cable installation cost	48.15		
300MW HVAC link at a distance of 72.9km from P2 to P1 including installation cost		84.16	
300MW HVAC link at a distance of 35.3km from P4 to P3 including installation cost		40.75	
HVDC 1GW Integrating T-Platform located at Dogger Bank		50	
HVDC 1.2GW at a distance of 120km from Dogger Bank to Hornsea including cable installation cost		171.24	
Hornsea			
HVDC 1GW radial link at a distance of 150km between P1 and KILL4 including cable installation cost and 1GW onshore VSC Converter	612.59		
HVDC 2.2GW radial link at a distance of 125km between P2 and WALP4 including cable installation cost and 2.2GW onshore VSC Converter	911.92		
Two 500MW HVAC Cables at a distance of 38km from P3 to P2 including cable installation cost	59.79		
Integration HVDC link at a distance of 64km from P1 to P3 including cable installation cost		89.66	
HVDC 1GW Integrating T-Platform located at Hornsea		50	
HVDC 1.2GW at a distance of 120km from Hornsea to East Anglia		59.64	
HVAC 300MWlink at a distance of 27km from P1 to HVDC Integration T-Platform located at P2		31.17	
East Anglia			
HVDC 1.8GW radial link at a distance of 73km between P1(1.2GW) and BRAM4 including cable installation cost and 1.8GW onshore VSC Converter	739		
HVDC 1.8GW radial link at a distance of 140km between P3(1.2GW) and BRAM4 including cable installation cost and 1.8GW onshore VSC Converter	838.13		
Two 300MW HVAC Cables at a distance of 30km from P4a to P3 including cable installation cost	69.27		
HVDC 1GW Integrating T-Platform located at East Anglia		50	
HVDC 1GW link at a distance of 30km from P1 to HVDC Integration T-Platform located at P3		42.03	
TOTAL	**5438.66**	**1153.54**	**6591.20**

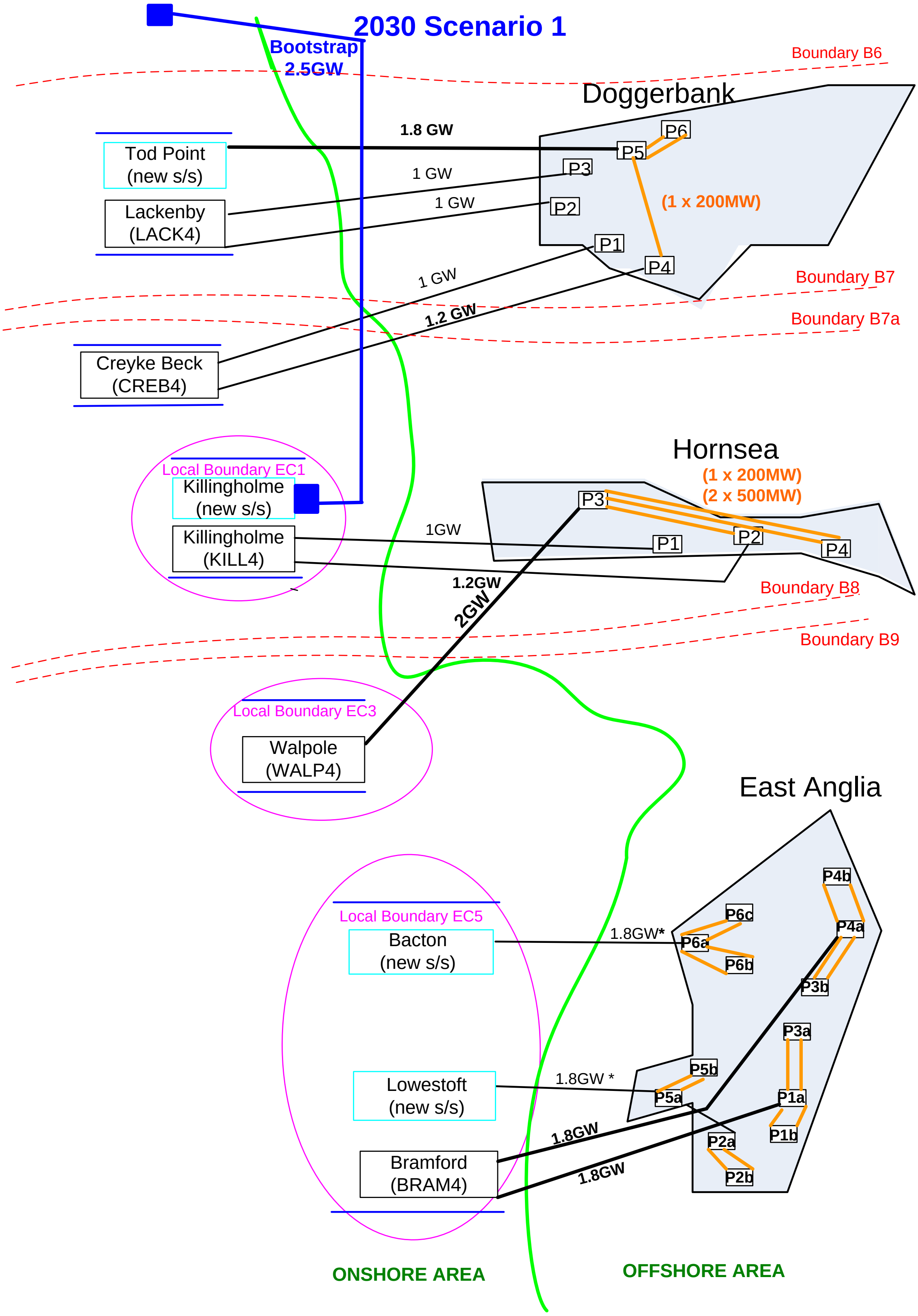
Design 10a – Bootstrap across B6, B7 and B7a Boundaries and onshore B8 reinforcements with 1GW Links to Shore.



Design 10a – Cost Breakdown

	Radial Cost (£m)	Reinforcement / Integration Cost (£m)	TOTAL
Dogger Bank			
HVDC 1GW radial link at a distance of 212.5km between P1 and CREB4 including cable installation cost and 1GW onshore VSC Converter	700.15		
HVDC 1GW radial link at a distance of 261km between P2 and LACK4 including cable installation cost and 1GW onshore VSC Converter	768.10		
HVDC 1GW radial link at a distance of 222.8km between P3 and LACK4 including cable installation cost and 1GW onshore VSC Converter	714.58		
HVDC 1GW radial link at a distance of 215.1km between P4 and CREB4 including cable installation cost and 1GW onshore VSC Converter	703.80		
HVDC 1GW radial link at a distance of 210.6km between P5 and a proposed new substation Tod Point (TODP4) including cable installation cost and 1GW onshore VSC Converter	697.49		
HVDC 1GW radial link at a distance of 246.3km between P6 and a proposed new substation Tod Point (TODP4) including cable installation cost and 1GW onshore VSC Converter	747.51		
HVDC 1GW radial link at a distance of 150km between P1 and KILL4 including cable installation cost and 1GW onshore VSC Converter	612.59		
HVDC 1GW radial link at a distance of 125km between P2 and KILL4 including cable installation cost and 1GW onshore VSC Converter	577.57		
HVDC 1GW radial link at a distance of 125km between P1 and WALP4 including cable installation cost and 1GW onshore VSC Converter	577.57		
HVDC 1GW radial link at a distance of 138km between P1 and WALP4 including cable installation cost and 1GW onshore VSC Converter	595.78		
East Anglia			
HVDC 1.2GW radial link at a distance of 73km between P1 and BRAM4 including cable installation cost and 1.2GW onshore VSC Converter	559.17		
1GW HVDC platform located for P2(800MW)	294.50		
HVDC 1.2GW radial link at a distance of 140km between P3 and BRAM4 including cable installation cost and 1.2GW onshore VSC Converter	654.78		
HVDC 1.2GW radial link at a distance of 160km between P4 and BRAM4 including cable installation cost and 1.2GW onshore VSC Converter	683.32		
HVDC 1.8GW radial link at a distance of 24km between P5(1GW) and a proposed new substation Lowestoft (LOWE4) including cable installation cost and 1.8GW onshore VSC Converter	666.51		
HVDC 1.8GW radial link at a distance of 68km between P6 and a proposed new substation Bacton (BACT4) including cable installation cost and 1.8GW onshore VSC Converter	731.61		
HVDC 1GW at a distance of 30km from P2 to P5 including cable installation cost	42.03		
Bootstrap (Intra Grid Link)			
2.5GW HVDC link at a distance of 250km from Scotland to proposed New Killingholme South substation(EC1) including cable installation cost, two 2.5GW onshore VSC Converters and cost of required reinforcement at point of connection in Scotland and New Killingholme South substation(EC1)		880.84	
Onshore Reinforcement			
Cost of proposed new Substation(New Killingholme South KILS4) and cost of KILS4-WBUR4 new double OHL		220	
Yorkshire Lines Reconductoring (1 Cable)		282.3	
TOTAL	**10285.01**	**1425.17**	**11710.18**

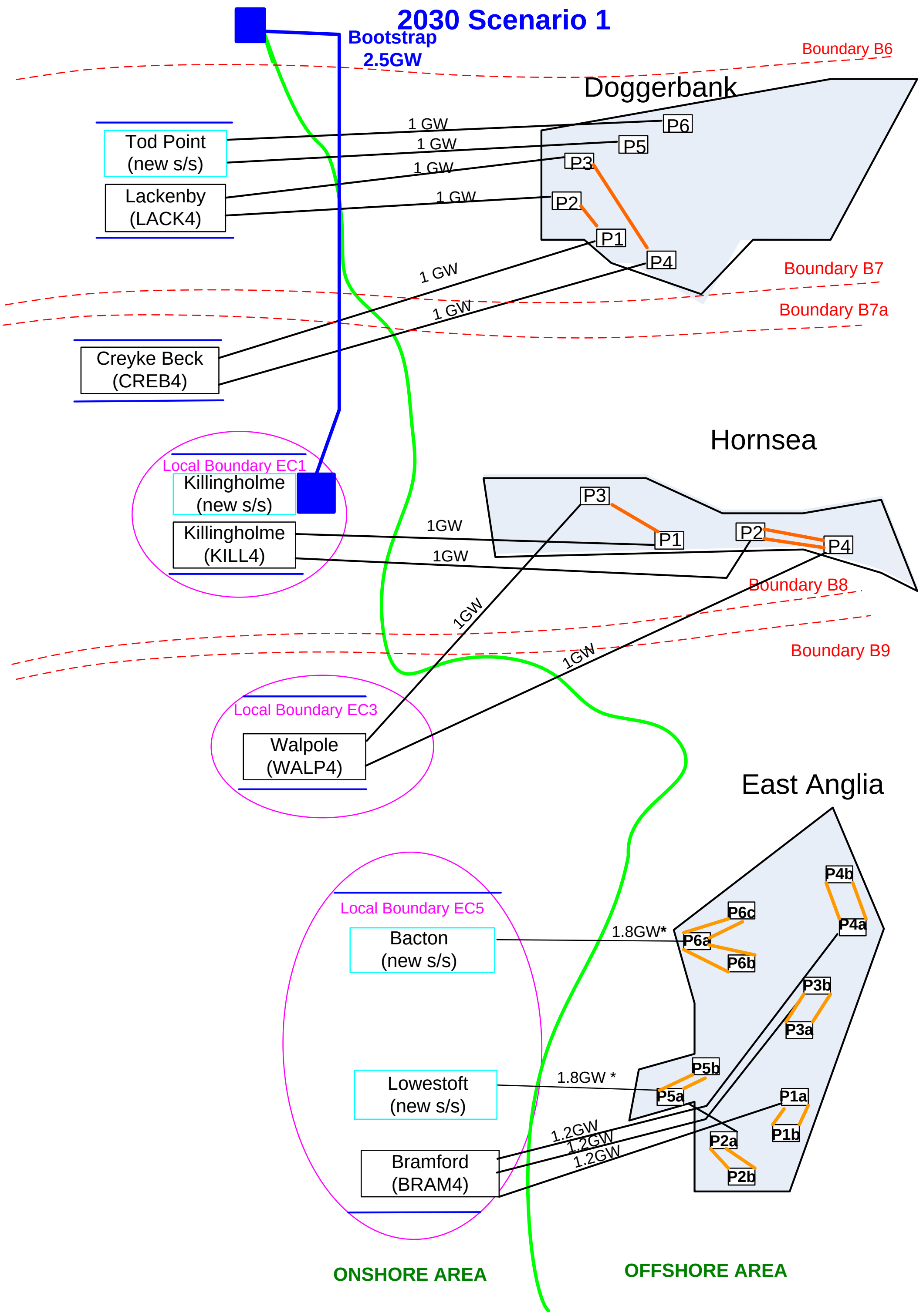
Design 10c - 2.5GW Bootstrap across B6, B7 and B7a Boundaries and onshore B8 reinforcements with 2GW Links to Shore.



Design 10c – Cost Breakdown

	Radial Cost (£m)	Reinforcement / Integration Cost (£m)	TOTAL
Dogger Bank			
HVDC 1GW radial link at a distance of 212.5km between P1 and CREB4 including cable installation cost and 1GW onshore VSC Converter	700.15		
HVDC 1GW radial link at a distance of 261km between P2 and LACK4 including cable installation cost and 1GW onshore VSC Converter	768.10		
HVDC 1GW radial link at a distance of 222.8km between P3 and LACK4 including cable installation cost and 1GW onshore VSC Converter	714.58		
HVDC 1.2GW radial link at a distance of 215.1km between P4 and CREB4 including cable installation cost and 1.2GW onshore VSC Converter	761.95		
HVDC 1.8GW radial link at a distance of 210.6km between P5 and a proposed new substation Tod Point (TODP4) including cable installation cost and 1.8GW onshore VSC Converter	942.58		
Two 500MW HVAC Cables at a distance of 36.5km from P6 to P5 including cable installation cost	57.43		
300MW HVAC Cables at a distance of 31.8km from P5 to P4 including cable installation cost	35.04		
Hornsea			
HVDC 1GW radial link at a distance of 150km between P1 and KILL4 including cable installation cost and 1GW onshore VSC Converter	612.59		
HVDC 1.2GW radial link at a distance of 125km between P2 and KILL4 including cable installation cost and 1.2GW onshore VSC Converter	633.38		
HVDC 2GW radial link at a distance of 125km between P1 and WALP4 including cable installation cost and 2GW onshore VSC Converter	829.06		
Two 500MW HVAC Cables at a distance of 38km from P3 to P2 including cable installation cost	59.79		
200MW HVAC Cables at a distance of 38km from P2 to P3 including cable installation cost	41.88		
East Anglia			
HVDC 1.8GW radial link at a distance of 73km between P1(1.2GW) and BRAM4 including cable installation cost and 1.2GW onshore VSC Converter	739		
1GW HVDC platform located for P2(800MW)	294.50		
HVDC 1.8GW radial link at a distance of 160km between P4(1.2GW) and BRAM4 including cable installation cost and 1.2GW onshore VSC Converter	867.72		
HVDC 1.8GW radial link at a distance of 24km between P5(1GW) and a proposed new substation Lowestoft (LOWE4) including cable installation cost and 1.8GW onshore VSC Converter	666.51		
HVDC 1.8GW radial link at a distance of 68km between P6 and a proposed new substation Bacton (BACT4) including cable installation cost and 1.8GW onshore VSC Converter	731.61		
HVDC 1GW at a distance of 30km from P2 to P5 including cable installation cost	42.03		
Two 300MW HVAC Cables at a distance of 60km from P3a to P1 including cable installation cost	69.27		
Two 300MW HVAC Cables at a distance of 60km from P3b to P4 including cable installation cost	69.27		
Bootstrap (Intra Grid Link)			
2.5GW HVDC link at a distance of 250km from Scotland to proposed New Killingholme South substation(EC1) including cable installation cost, two 2.5GW onshore VSC Converters and cost of required reinforcement at point of connection in Scotland and New Killingholme South substation(EC1)		880.84	
Onshore Reinforcement			
Cost of proposed new Substation(New Killingholme South KILS4) and cost of KILS4-WBUR4 new double OHL		220	
Yorkshire Lines Reconductoring (1 Cable)		282.3	
Reconductoring Drax-Thorton-Creyke Beck-Keady circuits		53.8	
TOTAL	**9636.45**	**1436.94**	**11073.39**

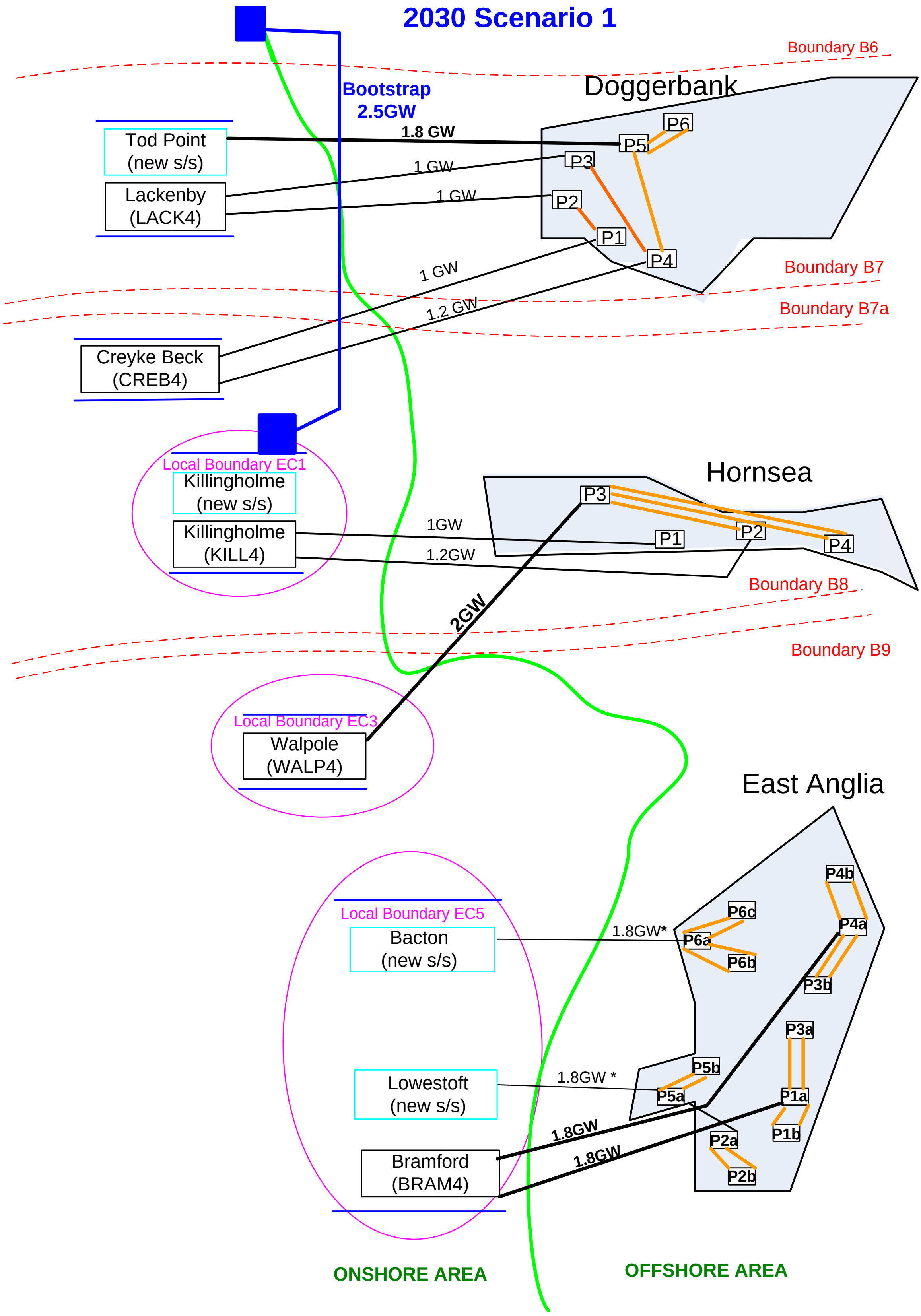
Design 13a - 2.5GW Hybrid Bootstrap across B6, B7 and B7a Boundaries, onshore B8 reinforcements with 1GW Links to Shore.



Design 13a – Cost Breakdown

	Radial Cost (£m)	Reinforcement / Integration Cost (£m)	TOTAL
Dogger Bank			
HVDC 1GW radial link at a distance of 212.5km between P1 and CREB4 including cable installation cost and 1GW onshore VSC Converter	700.15		
HVDC 1GW radial link at a distance of 261km between P2 and LACK4 including cable installation cost and 1GW onshore VSC Converter	768.10		
HVDC 1GW radial link at a distance of 222.8km between P3 and LACK4 including cable installation cost and 1GW onshore VSC Converter	714.58		
HVDC 1GW radial link at a distance of 215.1km between P4 and CREB4 including cable installation cost and 1GW onshore VSC Converter	703.80		
HVDC 1GW radial link at a distance of 210.6km between P5 and a proposed new substation Tod Point (TODP4) including cable installation cost and 1GW onshore VSC Converter	697.49		
HVDC 1GW radial link at a distance of 246.3km between P6 and a proposed new substation Tod Point (TODP4) including cable installation cost and 1GW onshore VSC Converter	747.51		
300MW HVAC link at a distance of 72.9km from P2 to P1 including installation cost		84.16	
300MW HVAC link at a distance of 35.3km from P4 to P3 including installation cost		40.75	
Hornsea			
HVDC 1GW radial link at a distance of 150km between P1 and KILL4 including cable installation cost and 1GW onshore VSC Converter	612.59		
HVDC 1GW radial link at a distance of 125km between P2 and KILL4 including cable installation cost and 1GW onshore VSC Converter	577.57		
HVDC 1GW radial link at a distance of 125km between P1 and WALP4 including cable installation cost and 1GW onshore VSC Converter	577.57		
HVDC 1GW radial link at a distance of 138km between P1 and WALP4 including cable installation cost and 1GW onshore VSC Converter	595.78		
300MW HVAC link at a distance of 64km from P3 to P1 including installation cost		73.89	
Two 500MW HVAC Cables at a distance of 112km from P4 to P2 including cable installation cost		176.23	
East Anglia			
HVDC 1.2GW radial link at a distance of 73km between P1 and BRAM4 including cable installation cost and 1.2GW onshore VSC Converter	559.17		
1GW HVDC platform located for P2(800MW)	294.50		
HVDC 1.2GW radial link at a distance of 140km between P3 and BRAM4 including cable installation cost and 1.2GW onshore VSC Converter	654.78		
HVDC 1.2GW radial link at a distance of 160km between P4 and BRAM4 including cable installation cost and 1.2GW onshore VSC Converter	683.32		
HVDC 1.8GW radial link at a distance of 24km between P5(1GW) and a proposed new substation Lowestoft (LOWE4) including cable installation cost and 1.8GW onshore VSC Converter	666.51		
HVDC 1.8GW radial link at a distance of 68km between P6 and a proposed new substation Bacton (BACT4) including cable installation cost and 1.8GW onshore VSC Converter	731.61		
HVDC 1GW at a distance of 30km from P2 to P5 including cable installation cost	42.03		
Bootstrap (Intra Grid Link)			
2.5GW HVDC link at a distance of 250km from Scotland to proposed New Killingholme South substation(EC1) including cable installation cost, two 2.5GW onshore VSC Converters and cost of required reinforcement at point of connection in Scotland and New Killingholme South substation(EC1)		880.84	
TOTAL	**10327.04**	**1255.88**	**11582.92**

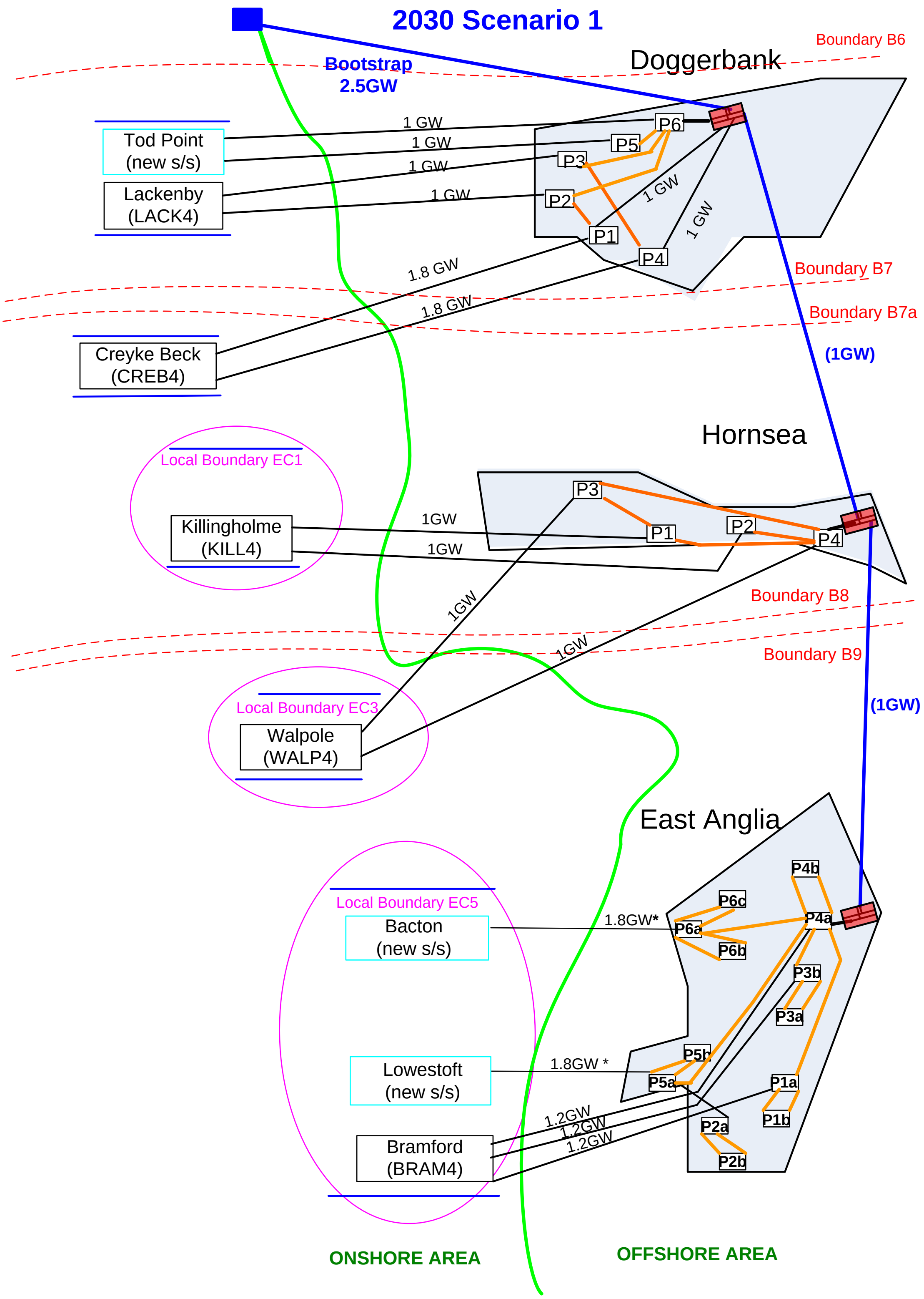
Design 13c - 2.5GW Hybrid Bootstrap across B6, B7 and B7a Boundaries, onshore B8 reinforcements with 2GW Links to Shore.



Design 13c – Cost Breakdown

	Radial Cost (£m)	Reinforcement / Integration Cost (£m)	TOTAL
Dogger Bank			
HVDC 1GW radial link at a distance of 212.5km between P1 and CREB4 including cable installation cost and 1GW onshore VSC Converter	700.15		
HVDC 1GW radial link at a distance of 261km between P2 and LACK4 including cable installation cost and 1GW onshore VSC Converter	768.10		
HVDC 1GW radial link at a distance of 222.8km between P3 and LACK4 including cable installation cost and 1GW onshore VSC Converter	714.58		
HVDC 1.2GW radial link at a distance of 215.1km between P4(1GW) and CREB4 including cable installation cost and 1.2GW onshore VSC Converter	761.95		
HVDC 1.8GW radial link at a distance of 210.6km between P5(1GW) and a proposed new substation Tod Point (TODP4) including cable installation cost and 1.8GW onshore VSC Converter	942.58		
Two 500MW HVAC Cables at a distance of 36.5km from P6 to P5 including cable installation cost	57.43		
300MW HVAC link at a distance of 72.9km from P2 to P1 including installation cost		84.16	
300MW HVAC link at a distance of 35.3km from P4 to P3 including installation cost		40.75	
200MW HVAC link at a distance of 31.8km from P4 to P5 including installation cost	35.04		
Hornsea			
HVDC 1GW radial link at a distance of 150km between P1 and KILL4 including cable installation cost and 1GW onshore VSC Converter	612.59		
HVDC 1.2GW radial link at a distance of 125km between P2(1GW) and KILL4 including cable installation cost and 1.2GW onshore VSC Converter	633.38		
HVDC 2GW radial link at a distance of 125km between P3(1GW) and WALP4 including cable installation cost and 2GW onshore VSC Converter	829.06		
300MW HVAC link at a distance of 38km from P3 to P1 including installation cost		43.87	
Two 500MW HVAC Cables at a distance of 38km from P4 to P3 including cable installation cost	59.79		
East Anglia			
HVDC 1.8GW radial link at a distance of 73km between P1(1.2GW) and BRAM4 including cable installation cost and 1.2GW onshore VSC Converter	739		
1GW HVDC platform located for P2(800MW)	294.50		
HVDC 1.8GW radial link at a distance of 160km between P4(1.2GW) and BRAM4 including cable installation cost and 1.2GW onshore VSC Converter	867.72		
HVDC 1.8GW radial link at a distance of 24km between P5(1GW) and a proposed new substation Lowestoft (LOWE4) including cable installation cost and 1.8GW onshore VSC Converter	666.51		
HVDC 1.8GW radial link at a distance of 68km between P6 and a proposed new substation Bacton (BACT4) including cable installation cost and 1.8GW onshore VSC Converter	731.61		
HVDC 1GW at a distance of 30km from P2 to P5 including cable installation cost	42.03		
Two 300MW HVAC Cables at a distance of 60km from P3a to P1 including cable installation cost	69.27		
Two 300MW HVAC Cables at a distance of 60km from P3b to P4 including cable installation cost	69.27		
Bootstrap (Intra Grid Link)			
2.5GW HVDC link at a distance of 250km from Scotland to proposed New Killingholme South substation(EC1) including cable installation cost, two 2.5GW onshore VSC Converters and cost of required reinforcement at point of connection in Scotland and New Killingholme South substation(EC1)		880.84	
TOTAL	**9594.57**	**1049.63**	**10644.20**

Design 15a (Optimised) - Offshore Mesh with 1GW links to Shore

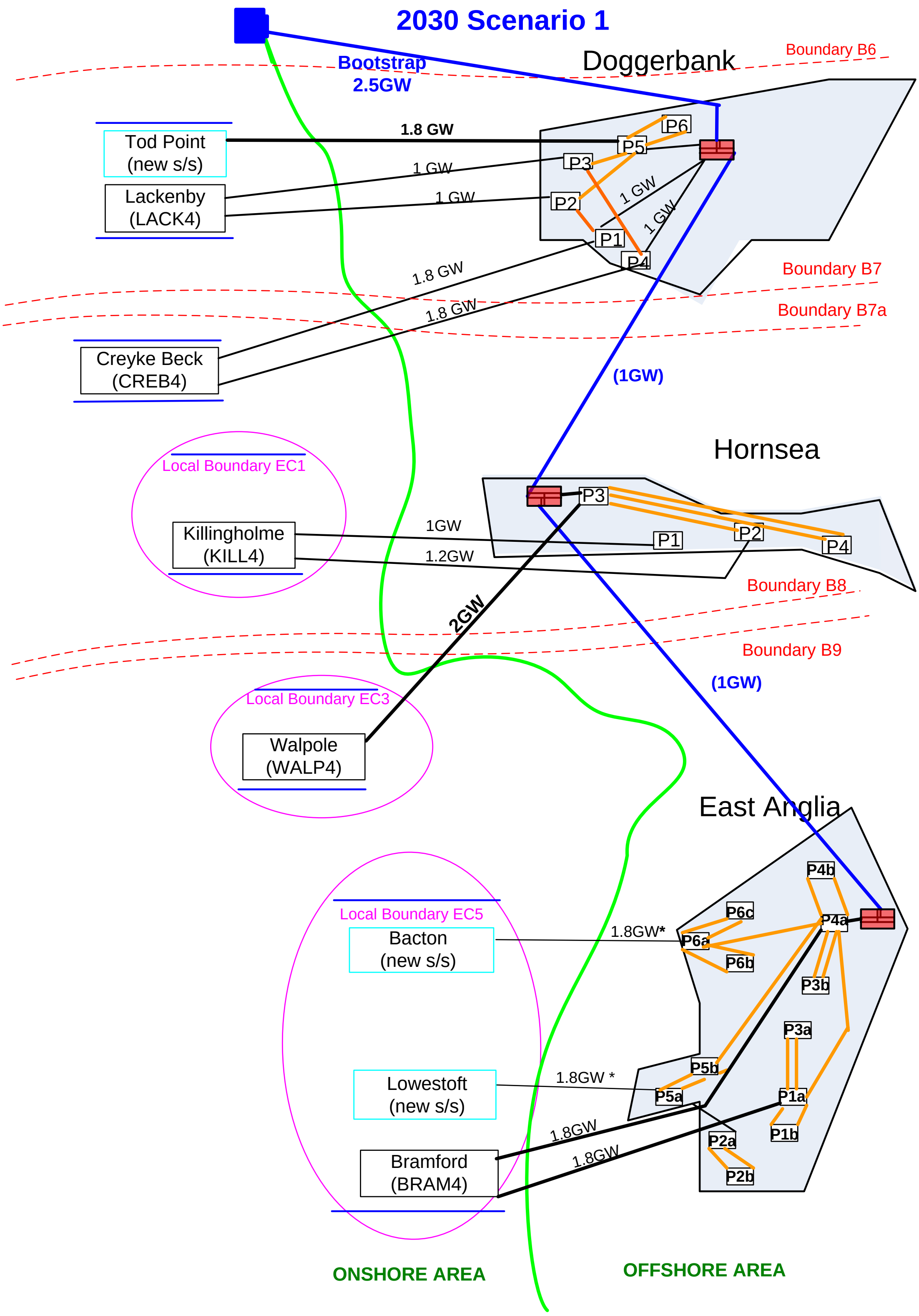


Design 15a (Optimised) - Cost Breakdown

	Radial Cost (£m)	Reinforcement / Integration Cost (£m)	TOTAL
Dogger Bank			
HVDC 1.8GW radial link at a distance of 212.5km between P1(1GW) and CREB4 including cable installation cost and 1.8GW onshore VSC Converter	945.67		
HVDC 1GW radial link at a distance of 261km between P2 and LACK4 including cable installation cost and 1GW onshore VSC Converter	768.10		
HVDC 1GW radial link at a distance of 222.8km between P3 and LACK4 including cable installation cost and 1GW onshore VSC Converter	714.58		
HVDC 1.8GW radial link at a distance of 215.1km between P4(1GW) and CREB4 including cable installation cost and 1.8GW onshore VSC Converter	949.19		
HVDC 1GW radial link at a distance of 210.6km between P5 and a proposed new substation Tod Point (TODP4) including cable installation cost and 1GW onshore VSC Converter	697.49		
HVDC 1GW radial link at a distance of 246.3km between P6 and a proposed new substation Tod Point (TODP4) including cable installation cost and 1GW onshore VSC Converter	747.51		
300MW HVAC link at a distance of 72.9km from P2 to P1 including installation cost		84.16	
300MW HVAC link at a distance of 35.3km from P4 to P3 including installation cost		40.75	
HVDC 1GW Integrating T-Platform located at Dogger Bank		50	
HVDC 1GW at a distance of 120km from Dogger Bank to Hornsea including cable installation cost		168.12	
HVDC 1GW at a distance of 98.8km from P1 to HVDC integration T-platform including installation cost		138.42	
HVAC 300MW at a distance of 49.4km from P2 to HVDC integration T-platform including installation cost		57.03	
HVAC 300MW at a distance of 70.6km from P3 to HVDC integration T-platform including installation cost		81.51	
HVDC 1GW at a distance of 68.3km from P4 to HVDC integration T-platform including installation cost		95.69	
HVAC 300MW at a distance of 36.5km from P5 to HVDC integration T-platform including installation cost		42.14	
2.5GW VSC Converter located in Scotland		176.17	
2.5GW HVDC Cable from Scottish Transmission Network to Dogger Bank at a distance of 200km		322.80	
Hornsea			
HVDC 1GW radial link at a distance of 150km between P1 and KILL4 including cable installation cost and 1GW onshore VSC Converter	612.59		
HVDC 1GW radial link at a distance of 125km between P2 and KILL4 including cable installation cost and 1GW onshore VSC Converter	577.57		
HVDC 1GW radial link at a distance of 125km between P3 and WALP4 including cable installation cost and 1GW onshore VSC Converter	577.57		
HVDC 1GW radial link at a distance of 138km between P4 and WALP4 including cable installation cost and 1GW onshore VSC Converter	595.78		
300MW HVAC link at a distance of 64km from P3 to P1 including installation cost		73.89	
300MW HVAC link at a distance of 56km from P2 to P4 including installation cost		64.65	
HVDC 1GW Integrating T-Platform located at Hornsea		50	
HVDC 1GW at a distance of 100km from East Anglia to Hornsea including cable installation cost		140.1	
HVAC 300MW at a distance of 29km from P2 to HVDC integration T-platform including installation cost		33.48	
HVAC 300MW at a distance of 38km from P3 to HVDC integration T-platform including installation cost		43.87	
East Anglia			
HVDC 1.2GW radial link at a distance of 73km between P1 and BRAM4 including cable installation cost and 1.2GW onshore VSC Converter	559.17		
1GW HVDC platform located for P2(800MW)	294.50		
HVDC 1.2GW radial link at a distance of 140km between P3 and BRAM4 including cable installation cost and 1.2GW onshore VSC Converter	654.78		
HVDC 1.2GW radial link at a distance of 160km between P4 and BRAM4 including cable installation cost and 1.2GW onshore VSC Converter	683.32		
HVDC 1.8GW radial link at a distance of 24km between P5(1GW) and a proposed new substation Lowestoft (LOWE4) including cable installation cost and 1.8GW onshore VSC	666.51		

Converter			
HVDC 1.8GW radial link at a distance of 68km between P6 and a proposed new substation Bacton (BACT4) including cable installation cost and 1.8GW onshore VSC Converter	731.61		
HVDC 1GW at a distance of 30km from P2 to P5 including cable installation cost	42.03		
HVDC 1GW Integrating T-Platform located at East Anglia		50	
HVAC 300MW at a distance of 30km from P1 to HVDC integration T-platform including installation cost		34.64	
HVAC 300MW at a distance of 30km from P3 to HVDC integration T-platform including installation cost		34.64	
HVAC 300MW at a distance of 30km from P5 to HVDC integration T-platform including installation cost		34.64	
HVAC 300MW at a distance of 30km from P6 to HVDC integration T-platform including installation cost		34.64	
Bootstrap (Intra Grid Link)			
2.5GW HVDC link at a distance of 250km from Scotland to proposed New Killingholme South substation(EC1) including cable installation cost, two 2.5GW onshore VSC Converters and cost of required reinforcement at point of connection in Scotland and New Killingholme South substation(EC1)		880.84	
TOTAL	**10327.04**	**1810.13**	**12137.18**

Design 15c - Offshore Mesh with 2GW links to Shore



Design 15c – Cost Breakdown

	Radial Cost (£m)	Reinforcement / Integration Cost (£m)	TOTAL
Dogger Bank			
HVDC 1.8GW radial link at a distance of 212.5km between P1(1GW) and CREB4 including cable installation cost and 1.8GW onshore VSC Converter	945.67		
HVDC 1GW radial link at a distance of 261km between P2 and LACK4 including cable installation cost and 1GW onshore VSC Converter	768.10		
HVDC 1GW radial link at a distance of 222.8km between P3 and LACK4 including cable installation cost and 1GW onshore VSC Converter	714.58		
HVDC 1.8GW radial link at a distance of 215.1km between P4(1GW) and CREB4 including cable installation cost and 1.8GW onshore VSC Converter	949.19		
HVDC 1.8GW radial link at a distance of 210.6km between P5(1GW) and a proposed new substation Tod Point (TODP4) including cable installation cost and 1.8GW onshore VSC Converter	942.58		
Two 500MW HVAC Cables at a distance of 36.5km from P6 to P5 including cable installation cost	57.43		
300MW HVAC link at a distance of 72.9km from P2 to P1 including installation cost		84.16	
300MW HVAC link at a distance of 35.3km from P4 to P3 including installation cost		40.75	
HVDC 1GW Integrating T-Platform located at Dogger Bank		50	
HVDC 1GW at a distance of 120km from Dogger Bank to Hornsea including cable installation cost		168.12	
HVDC 1GW at a distance of 98.8km from P1 to HVDC integration T-platform including installation cost		138.42	
HVAC 300MW at a distance of 49.4km from P2 to HVDC integration T-platform including installation cost		57.03	
HVAC 300MW at a distance of 70.6km from P3 to HVDC integration T-platform including installation cost		81.51	
HVDC 1GW at a distance of 68.3km from P4 to HVDC integration T-platform including installation cost		95.69	
HVAC 300MW at a distance of 36.5km from P5 to HVDC integration T-platform including installation cost		42.14	
2.5GW VSC Converter located in Scotland		176.17	
2.5GW HVDC Cable from Scottish Transmission Network to Dogger Bank at a distance of 200km		322.80	
Hornsea			
HVDC 1GW radial link at a distance of 150km between P1 and KILL4 including cable installation cost and 1GW onshore VSC Converter	612.59		
HVDC 1.2GW radial link at a distance of 125km between P2(1GW) and KILL4 including cable installation cost and 1.2GW onshore VSC Converter	577.57		
HVDC 2GW radial link at a distance of 125km between P3(1GW) and WALP4 including cable installation cost and 2GW onshore VSC Converter	829.06		
Two 500MW HVAC Cables at a distance of 38km from P3 to P4 including cable installation cost	59.79		
300MW HVAC link at a distance of 56km from P2 to P1 including installation cost		43.87	
HVDC 1GW Integrating T-Platform located at Hornsea		50	
HVDC 1GW at a distance of 100km from East Anglia to Hornsea including cable installation cost		140.1	
HVAC 300MW at a distance of 38km from P2 to HVDC integration T-platform including installation cost		43.87	
East Anglia			
HVDC 1.8GW radial link at a distance of 73km between P1(1.2GW) and BRAM4 including cable installation cost and 1.2GW onshore VSC Converter	739		

1GW HVDC platform located for P2(800MW)	294.50		
HVDC 1.8GW radial link at a distance of 160km between P4(1.2GW) and BRAM4 including cable installation cost and 1.2GW onshore VSC Converter	867.72		
HVDC 1.8GW radial link at a distance of 24km between P5(1GW) and a proposed new substation Lowestoft (LOWE4) including cable installation cost and 1.8GW onshore VSC Converter	666.51		
HVDC 1.8GW radial link at a distance of 68km between P6 and a proposed new substation Bacton (BACT4) including cable installation cost and 1.8GW onshore VSC Converter	731.61		
HVDC 1GW at a distance of 30km from P2 to P5 including cable installation cost	42.03		
Two 300MW HVAC Cables at a distance of 60km from P3a to P1 including cable installation cost	69.27		
Two 300MW HVAC Cables at a distance of 60km from P3b to P4 including cable installation cost	69.27		
HVDC 1GW Integrating T-Platform located at East Anglia		50	
HVAC 300MW at a distance of 30km from P1 to HVDC integration T-platform including installation cost		34.64	
HVAC 300MW at a distance of 30km from P5 to HVDC integration T-platform including installation cost		34.64	
HVAC 300MW at a distance of 30km from P6 to HVDC integration T-platform including installation cost		34.64	
Bootstrap (Intra Grid Link)			
2.5GW HVDC link at a distance of 250km from Scotland to proposed New Killingholme South substation(EC1) including cable installation cost, two 2.5GW onshore VSC Converters and cost of required reinforcement at point of connection in Scotland and New Killingholme South substation(EC1)		880.84	
Onshore Reinforcement			
Cost of Additional Enabling Work at CREB4	113.9		
TOTAL	**10050.43**	**1532.03**	**11582.46**

Appendix 2 – Model Boundary Capabilities by Scenario and Season

TEC2030 Radial	Gone Green			Slow Progression		
Model Boundary	Winter	Spr/Aut	Summer	Winter	Spr/Aut	Summer
B6	8,000	7,200	6,400	8,000	7,200	6,400
B10	5,900	5,310	4,720	5,900	5,310	4,720
B12	8,300	7,470	6,640	7,200	6,480	5,760
B13	5,500	4,950	4,400	5,500	4,950	4,400
B14	10,800	9,720	8,640	10,800	9,720	8,640
B15	8,000	7,200	6,400	8,000	7,200	6,400
B17	5,500	4,950	4,400	7,100	6,390	5,680
DB1	1,000	1,000	1,000	1,000	1,000	1,000
DB2	1,000	1,000	1,000	1,000	1,000	1,000
DB3	1,000	1,000	1,000	1,000	1,000	1,000
DB4	1,000	1,000	1,000	1,000	1,000	1,000
DB5	1,000	1,000	1,000	1,000	1,000	1,000
DB6	1,000	1,000	1,000	1,000	1,000	1,000
H1	1,000	1,000	1,000	1,000	1,000	1,000
H2	1,000	1,000	1,000	1,000	1,000	1,000
H3	1,000	1,000	1,000	1,000	1,000	1,000
H4	1,000	1,000	1,000	1,000	1,000	1,000
EA1	1,200	1,200	1,200	1,200	1,200	1,200
EA2	900	900	900	900	900	900
EA3	1,200	1,200	1,200	1,200	1,200	1,200
EA4	1,200	1,200	1,200	1,200	1,200	1,200
EA25	1,800	1,800	1,800	1,800	1,800	1,800
EA6	1,800	1,800	1,800	1,800	1,800	1,800
B7DB123456	10,600	9,740	8,880	10,600	9,740	8,880
B7DB2356	8,600	7,740	6,880	8,600	7,740	6,880
B7aDB123456	10,400	9,560	8,720	10,400	9,560	8,720
B7aDB2356	8,400	7,560	6,720	8,400	7,560	6,720
B8DB123456H1234	12,200	11,180	10,160	12,200	11,180	10,160
B8DB123456H12	10,200	9,180	8,160	10,200	9,180	8,160
B9DB123456H12	6,900	6,210	5,520	6,900	6,210	5,520
B9DB123456H1234	8,900	8,210	7,520	8,900	8,210	7,520
SC1	5,900	5,310	4,720	5,900	5,310	4,720
EC1	9,400	8,460	7,520	5,500	4,950	4,400
EC3	3,600	3,240	2,880	3,600	3,240	2,880
EC5	7,600	6,840	6,080	7,300	6,570	5,840
NW1	6,400	5,760	5,120	5,600	5,040	4,480
NW2	6,700	6,030	5,360	4,900	4,410	3,920
NW3	7,200	6,480	5,760	5,400	4,860	4,320
NW4	7,700	6,930	6,160	5,000	4,500	4,000
B15Rev	8,000	7,200	6,400	8,000	7,200	6,400
SC1Rev	5,900	5,310	4,720	5,900	5,310	4,720

TEC 2030 Radial + Onshore	Gone Green			Slow Progression		
Model Boundary	Winter	Spr/Aut	Summer	Winter	Spr/Aut	Summer
B6	10,500	9,450	8,400	10,500	9,450	8,400
B10	5,900	5,310	4,720	5,900	5,310	4,720
B12	8,300	7,470	6,640	7,200	6,480	5,760
B13	5,500	4,950	4,400	5,500	4,950	4,400
B14	10,800	9,720	8,640	10,800	9,720	8,640
B15	8,000	7,200	6,400	8,000	7,200	6,400
B17	5,500	4,950	4,400	7,100	6,390	5,680
DB1	1,000	1,000	1,000	1,000	1,000	1,000
DB2	1,000	1,000	1,000	1,000	1,000	1,000
DB3	1,000	1,000	1,000	1,000	1,000	1,000
DB4	1,000	1,000	1,000	1,000	1,000	1,000
DB5	1,000	1,000	1,000	1,000	1,000	1,000
DB6	1,000	1,000	1,000	1,000	1,000	1,000
H1	1,000	1,000	1,000	1,000	1,000	1,000
H2	1,000	1,000	1,000	1,000	1,000	1,000
H3	1,000	1,000	1,000	1,000	1,000	1,000
H4	1,000	1,000	1,000	1,000	1,000	1,000
EA1	1,200	1,200	1,200	1,200	1,200	1,200
EA2	900	900	900	900	900	900
EA3	1,200	1,200	1,200	1,200	1,200	1,200
EA4	1,200	1,200	1,200	1,200	1,200	1,200
EA25	1,800	1,800	1,800	1,800	1,800	1,800
EA6	1,800	1,800	1,800	1,800	1,800	1,800
B7DB123456	12,800	11,720	10,640	12,800	11,720	10,640
B7DB2356	10,800	9,720	8,640	10,800	9,720	8,640
B7aDB123456	12,700	11,630	10,560	12,700	11,630	10,560
B7aDB2356	10,700	9,630	8,560	10,700	9,630	8,560
B8DB123456H1234	14,400	13,060	11,720	15,400	14,060	12,720
B8DB123456H12	13,400	12,060	10,720	13,400	12,060	10,720
B9DB123456H12	10,100	9,090	8,080	10,100	9,090	8,080
B9DB123456H1234	11,100	10,090	9,080	12,100	11,090	10,080
SC1	5,900	5,310	4,720	5,900	5,310	4,720
EC1	9,400	8,460	7,520	5,500	4,950	4,400
EC3	3,600	3,240	2,880	3,600	3,240	2,880
EC5	7,600	6,840	6,080	7,300	6,570	5,840
NW1	6,400	5,760	5,120	5,600	5,040	4,480
NW2	6,700	6,030	5,360	4,900	4,410	3,920
NW3	7,200	6,480	5,760	5,400	4,860	4,320
NW4	7,700	6,930	6,160	5,000	4,500	4,000
B15Rev	8,000	7,200	6,400	8,000	7,200	6,400
SC1Rev	5,900	5,310	4,720	5,900	5,310	4,720

TEC2030 10a	Gone Green			Slow Progression		
Model Boundary	Winter	Spr/Aut	Summer	Winter	Spr/Aut	Summer
B6L0	8,000	7,200	6,400	8,000	7,200	6,400
B10	5,900	5,310	4,720	5,900	5,310	4,720
B12	8,300	7,470	6,640	7,200	6,480	5,760
B13	5,500	4,950	4,400	5,500	4,950	4,400
B14	10,800	9,720	8,640	10,800	9,720	8,640
B15	8,000	7,200	6,400	8,000	7,200	6,400
B17	5,500	4,950	4,400	7,100	6,390	5,680
DB1	1,000	1,000	1,000	1,000	1,000	1,000
DB2	1,000	1,000	1,000	1,000	1,000	1,000
DB3	1,000	1,000	1,000	1,000	1,000	1,000
DB4	1,000	1,000	1,000	1,000	1,000	1,000
DB5	1,000	1,000	1,000	1,000	1,000	1,000
DB6	1,000	1,000	1,000	1,000	1,000	1,000
H1	1,000	1,000	1,000	1,000	1,000	1,000
H2	1,000	1,000	1,000	1,000	1,000	1,000
H3	1,000	1,000	1,000	1,000	1,000	1,000
H4	1,000	1,000	1,000	1,000	1,000	1,000
EA1	1,200	1,200	1,200	1,200	1,200	1,200
EA2	900	900	900	900	900	900
EA3	1,200	1,200	1,200	1,200	1,200	1,200
EA4	1,200	1,200	1,200	1,200	1,200	1,200
EA25	1,800	1,800	1,800	1,800	1,800	1,800
EA6	1,800	1,800	1,800	1,800	1,800	1,800
B7DB123456L0	11,100	10,240	9,380	11,100	10,240	9,380
B7aDB123456L0	10,900	10,060	9,220	10,900	10,060	9,220
B8DB123456H12	13,400	12,060	10,720	13,400	12,060	10,720
B9DB123456H12	10,100	9,090	8,080	10,100	9,090	8,080
SC1	5,900	5,310	4,720	5,900	5,310	4,720
EC1	9,400	8,460	7,520	5,500	4,950	4,400
EC3	3,600	3,240	2,880	3,600	3,240	2,880
EC5	7,600	6,840	6,080	7,300	6,570	5,840
NW1	6,400	5,760	5,120	5,600	5,040	4,480
NW2	6,700	6,030	5,360	4,900	4,410	3,920
NW3	7,200	6,480	5,760	5,400	4,860	4,320
NW4	7,700	6,930	6,160	5,000	4,500	4,000
B15Rev	8,000	7,200	6,400	8,000	7,200	6,400
SC1Rev	5,900	5,310	4,720	5,900	5,310	4,720

TEC2030 10c	Gone Green			Slow Progression		
Model Boundary	Winter	Spr/Aut	Summer	Winter	Spr/Aut	Summer
B10	5,900	5,310	4,720	5,900	5,310	4,720
B12	8,300	7,470	6,640	7,200	6,480	5,760
B13	5,500	4,950	4,400	5,500	4,950	4,400
B14	10,800	9,720	8,640	10,800	9,720	8,640
B15	8,000	7,200	6,400	8,000	7,200	6,400
B17	5,500	4,950	4,400	7,100	6,390	5,680
DB1	1,000	1,000	1,000	1,000	1,000	1,000
DB2	1,000	1,000	1,000	1,000	1,000	1,000
DB3	1,000	1,000	1,000	1,000	1,000	1,000
DB4	1,400	1,400	1,400	1,400	1,400	1,400
DB45	2,000	2,000	2,000	2,000	2,000	2,000
DB456	3,000	3,000	3,000	3,000	3,000	3,000
DB5	1,000	1,000	1,000	1,000	1,000	1,000
DB56	2,000	2,000	2,000	2,000	2,000	2,000
DB6	2,600	2,600	2,600	2,600	2,600	2,600
H1	1,000	1,000	1,000	1,000	1,000	1,000
H2	1,400	1,400	1,400	1,400	1,400	1,400
H23	3,200	3,200	3,200	3,200	3,200	3,200
H3	2,200	2,200	2,200	2,200	2,200	2,200
H4	1,000	1,000	1,000	1,000	1,000	1,000
H34	2,200	2,200	2,200	2,200	2,200	2,200
H234	3,200	3,200	3,200	3,200	3,200	3,200
EA1	1,800	1,800	1,800	1,800	1,800	1,800
EA2	900	900	900	900	900	900
EA25	1,800	1,800	1,800	1,800	1,800	1,800
EA4	1,800	1,800	1,800	1,800	1,800	1,800
EA5	1,800	1,800	1,800	1,800	1,800	1,800
EA6	1,800	1,800	1,800	1,800	1,800	1,800
B6L0	10,500	9,700	8,900	10,500	9,700	8,900
B7DB236L0	12,700	11,760	10,820	12,700	11,760	10,820
B7DB2356L0	12,100	11,160	10,220	12,100	11,160	10,220
B7DB23456L0	13,100	12,160	11,220	13,100	12,160	11,220
B7aDB236L0	12,800	11,850	10,900	12,800	11,850	10,900
B7aDB2356L0	12,200	11,250	10,300	12,200	11,250	10,300
B7aDB23456L0	13,200	12,250	11,300	13,200	12,250	11,300
B8DB123456H12	14,700	13,250	11,800	14,700	13,250	11,800
B8DB123456H1234	16,500	15,050	13,600	16,500	15,050	13,600
B9DB123456H12	11,500	10,370	9,240	11,500	10,370	9,240
B9DB123456H1234	13,300	12,170	11,040	13,300	12,170	11,040
SC1	5,900	5,310	4,720	5,900	5,310	4,720
EC1	9,400	8,460	7,520	5,500	4,950	4,400
EC3	3,600	3,240	2,880	3,600	3,240	2,880
EC5	7,600	6,840	6,080	7,300	6,570	5,840
NW1	6,400	5,760	5,120	5,600	5,040	4,480
NW2	6,700	6,030	5,360	4,900	4,410	3,920
NW3	7,200	6,480	5,760	5,400	4,860	4,320
NW4	7,700	6,930	6,160	5,000	4,500	4,000
B15Rev	8,000	7,200	6,400	8,000	7,200	6,400
SC1Rev	5,900	5,310	4,720	5,900	5,310	4,720

TEC2030 13a	Gone Green			Slow Progression		
Model Boundary	Winter	Spr/Aut	Summer	Winter	Spr/Aut	Summer
B6L0	10,500	9,700	8,900	10,500	9,700	8,900
B10	5,900	5,310	4,720	5,900	5,310	4,720
B12	8,300	7,470	6,640	6,800	6,120	5,440
B13	5,500	4,950	4,400	2,300	2,070	1,840
B14	10,800	9,720	8,640	10,400	9,360	8,320
B15	8,000	7,200	6,400	8,600	7,740	6,880
B17	5,500	4,950	4,400	5,700	5,130	4,560
DB1	1,300	1,300	1,300	1,300	1,300	1,300
DB2	1,300	1,300	1,300	1,300	1,300	1,300
DB3	300	300	300	300	300	300
DB4	1,300	1,300	1,300	1,300	1,300	1,300
DB5	1,000	1,000	1,000	1,000	1,000	1,000
DB6	1,000	1,000	1,000	1,000	1,000	1,000
H1	1,300	1,300	1,300	1,300	1,300	1,300
H2	1,600	1,600	1,600	1,600	1,600	1,600
H3	1,300	1,300	1,300	1,300	1,300	1,300
H4	1,600	1,600	1,600	1,600	1,600	1,600
EA1	1,200	1,200	1,200	1,200	1,200	1,200
EA2	900	900	900	900	900	900
EA3	1,200	1,200	1,200	1,200	1,200	1,200
EA4	1,200	1,200	1,200	1,200	1,200	1,200
EA25	1,800	1,800	1,800	1,800	1,800	1,800
EA6	1,800	1,800	1,800	1,800	1,800	1,800
EA5	1,800	1,800	1,800	1,800	1,800	1,800
B7DB2356L0	12,500	11,560	10,620	12,500	11,560	10,620
B7DB123456L0	13,900	12,960	12,020	13,900	12,960	12,020
B7aDB2356L0	12,600	11,650	10,700	12,600	11,650	10,700
B7aDB123456L0	14,000	13,050	12,100	14,000	13,050	12,100
B8DB123456H3	11,600	10,470	9,340	11,600	10,470	9,340
B8DB123456H13	12,300	11,170	10,040	12,300	11,170	10,040
B8DB123456H123	12,900	11,770	10,640	12,900	11,770	10,640
B8DB123456H1234	13,300	12,170	11,040	13,300	12,170	11,040
B9DB123456H3	8,400	7,590	6,780	8,400	7,590	6,780
B9DB123456H13	9,100	8,290	7,480	9,100	8,290	7,480
B9DB123456H123	9,700	8,890	8,080	9,700	8,890	8,080
B9DB123456H1234	10,100	9,290	8,480	10,100	9,290	8,480
DB34	1,000	1,000	1,000	1,000	1,000	1,000
DB12	2,000	2,000	2,000	2,000	2,000	2,000
SC1	5,900	5,310	4,720	5,900	5,310	4,720
EC1	9,400	8,460	7,520	5,500	4,950	4,400
EC3	3,600	3,240	2,880	3,600	3,240	2,880
EC5	7,600	6,840	6,080	3,000	2,700	2,400
NW1	6,400	5,760	5,120	1,800	1,620	1,440
NW2	6,700	6,030	5,360	4,900	4,410	3,920
NW3	7,200	6,480	5,760	5,400	4,860	4,320
NW4	7,700	6,930	6,160	6,700	6,030	5,360
B15Rev	8,000	7,200	6,400	8,600	7,740	6,880
SC1Rev	5,900	5,310	4,720	5,900	5,310	4,720

TEC2030 13c	Gone Green			Slow Progression		
	Winter	Spr/Aut	Summer	Winter	Spr/Aut	Summer
B6L0	10,500	9,700	8,900	10,500	9,700	8,900
B10	5,900	5,310	4,720	5,900	5,310	4,720
B12	8,300	7,470	6,640	7,200	6,480	5,760
B13	5,500	4,950	4,400	5,500	4,950	4,400
B14	10,800	9,720	8,640	10,800	9,720	8,640
B15	8,000	7,200	6,400	8,000	7,200	6,400
B17	5,500	4,950	4,400	7,100	6,390	5,680
DB1	1,300	1,300	1,300	1,300	1,300	1,300
DB2	1,300	1,300	1,300	1,300	1,300	1,300
DB3	300	300	300	300	300	300
DB4	1,800	1,800	1,800	1,800	1,800	1,800
DB5	1,100	1,100	1,100	1,100	1,100	1,100
DB6	2,600	2,600	2,600	2,600	2,600	2,600
H1	1,000	1,000	1,000	1,000	1,000	1,000
H2	1,500	1,500	1,500	1,500	1,500	1,500
H3	2,300	2,300	2,300	2,300	2,300	2,300
H4	1,000	1,000	1,000	1,000	1,000	1,000
EA13a	1,800	1,800	1,800	1,800	1,800	1,800
EA2	900	900	900	900	900	900
H23	3,200	3,200	3,200	3,200	3,200	3,200
EA43b	1,800	1,800	1,800	1,800	1,800	1,800
EA25	1,800	1,800	1,800	1,800	1,800	1,800
EA6	1,800	1,800	1,800	1,800	1,800	1,800
EA5	1,800	1,800	1,800	1,800	1,800	1,800
B7DB2356L0	12,800	11,860	10,920	12,800	11,860	10,920
B7DB123456L0	14,100	13,160	12,220	14,100	13,160	12,220
B7aDB2356L0	12,900	11,950	11,000	12,900	11,950	11,000
B7aDB123456L0	14,200	13,250	12,300	14,200	13,250	12,300
B8DB123456H124	12,600	11,470	10,340	12,600	11,470	10,340
B8DB123456H1234	13,300	12,170	11,040	13,300	12,170	11,040
DB56	2,100	2,100	2,100	2,100	2,100	2,100
DB456	3,300	3,300	3,300	3,300	3,300	3,300
B9DB123456H124	9,400	8,590	7,780	9,400	8,590	7,780
B9DB123456H1234	10,100	9,290	8,480	10,100	9,290	8,480
DB3456	3,000	3,000	3,000	3,000	3,000	3,000
DB45	2,300	2,300	2,300	2,300	2,300	2,300
DB34	1,500	1,500	1,500	1,500	1,500	1,500
DB12	2,000	2,000	2,000	2,000	2,000	2,000
DB345	2,000	2,000	2,000	2,000	2,000	2,000
H34	2,300	2,300	2,300	2,300	2,300	2,300
H234	3,200	3,200	3,200	3,200	3,200	3,200
SC1	5,900	5,310	4,720	5,900	5,310	4,720
EC1	9,400	8,460	7,520	5,500	4,950	4,400
EC3	3,600	3,240	2,880	3,600	3,240	2,880
EC5	7,600	6,840	6,080	7,300	6,570	5,840
NW1	6,400	5,760	5,120	5,600	5,040	4,480
NW2	6,700	6,030	5,360	4,900	4,410	3,920
NW3	7,200	6,480	5,760	5,400	4,860	4,320
NW4	7,700	6,930	6,160	5,000	4,500	4,000
B15Rev	8,000	7,200	6,400	8,000	7,200	6,400
SC1Rev	5,900	5,310	4,720	5,900	5,310	4,720

TEC2030 15a (Opt)	Gone Green			Slow Progression		
Model Boundary	Winter	Spr/Aut	Summer	Winter	Spr/Aut	Summer
B10	5,900	5,310	4,720	5,900	5,310	4,720
B12	8,300	7,470	6,640	7,200	6,480	5,760
B13	5,500	4,950	4,400	5,500	4,950	4,400
B14	10,800	9,720	8,640	10,800	9,720	8,640
B15	8,000	7,200	6,400	8,000	7,200	6,400
B17	5,500	4,950	4,400	7,100	6,390	5,680
DB3L1	7,000	7,000	7,000	7,000	7,000	7,000
DB3	1,600	1,600	1,600	1,600	1,600	1,600
DB34	3,900	3,900	3,900	3,900	3,900	3,900
DB36L1	6,700	6,700	6,700	6,700	6,700	6,700
DB35L1	7,700	7,700	7,700	7,700	7,700	7,700
DB13L1	8,000	8,000	8,000	8,000	8,000	8,000
DB123L1	9,000	9,000	9,000	9,000	9,000	9,000
DB34L1	7,700	7,700	7,700	7,700	7,700	7,700
DB345L1	8,400	8,400	8,400	8,400	8,400	8,400
DB346L1	8,400	8,400	8,400	8,400	8,400	8,400
DB134L1	9,000	9,000	9,000	9,000	9,000	9,000
DB1234L1	9,700	9,700	9,700	9,700	9,700	9,700
DB6	1,300	1,300	1,300	1,300	1,300	1,300
DB6L1	6,700	6,700	6,700	6,700	6,700	6,700
DB56L1	7,400	7,400	7,400	7,400	7,400	7,400
DB1	2,900	2,900	2,900	2,900	2,900	2,900
DB12L1	8,000	8,000	8,000	8,000	8,000	8,000
DB15L1	8,000	8,000	8,000	8,000	8,000	8,000
DB16L1	8,000	8,000	8,000	8,000	8,000	8,000
DB5	1,300	1,300	1,300	1,300	1,300	1,300
DB5L1	6,700	6,700	6,700	6,700	6,700	6,700
DB2	1,300	1,300	1,300	1,300	1,300	1,300
DB12	3,600	3,600	3,600	3,600	3,600	3,600
DB125L1	8,700	8,700	8,700	8,700	8,700	8,700
DB126L1	8,700	8,700	8,700	8,700	8,700	8,700
DB4	2,900	2,900	2,900	2,900	2,900	2,900
DB4L1	7,300	7,300	7,300	7,300	7,300	7,300
DB46L1	8,000	8,000	8,000	8,000	8,000	8,000
DB45L1	8,000	8,000	8,000	8,000	8,000	8,000
DB14L1	8,600	8,600	8,600	8,600	8,600	8,600
DB124L1	9,300	9,300	9,300	9,300	9,300	9,300
EA14L3	3,700	3,700	3,700	3,700	3,700	3,700
EA13L3	3,700	3,700	3,700	3,700	3,700	3,700
EA3	1,500	1,500	1,500	1,500	1,500	1,500
EA1	1,500	1,500	1,500	1,500	1,500	1,500
EA1L3	2,800	2,800	2,800	2,800	2,800	2,800
EA3L3	2,800	2,800	2,800	2,800	2,800	2,800
EA134L3	4,600	4,600	4,600	4,600	4,600	4,600
EA34L3	3,700	3,700	3,700	3,700	3,700	3,700
EA4	1,500	1,500	1,500	1,500	1,500	1,500
EA4L3	2,800	2,800	2,800	2,800	2,800	2,800
EA2	900	900	900	900	900	900
EA5	1,800	1,800	1,800	1,800	1,800	1,800
EA6	1,800	1,800	1,800	1,800	1,800	1,800
EA25	1,800	1,800	1,800	1,800	1,800	1,800
H3	1,800	1,800	1,800	1,800	1,800	1,800
H1	1,300	1,300	1,300	1,300	1,300	1,300
H2	1,600	1,600	1,600	1,600	1,600	1,600
H4	2,100	2,100	2,100	2,100	2,100	2,100
H13	2,500	2,500	2,500	2,500	2,500	2,500
H24	2,500	2,500	2,500	2,500	2,500	2,500
EA134H4L23	6,700	6,700	6,700	6,700	6,700	6,700
EA134H24L23	7,100	7,100	7,100	7,100	7,100	7,100
EA134L23	5,600	5,600	5,600	5,600	5,600	5,600

EA134H1234DB34L123	14,300	14,300	14,300	14,300	14,300	14,300
EA134H1234DB12L123	16,700	16,700	16,700	16,700	16,700	16,700
EA134H1234L123	12,600	12,600	12,600	12,600	12,600	12,600
EA134H1234DB6L123	13,300	13,300	13,300	13,300	13,300	13,300
EA134H1234DB5L123	13,300	13,300	13,300	13,300	13,300	13,300
EA134H1234DB4L123	13,900	13,900	13,900	13,900	13,900	13,900
EA134H1234DB3L123	13,600	13,600	13,600	13,600	13,600	13,600
EA134H1234DB1L123	13,900	13,900	13,900	13,900	13,900	13,900
DB123456L12	12,100	12,100	12,100	12,100	12,100	12,100
DB123456L1	11,100	11,100	11,100	11,100	11,100	11,100
DB123456H4L12	13,200	13,200	13,200	13,200	13,200	13,200
DB123456H24L12	13,600	13,600	13,600	13,600	13,600	13,600
DB123456H3L12	12,900	12,900	12,900	12,900	12,900	12,900
DB123456H13L12	13,600	13,600	13,600	13,600	13,600	13,600
DB123456H1234L123	15,000	15,000	15,000	15,000	15,000	15,000
DB123456H1234EA4L123	15,900	15,900	15,900	15,900	15,900	15,900
DB123456H1234EA3L123	15,900	15,900	15,900	15,900	15,900	15,900
DB123456H1234EA1L123	15,900	15,900	15,900	15,900	15,900	15,900
B6L0	10,500	9,700	8,900	10,500	9,700	8,900
B6DB123456L01	16,600	15,800	15,000	16,600	15,800	15,000
B6L01	11,500	10,700	9,900	11,500	10,700	9,900
B6DB14L01	14,100	13,300	12,500	14,100	13,300	12,500
B7DB2356L01	12,600	11,660	10,720	12,600	11,660	10,720
B7DB123456L01	14,000	13,060	12,120	14,000	13,060	12,120
B7DB123456L012	15,000	14,060	13,120	15,000	14,060	13,120
B7DB123456H34L012	16,900	15,960	15,020	16,900	15,960	15,020
B7DB123456H1234L012	18,000	17,060	16,120	18,000	17,060	16,120
B7aDB2356L01	12,700	11,750	10,800	12,700	11,750	10,800
B7aDB123456L01	14,100	13,150	12,200	14,100	13,150	12,200
B7aDB123456L012	15,100	14,150	13,200	15,100	14,150	13,200
B7aDB123456H34L012	17,000	16,050	15,100	17,000	16,050	15,100
B7aDB123456H1234L012	18,100	17,150	16,200	18,100	17,150	16,200
B8DB123456H13L012	13,800	12,670	11,540	13,800	12,670	11,540
B8DB123456H1234L012	14,300	13,170	12,040	14,300	13,170	12,040
B8DB123456H1234L0123	14,200	13,070	11,940	14,200	13,070	11,940
B8DB123456H1234EA134L0123	16,900	15,770	14,640	16,900	15,770	14,640
B9DB123456H13L012	10,600	9,790	8,980	10,600	9,790	8,980
B9DB123456H1234L012	11,100	10,290	9,480	11,100	10,290	9,480
B9DB123456H1234L0123	11,000	10,190	9,380	11,000	10,190	9,380
B9DB123456H1234EA134L0123	13,700	12,890	12,080	13,700	12,890	12,080
EA134H13L23	7,100	7,100	7,100	7,100	7,100	7,100
EA134H3L23	6,400	6,400	6,400	6,400	6,400	6,400
B6DB3L01	12,500	11,700	10,900	12,500	11,700	10,900
SC1	5,900	5,310	4,720	5,900	5,310	4,720
EC1	9,400	8,460	7,520	5,500	4,950	4,400
EC3	3,600	3,240	2,880	3,600	3,240	2,880
EC5	7,600	6,840	6,080	7,300	6,570	5,840
NW1	6,400	5,760	5,120	5,600	5,040	4,480
NW2	6,700	6,030	5,360	4,900	4,410	3,920
NW3	7,200	6,480	5,760	5,400	4,860	4,320
NW4	7,700	6,930	6,160	5,000	4,500	4,000
B15Rev	8,000	7,200	6,400	8,000	7,200	6,400
SC1Rev	5,900	5,310	4,720	5,900	5,310	4,720

TEC2030 15c (Opt)	Gone Green			Slow Progression		
Model Boundary	Winter	Spr/Aut	Summer	Winter	Spr/Aut	Summer
EA13A43BL3	4,600	4,600	4,600	4,600	4,600	4,600
EA13A	2,100	2,100	2,100	2,100	2,100	2,100
EA43BL3	3,100	3,100	3,100	3,100	3,100	3,100
EA25	1,800	1,800	1,800	1,800	1,800	1,800
EA13AL3	3,400	3,400	3,400	3,400	3,400	3,400
EA2	900	900	900	900	900	900
EA13A43B	4,500	4,500	4,500	4,500	4,500	4,500
EA6	1,800	1,800	1,800	1,800	1,800	1,800
B10	5,900	5,310	4,720	5,900	5,310	4,720
EA13A43BH34L23	6,900	6,900	6,900	6,900	6,900	6,900
B12	8,300	7,470	6,640	7,200	6,480	5,760
B13	5,500	4,950	4,400	5,500	4,950	4,400
B14	10,800	9,720	8,640	10,800	9,720	8,640
B15	8,000	7,200	6,400	8,000	7,200	6,400
EA13A43BH4L23	5,600	5,600	5,600	5,600	5,600	5,600
B17	5,500	4,950	4,400	7,100	6,390	5,680
B9DB123456H1234EA13A43BL0123	13,700	12,890	12,080	13,700	12,890	12,080
B9DB123456H1234L0123	11,000	10,190	9,380	11,000	10,190	9,380
B9DB123456H1234L012	11,100	10,290	9,480	11,100	10,290	9,480
B9DB123456H134L012	11,400	10,590	9,780	11,400	10,590	9,780
B8DB123456H1234L012	16,900	15,770	14,640	16,900	15,770	14,640
B8DB123456H1234L0123	14,200	13,070	11,940	14,200	13,070	11,940
B8DB123456H1234L012	14,300	13,170	12,040	14,300	13,170	12,040
B8DB123456H134L012	14,600	13,470	12,340	14,600	13,470	12,340
B7aDB123456H234L012	17,300	16,350	15,400	17,300	16,350	15,400
B7aDB123456H34L012	16,400	15,450	14,500	16,400	15,450	14,500
B7aDB123456H4L012	15,100	14,150	13,200	15,100	14,150	13,200
B7aDB123456L012	14,700	13,750	12,800	14,700	13,750	12,800
B7aDB123456L01	14,100	13,150	12,200	14,100	13,150	12,200
B7aDB2356L01	13,000	12,050	11,100	13,000	12,050	11,100
B7DB123456H234L012	17,200	16,260	15,320	17,200	16,260	15,320
B7DB123456H34L012	16,300	15,360	14,420	16,300	15,360	14,420
B7DB123456H4L012	15,000	14,060	13,120	15,000	14,060	13,120
B7DB123456L012	14,600	13,660	12,720	14,600	13,660	12,720
B7DB123456L01	14,000	13,060	12,120	14,000	13,060	12,120
B7DB2356L01	12,900	11,960	11,020	12,900	11,960	11,020
B6DB35L01	13,600	12,800	12,000	13,600	12,800	12,000
B6DB146L01	15,600	14,800	14,000	15,600	14,800	14,000
B6DB123456L01	16,400	15,600	14,800	16,400	15,600	14,800
B6L01	11,200	10,400	9,600	11,200	10,400	9,600
B6L0	10,500	9,700	8,900	10,500	9,700	8,900
DB123456H234L12	14,100	14,100	14,100	14,100	14,100	14,100
DB123456H34L12	13,200	13,200	13,200	13,200	13,200	13,200
DB123456H4L12	11,900	11,900	11,900	11,900	11,900	11,900
DB123456H234EA13AL123	15,500	15,500	15,500	15,500	15,500	15,500
DB123456H234EA43BL123	15,200	15,200	15,200	15,200	15,200	15,200
DB123456L123	11,400	11,400	11,400	11,400	11,400	11,400
DB123456L12	11,500	11,500	11,500	11,500	11,500	11,500
DB6L1	8,000	8,000	8,000	8,000	8,000	8,000
DB6	2,900	2,900	2,900	2,900	2,900	2,900
DB45L1	7,800	7,800	7,800	7,800	7,800	7,800
DB56L1	7,200	7,200	7,200	7,200	7,200	7,200
DB56	2,400	2,400	2,400	2,400	2,400	2,400
DB5	1,100	1,100	1,100	1,100	1,100	1,100
DB456L1	8,500	8,500	8,500	8,500	8,500	8,500
DB456	5,000	5,000	5,000	5,000	5,000	5,000
DB45	3,700	3,700	3,700	3,700	3,700	3,700
DB4L1	7,300	7,300	7,300	7,300	7,300	7,300
DB46L1	9,600	9,600	9,600	9,600	9,600	9,600
DB4	3,200	3,200	3,200	3,200	3,200	3,200

DB356L1	8,500	8,500	8,500	8,500	8,500	8,500
DB36L1	9,000	9,000	9,000	9,000	9,000	9,000
DB345L1	8,200	8,200	8,200	8,200	8,200	8,200
DB3L1	6,700	6,700	6,700	6,700	6,700	6,700
DB346L1	10,000	10,000	10,000	10,000	10,000	10,000
DB34L1	7,700	7,700	7,700	7,700	7,700	7,700
DB3456L1	8,900	8,900	8,900	8,900	8,900	8,900
DB3456	6,000	6,000	6,000	6,000	6,000	6,000
DB345	4,700	4,700	4,700	4,700	4,700	4,700
DB34	4,200	4,200	4,200	4,200	4,200	4,200
DB3	1,600	1,600	1,600	1,600	1,600	1,600
DB1256L1	9,200	9,200	9,200	9,200	9,200	9,200
DB126L1	9,700	9,700	9,700	9,700	9,700	9,700
DB12456L1	10,500	10,500	10,500	10,500	10,500	10,500
DB1245L1	9,800	9,800	9,800	9,800	9,800	9,800
DB124L1	9,300	9,300	9,300	9,300	9,300	9,300
DB123456L1	10,900	10,900	10,900	10,900	10,900	10,900
DB12345L1	10,200	10,200	10,200	10,200	10,200	10,200
DB1234L1	9,700	9,700	9,700	9,700	9,700	9,700
DB123L1	8,400	8,400	8,400	8,400	8,400	8,400
DB12L1	7,700	7,700	7,700	7,700	7,700	7,700
DB2	1,300	1,300	1,300	1,300	1,300	1,300
DB156L1	8,500	8,500	8,500	8,500	8,500	8,500
DB16L1	9,000	9,000	9,000	9,000	9,000	9,000
DB13456L1	10,200	10,200	10,200	10,200	10,200	10,200
DB1345L1	9,500	9,500	9,500	9,500	9,500	9,500
DB13L1	8,000	8,000	8,000	8,000	8,000	8,000
DB1456L1	9,800	9,800	9,800	9,800	9,800	9,800
DB145L1	9,100	9,100	9,100	9,100	9,100	9,100
DB134L1	9,000	9,000	9,000	9,000	9,000	9,000
DB14L1	8,600	8,600	8,600	8,600	8,600	8,600
DB1L1	7,000	7,000	7,000	7,000	7,000	7,000
DB12	3,600	3,600	3,600	3,600	3,600	3,600
DB1	2,900	2,900	2,900	2,900	2,900	2,900
H4L2	3,000	3,000	3,000	3,000	3,000	3,000
H234L2	5,200	5,200	5,200	5,200	5,200	5,200
H4	1,600	1,600	1,600	1,600	1,600	1,600
H234	3,800	3,800	3,800	3,800	3,800	3,800
H34L2	4,300	4,300	4,300	4,300	4,300	4,300
H23	4,200	4,200	4,200	4,200	4,200	4,200
H34	2,900	2,900	2,900	2,900	2,900	2,900
H2	1,500	1,500	1,500	1,500	1,500	1,500
H3	3,300	3,300	3,300	3,300	3,300	3,300
H1	1,000	1,000	1,000	1,000	1,000	1,000
EA13A43BH234DB45L123	13,600	13,600	13,600	13,600	13,600	13,600
EA13A43BH234DB4L123	13,100	13,100	13,100	13,100	13,100	13,100
EA13A43BH234DB3456L123	14,700	14,700	14,700	14,700	14,700	14,700
EA13A43BH234DB34L123	13,500	13,500	13,500	13,500	13,500	13,500
EA13A43BH234DB56L123	13,300	13,300	13,300	13,300	13,300	13,300
EA13A43BH234DB3L123	12,500	12,500	12,500	12,500	12,500	12,500
EA13A43BH234DB6L123	13,800	13,800	13,800	13,800	13,800	13,800
EA13A43BH234DB12L123	13,500	13,500	13,500	13,500	13,500	13,500
EA13A43BH234DB456L123	14,300	14,300	14,300	14,300	14,300	14,300
EA13A43BH234DB1L123	12,800	12,800	12,800	12,800	12,800	12,800
EA13A43BH234L123	11,500	11,500	11,500	11,500	11,500	11,500
EA13A43BH234L23	7,800	7,800	7,800	7,800	7,800	7,800
SC1	5,900	5,310	4,720	5,900	5,310	4,720
EC1	9,400	8,460	7,520	5,500	4,950	4,400
EC3	3,600	3,240	2,880	3,600	3,240	2,880
EC5	7,600	6,840	6,080	7,300	6,570	5,840
EA13A43BL23	5,200	5,200	5,200	5,200	5,200	5,200
EA43B	2,400	2,400	2,400	2,400	2,400	2,400
NW1	6,400	5,760	5,120	5,600	5,040	4,480
NW2	6,700	6,030	5,360	4,900	4,410	3,920
NW3	7,200	6,480	5,760	5,400	4,860	4,320
NW4	7,700	6,930	6,160	5,000	4,500	4,000
B15Rev	8,000	7,200	6,400	8,000	7,200	6,400
SC1Rev	5,900	5,310	4,720	5,900	5,310	4,720

CENTRAL2030 Radial	Gone Green			Slow Progression		
Model Boundary	Winter	Spr/Aut	Summer	Winter	Spr/Aut	Summer
B6	8,500	7,650	6,800	8,500	7,650	6,800
B10	5,900	5,310	4,720	5,900	5,310	4,720
B12	8,300	7,470	6,640	7,200	6,480	5,760
B13	5,500	4,950	4,400	5,500	4,950	4,400
B14	10,800	9,720	8,640	10,800	9,720	8,640
B15	8,000	7,200	6,400	8,000	7,200	6,400
B17	5,500	4,950	4,400	7,100	6,390	5,680
DB1	1,000	1,000	1,000	1,000	1,000	1,000
DB2	1,000	1,000	1,000	1,000	1,000	1,000
DB4	1,000	1,000	1,000	1,000	1,000	1,000
H1	1,000	1,000	1,000	1,000	1,000	1,000
H2	1,000	1,000	1,000	1,000	1,000	1,000
H3	1,000	1,000	1,000	1,000	1,000	1,000
EA1	1,200	1,200	1,200	1,200	1,200	1,200
EA3	1,200	1,200	1,200	1,200	1,200	1,200
EA4	800	800	800	800	800	800
B7DB23	8,000	7,200	6,400	8,000	7,200	6,400
B7DB1234	10,000	9,200	8,400	10,000	9,200	8,400
B7aDB23	8,800	7,920	7,040	8,800	7,920	7,040
B7aDB1234	10,800	9,920	9,040	10,800	9,920	9,040
B8DB1234H12	11,000	9,900	8,800	11,000	9,900	8,800
B8DB1234H123	12,000	10,900	9,800	12,000	10,900	9,800
B9DB1234H12	8,800	7,920	7,040	8,800	7,920	7,040
B9DB1234H123	9,800	8,920	8,040	9,800	8,920	8,040
SC1	5,900	5,310	4,720	5,900	5,310	4,720
EC1	9,400	8,460	7,520	5,500	4,950	4,400
EC3	3,600	3,240	2,880	3,600	3,240	2,880
EC5	7,600	6,840	6,080	7,300	6,570	5,840
NW1	6,400	5,760	5,120	5,600	5,040	4,480
NW2	6,700	6,030	5,360	4,900	4,410	3,920
NW3	7,200	6,480	5,760	5,400	4,860	4,320
NW4	7,700	6,930	6,160	5,000	4,500	4,000
B15Rev	8,000	7,200	6,400	8,000	7,200	6,400
SC1Rev	5,900	5,310	4,720	5,900	5,310	4,720

CENTRAL2030 2a	**Gone Green**			**Slow Progression**		
Model Boundary	Winter	Spr/Aut	Summer	Winter	Spr/Aut	Summer
B10	5,900	5,310	4,720	5,900	5,310	4,720
B12	8,300	7,470	6,640	7,200	6,480	5,760
B13	5,500	4,950	4,400	5,500	4,950	4,400
B14	10,800	9,720	8,640	10,800	9,720	8,640
B15	8,000	7,200	6,400	8,000	7,200	6,400
B17	5,500	4,950	4,400	7,100	6,390	5,680
DB1	1,000	1,000	1,000	1,000	1,000	1,000
DB2	1,000	1,000	1,000	1,000	1,000	1,000
DB3	1,000	1,000	1,000	1,000	1,000	1,000
DB4	1,000	1,000	1,000	1,000	1,000	1,000
H1	1,000	1,000	1,000	1,000	1,000	1,000
H2	1,000	1,000	1,000	1,000	1,000	1,000
H3	1,000	1,000	1,000	1,000	1,000	1,000
EA1	1,200	1,200	1,200	1,200	1,200	1,200
EA3	1,200	1,200	1,200	1,200	1,200	1,200
EA4	800	800	800	800	800	800
B6L0	11,000	10,150	9,300	11,000	10,150	9,300
B7DB23L0	10,500	9,700	8,900	10,500	9,700	8,900
B7aDB23L0	11,300	10,420	9,540	11,300	10,420	9,540
B8DB1234H123L0	14,500	13,400	12,300	14,500	13,400	12,300
B8DB1234H12L0	13,500	12,400	11,300	13,500	12,400	11,300
B9DB1234H123L0	12,300	11,420	10,540	12,300	11,420	10,540
B9DB1234H12L0	11,300	10,420	9,540	11,300	10,420	9,540
SC1	5,900	5,310	4,720	5,900	5,310	4,720
EC1	9,400	8,460	7,520	5,500	4,950	4,400
EC3	3,600	3,240	2,880	3,600	3,240	2,880
EC5	7,600	6,840	6,080	7,300	6,570	5,840
NW1	6,400	5,760	5,120	5,600	5,040	4,480
NW2	6,700	6,030	5,360	4,900	4,410	3,920
NW3	7,200	6,480	5,760	5,400	4,860	4,320
NW4	7,700	6,930	6,160	5,000	4,500	4,000
B15Rev	8,000	7,200	6,400	8,000	7,200	6,400
SC1Rev	5,900	5,310	4,720	5,900	5,310	4,720

CENTRAL2030 2c	Gone Green			Slow Progression		
Model Boundary	Winter	Spr/Aut	Summer	Winter	Spr/Aut	Summer
B10	5,900	5,310	4,720	5,900	5,310	4,720
B12	8,300	7,470	6,640	7,200	6,480	5,760
B13	5,500	4,950	4,400	5,500	4,950	4,400
B14	10,800	9,720	8,640	10,800	9,720	8,640
B15	8,000	7,200	6,400	8,000	7,200	6,400
B17	5,500	4,950	4,400	7,100	6,390	5,680
DB1	1,000	1,000	1,000	1,000	1,000	1,000
DB2	1,000	1,000	1,000	1,000	1,000	1,000
DB23	2,300	2,300	2,300	2,300	2,300	2,300
DB234	3,000	3,000	3,000	3,000	3,000	3,000
DB3	2,300	2,300	2,300	2,300	2,300	2,300
DB34	3,000	3,000	3,000	3,000	3,000	3,000
DB4	1,300	1,300	1,300	1,300	1,300	1,300
H1	1,300	1,300	1,300	1,300	1,300	1,300
H13	2,000	2,000	2,000	2,000	2,000	2,000
H123	3,000	3,000	3,000	3,000	3,000	3,000
H2	3,000	3,000	3,000	3,000	3,000	3,000
H23	2,300	2,300	2,300	2,300	2,300	2,300
H3	1,300	1,300	1,300	1,300	1,300	1,300
EA1	1,500	1,500	1,500	1,500	1,500	1,500
EA13	3,000	3,000	3,000	3,000	3,000	3,000
EA3	2,100	2,100	2,100	2,100	2,100	2,100
EA4	800	800	800	800	800	800
EA34	2,100	2,100	2,100	2,100	2,100	2,100
EA134	3,000	3,000	3,000	3,000	3,000	3,000
B6L0	11,000	10,150	9,300	11,000	10,150	9,300
B6DB23L0	13,300	12,450	11,600	13,300	12,450	11,600
B7DB23L0	11,300	10,450	9,600	11,300	10,450	9,600
B7DB1234L0	12,000	11,150	10,300	12,000	11,150	10,300
B7aDB23L0	11,800	10,900	10,000	11,800	10,900	10,000
B7aDB1234L0	12,500	11,600	10,700	12,500	11,600	10,700
B8DB1234H1L0	16,800	15,400	14,000	16,800	15,400	14,000
B8DB1234H13L0	17,500	16,100	14,700	17,500	16,100	14,700
B8DB1234H123L0	18,500	17,100	15,700	18,500	17,100	15,700
B9DB1234H1L0	15,200	13,960	12,720	15,200	13,960	12,720
B9DB1234H13L0	15,900	14,660	13,420	15,900	14,660	13,420
B9DB1234H123L0	16,900	15,660	14,420	16,900	15,660	14,420
SC1	5,900	5,310	4,720	5,900	5,310	4,720
EC1	9,400	8,460	7,520	5,500	4,950	4,400
EC3	3,600	3,240	2,880	3,600	3,240	2,880
EC5	7,600	6,840	6,080	7,300	6,570	5,840
NW1	6,400	5,760	5,120	5,600	5,040	4,480
NW2	6,700	6,030	5,360	4,900	4,410	3,920
NW3	7,200	6,480	5,760	5,400	4,860	4,320
NW4	7,700	6,930	6,160	5,000	4,500	4,000
B15Rev	8,000	7,200	6,400	8,000	7,200	6,400
SC1Rev	5,900	5,310	4,720	5,900	5,310	4,720

CENTRAL2030 3a	Gone Green			Slow Progression		
Model Boundary	Winter	Spr/Aut	Summer	Winter	Spr/Aut	Summer
B6L0	11,000	10,150	9,300	11,000	10,150	9,300
B10	5,900	5,310	4,720	5,900	5,310	4,720
B12	8,300	7,470	6,640	7,200	6,480	5,760
B13	5,500	4,950	4,400	5,500	4,950	4,400
B14	10,800	9,720	8,640	10,800	9,720	8,640
B15	8,000	7,200	6,400	8,000	7,200	6,400
B17	5,500	4,950	4,400	7,100	6,390	5,680
DB1	1,000	1,000	1,000	1,000	1,000	1,000
DB2	1,000	1,000	1,000	1,000	1,000	1,000
DB3	1,000	1,000	1,000	1,000	1,000	1,000
DB4	1,000	1,000	1,000	1,000	1,000	1,000
H1	1,000	1,000	1,000	1,000	1,000	1,000
H2	1,000	1,000	1,000	1,000	1,000	1,000
H3	1,000	1,000	1,000	1,000	1,000	1,000
EA1	1,200	1,200	1,200	1,200	1,200	1,200
EA3	1,200	1,200	1,200	1,200	1,200	1,200
EA4	800	800	800	800	800	800
B7DB23L0	10,500	9,700	8,900	10,500	9,700	8,900
B7DB1234L0	12,500	11,700	10,900	12,500	11,700	10,900
B7aDB23L0	11,300	10,420	9,540	11,300	10,420	9,540
B7aDB1234L0	13,300	12,420	11,540	13,300	12,420	11,540
B8DB1234H12	12,700	11,430	10,160	12,700	11,430	10,160
B8DB1234H123	13,700	12,430	11,160	13,700	12,430	11,160
B9DB1234H12	10,800	9,720	8,640	10,800	9,720	8,640
B9DB1234H123	11,800	10,720	9,640	11,800	10,720	9,640
SC1	5,900	5,310	4,720	5,900	5,310	4,720
EC1	9,400	8,460	7,520	5,500	4,950	4,400
EC3	3,600	3,240	2,880	3,600	3,240	2,880
EC5	7,600	6,840	6,080	7,300	6,570	5,840
NW1	6,400	5,760	5,120	5,600	5,040	4,480
NW2	6,700	6,030	5,360	4,900	4,410	3,920
NW3	7,200	6,480	5,760	5,400	4,860	4,320
NW4	7,700	6,930	6,160	5,000	4,500	4,000
B15Rev	8,000	7,200	6,400	8,000	7,200	6,400
SC1Rev	5,900	5,310	4,720	5,900	5,310	4,720

CENTRAL2030 4a	Gone Green			Slow Progression		
Model Boundary	Winter	Spr/Aut	Summer	Winter	Spr/Aut	Summer
B6L0	11,000	10,150	9,300	11,000	10,150	9,300
B10	5,900	5,310	4,720	5,900	5,310	4,720
B12	8,300	7,470	6,640	7,200	6,480	5,760
B13	5,500	4,950	4,400	5,500	4,950	4,400
B14	10,800	9,720	8,640	10,800	9,720	8,640
B15	8,000	7,200	6,400	8,000	7,200	6,400
B17	5,500	4,950	4,400	7,100	6,390	5,680
DB1	1,300	1,300	1,300	1,300	1,300	1,300
DB2	1,300	1,300	1,300	1,300	1,300	1,300
DB3	1,300	1,300	1,300	1,300	1,300	1,300
DB4	1,300	1,300	1,300	1,300	1,300	1,300
H1	1,000	1,000	1,000	1,000	1,000	1,000
H2	1,300	1,300	1,300	1,300	1,300	1,300
H3	1,300	1,300	1,300	1,300	1,300	1,300
EA1	1,200	1,200	1,200	1,200	1,200	1,200
EA3	1,200	1,200	1,200	1,200	1,200	1,200
EA4	800	800	800	800	800	800
B7DB23L0	11,600	10,750	9,900	11,600	10,750	9,900
B7DB1234L0	13,000	12,150	11,300	13,000	12,150	11,300
B7aDB23L0	12,100	11,200	10,300	12,100	11,200	10,300
B7aDB1234L0	13,500	12,600	11,700	13,500	12,600	11,700
B8DB1234H12	14,300	12,900	11,500	14,300	12,900	11,500
B8DB1234H123	15,000	13,600	12,200	15,000	13,600	12,200
B9DB1234H12	12,700	11,460	10,220	12,700	11,460	10,220
B9DB1234H123	13,400	12,160	10,920	13,400	12,160	10,920
DB12	2,000	2,000	2,000	2,000	2,000	2,000
DB34	2,000	2,000	2,000	2,000	2,000	2,000
H23	2,000	2,000	2,000	2,000	2,000	2,000
SC1	5,900	5,310	4,720	5,900	5,310	4,720
EC1	9,400	8,460	7,520	5,500	4,950	4,400
EC3	3,600	3,240	2,880	3,600	3,240	2,880
EC5	7,600	6,840	6,080	7,300	6,570	5,840
NW1	6,400	5,760	5,120	5,600	5,040	4,480
NW2	6,700	6,030	5,360	4,900	4,410	3,920
NW3	7,200	6,480	5,760	5,400	4,860	4,320
NW4	7,700	6,930	6,160	5,000	4,500	4,000
B15Rev	8,000	7,200	6,400	8,000	7,200	6,400
SC1Rev	5,900	5,310	4,720	5,900	5,310	4,720

CENTRAL2030 5a (Opt)	Gone Green			Slow Progression		
Model Boundary	Winter	Spr/Aut	Summer	Winter	Spr/Aut	Summer
B10	5,900	5,310	4,720	5,900	5,310	4,720
B12	8,300	7,470	6,640	7,200	6,480	5,760
B13	5,500	4,950	4,400	5,500	4,950	4,400
B14	10,800	9,720	8,640	10,800	9,720	8,640
B15	8,000	7,200	6,400	8,000	7,200	6,400
B17	5,500	4,950	4,400	7,100	6,390	5,680
DB1	2,600	2,600	2,600	2,600	2,600	2,600
DB2	1,300	1,300	1,300	1,300	1,300	1,300
DB3	1,300	1,300	1,300	1,300	1,300	1,300
DB4	2,600	2,600	2,600	2,600	2,600	2,600
DB1L1	6,700	6,700	6,700	6,700	6,700	6,700
DB12L1	7,400	7,400	7,400	7,400	7,400	7,400
DB13L1	7,400	7,400	7,400	7,400	7,400	7,400
DB14L1	7,700	7,700	7,700	7,700	7,700	7,700
DB2L1	6,400	6,400	6,400	6,400	6,400	6,400
DB23L1	7,100	7,100	7,100	7,100	7,100	7,100
DB24L1	7,400	7,400	7,400	7,400	7,400	7,400
DB3L1	6,400	6,400	6,400	6,400	6,400	6,400
DB34L1	7,400	7,400	7,400	7,400	7,400	7,400
DB4L1	6,700	6,700	6,700	6,700	6,700	6,700
H1	1,300	1,300	1,300	1,300	1,300	1,300
H2	1,300	1,300	1,300	1,300	1,300	1,300
H3	1,600	1,600	1,600	1,600	1,600	1,600
H13	2,300	2,300	2,300	2,300	2,300	2,300
H13L2	4,300	4,300	4,300	4,300	4,300	4,300
H3L2	3,600	3,600	3,600	3,600	3,600	3,600
H2L2	3,300	3,300	3,300	3,300	3,300	3,300
EA1	1,500	1,500	1,500	1,500	1,500	1,500
EA3	1,500	1,500	1,500	1,500	1,500	1,500
EA4	1,100	1,100	1,100	1,100	1,100	1,100
EA1L3	2,800	2,800	2,800	2,800	2,800	2,800
EA3L3	2,800	2,800	2,800	2,800	2,800	2,800
EA4L3	2,400	2,400	2,400	2,400	2,400	2,400
DB1234L12	9,700	9,700	9,700	9,700	9,700	9,700
DB1234H2L12	10,400	10,400	10,400	10,400	10,400	10,400
DB1234H3L12	10,400	10,400	10,400	10,400	10,400	10,400
DB1234H13L12	11,400	11,400	11,400	11,400	11,400	11,400
DB1234H123L123	12,000	12,000	12,000	12,000	12,000	12,000
DB1234H123EA1L123	12,900	12,900	12,900	12,900	12,900	12,900
DB1234H123EA3L123	12,900	12,900	12,900	12,900	12,900	12,900
DB1234H123EA4L123	12,500	12,500	12,500	12,500	12,500	12,500
EA134L23	4,800	4,800	4,800	4,800	4,800	4,800
EA134H2L23	5,500	5,500	5,500	5,500	5,500	5,500
EA134H3L23	5,800	5,800	5,800	5,800	5,800	5,800
EA134H13L23	6,500	6,500	6,500	6,500	6,500	6,500
EA134H123L123	10,900	10,900	10,900	10,900	10,900	10,900
EA134H123DB1L123	11,900	11,900	11,900	11,900	11,900	11,900
EA134H123DB2L123	11,600	11,600	11,600	11,600	11,600	11,600
EA134H123DB3L123	11,600	11,600	11,600	11,600	11,600	11,600
EA134H123DB4L123	11,900	11,900	11,900	11,900	11,900	11,900
B6L0	11,000	10,150	9,300	11,000	10,150	9,300
B6L01	11,700	10,850	10,000	11,700	10,850	10,000
B6DB1234L01	15,100	14,250	13,400	15,100	14,250	13,400
B7DB23L01	11,400	10,520	9,640	11,400	10,520	9,640
B7DB1234L01	13,400	12,520	11,640	13,400	12,520	11,640
B7DB1234L012	14,000	13,120	12,240	14,000	13,120	12,240
B7DB1234H23L012	15,700	14,820	13,940	15,700	14,820	13,940
B7DB1234H123L012	16,400	15,520	14,640	16,400	15,520	14,640
B7aDB23L01	12,500	11,510	10,520	12,500	11,510	10,520
B7aDB1234L01	14,500	13,510	12,520	14,500	13,510	12,520
B7aDB1234L012	15,100	14,110	13,120	15,100	14,110	13,120
B7aDB1234H23L012	16,800	15,810	14,820	16,800	15,810	14,820
B7aDB1234H123L012	17,500	16,510	15,520	17,500	16,510	15,520
B8DB1234H123L012	14,100	12,890	11,680	14,100	12,890	11,680
B8DB1234H123L0123	14,000	12,790	11,580	14,000	12,790	11,580
B8DB1234H123EA134L0123	16,300	15,090	13,880	16,300	15,090	13,880
B9DB1234H123L012	12,000	11,000	10,000	12,000	11,000	10,000
B9DB1234H123L0123	11,900	10,900	9,900	11,900	10,900	9,900
B9DB1234H123EA134L0123	14,200	13,200	12,200	14,200	13,200	12,200
EA134L3	4,200	4,200	4,200	4,200	4,200	4,200
DB1234L1	9,100	9,100	9,100	9,100	9,100	9,100
DB1234H123L12	12,100	12,100	12,100	12,100	12,100	12,100
EA134H123L12	7,200	7,200	7,200	7,200	7,200	7,200
B8DB1234H12L012	13,700	12,490	11,280	13,700	12,490	11,280
B9DB1234H12L012	11,600	10,600	9,600	11,600	10,600	9,600
SC1	5,900	5,310	4,720	5,900	5,310	4,720
EC1	9,400	8,460	7,520	5,500	4,950	4,400
EC3	3,600	3,240	2,880	3,600	3,240	2,880
EC5	7,600	6,840	6,080	7,300	6,570	5,840
NW1	6,400	5,760	5,120	5,600	5,040	4,480
NW2	6,700	6,030	5,360	4,900	4,410	3,920
NW3	7,200	6,480	5,760	5,400	4,860	4,320
NW4	7,700	6,930	6,160	5,000	4,500	4,000
B15Rev	8,000	7,200	6,400	8,000	7,200	6,400
SC1Rev	5,900	5,310	4,720	5,900	5,310	4,720

CENTRAL2030 5b (Opt)	Gone Green			Slow Progression		
Model Boundary	Winter	Spr/Aut	Summer	Winter	Spr/Aut	Summer
B10	5,900	5,310	4,720	5,900	5,310	4,720
B12	8,300	7,470	6,640	7,200	6,480	5,760
B13	5,500	4,950	4,400	5,500	4,950	4,400
B14	10,800	9,720	8,640	10,800	9,720	8,640
B15	8,000	7,200	6,400	8,000	7,200	6,400
B17	5,500	4,950	4,400	7,100	6,390	5,680
DB1	3,200	3,200	3,200	3,200	3,200	3,200
DB2	1,200	1,200	1,200	1,200	1,200	1,200
DB3	3,100	3,100	3,100	3,100	3,100	3,100
DB4	900	900	900	900	900	900
DB12	3,200	3,200	3,200	3,200	3,200	3,200
DB123	5,100	5,100	5,100	5,100	5,100	5,100
DB123L1	8,600	8,600	8,600	8,600	8,600	8,600
DB14	2,900	2,900	2,900	2,900	2,900	2,900
DB14L1	6,400	6,400	6,400	6,400	6,400	6,400
DB134L1	6,700	6,700	6,700	6,700	6,700	6,700
DB23	3,100	3,100	3,100	3,100	3,100	3,100
DB23L1	6,600	6,600	6,600	6,600	6,600	6,600
DB234L1	6,900	6,900	6,900	6,900	6,900	6,900
DB1234L1	7,700	7,700	7,700	7,700	7,700	7,700
DB124	2,900	2,900	2,900	2,900	2,900	2,900
DB124L1	6,400	6,400	6,400	6,400	6,400	6,400
DB1234	4,800	4,800	4,800	4,800	4,800	4,800
DB3L1	6,600	6,600	6,600	6,600	6,600	6,600
DB34L1	6,900	6,900	6,900	6,900	6,900	6,900
DB4L1	4,400	4,400	4,400	4,400	4,400	4,400
H1	2,700	2,700	2,700	2,700	2,700	2,700
H2	4,400	4,400	4,400	4,400	4,400	4,400
H3	2,100	2,100	2,100	2,100	2,100	2,100
H13	3,000	3,000	3,000	3,000	3,000	3,000
H123	5,000	5,000	5,000	5,000	5,000	5,000
H123L2	5,800	5,800	5,800	5,800	5,800	5,800
H2L2	5,200	5,200	5,200	5,200	5,200	5,200
H23	4,100	4,100	4,100	4,100	4,100	4,100
H23L2	4,900	4,900	4,900	4,900	4,900	4,900
EA1	3,000	3,000	3,000	3,000	3,000	3,000
EA3	3,300	3,300	3,300	3,300	3,300	3,300
EA4	600	600	600	600	600	600
EA13	5,700	5,700	5,700	5,700	5,700	5,700
EA13L3	5,200	5,200	5,200	5,200	5,200	5,200
EA1L3	3,700	3,700	3,700	3,700	3,700	3,700
EA3L3	4,600	4,600	4,600	4,600	4,600	4,600
EA34	2,700	2,700	2,700	2,700	2,700	2,700
EA134	5,100	5,100	5,100	5,100	5,100	5,100
EA134L3	4,600	4,600	4,600	4,600	4,600	4,600
EA34L3	4,000	4,000	4,000	4,000	4,000	4,000
DB1234L12	8,900	8,900	8,900	8,900	8,900	8,900
DB1234H2L12	10,900	10,900	10,900	10,900	10,900	10,900
DB1234H23L12	10,600	10,600	10,600	10,600	10,600	10,600
DB1234H123L12	11,500	11,500	11,500	11,500	11,500	11,500
DB1234H123L123	12,000	12,000	12,000	12,000	12,000	12,000
DB1234H123EA1L123	13,800	13,800	13,800	13,800	13,800	13,800
DB1234H123EA34L123	13,500	13,500	13,500	13,500	13,500	13,500
DB1234H123EA134L123	14,100	14,100	14,100	14,100	14,100	14,100

EA134L23	5,800	5,800	5,800	5,800	5,800	5,800
EA134H2L23	7,800	7,800	7,800	7,800	7,800	7,800
EA134H23L23	7,500	7,500	7,500	7,500	7,500	7,500
EA134H123L23	8,400	8,400	8,400	8,400	8,400	8,400
EA134H123L123	10,500	10,500	10,500	10,500	10,500	10,500
EA134H123DB4L123	10,800	10,800	10,800	10,800	10,800	10,800
EA134H123DB14L123	12,800	12,800	12,800	12,800	12,800	12,800
EA134H123DB124L123	12,800	12,800	12,800	12,800	12,800	12,800
EA134H123DB3L123	13,000	13,000	13,000	13,000	13,000	13,000
EA134H123DB23L123	13,000	13,000	13,000	13,000	13,000	13,000
EA134H123DB123L123	15,000	15,000	15,000	15,000	15,000	15,000
B6L0	11,000	10,150	9,300	11,000	10,150	9,300
B6L01	10,100	9,250	8,400	10,100	9,250	8,400
B6DB3L01	12,600	11,750	10,900	12,600	11,750	10,900
B6DB23L01	12,600	11,750	10,900	12,600	11,750	10,900
B6DB123L01	14,600	13,750	12,900	14,600	13,750	12,900
B7DB1234L012	13,000	12,120	11,240	13,000	12,120	11,240
B7DB1234H2L012	15,000	14,120	13,240	15,000	14,120	13,240
B7DB1234H23L012	14,700	13,820	12,940	14,700	13,820	12,940
B7DB1234H123L012	15,600	14,720	13,840	15,600	14,720	13,840
B7aDB1234L012	14,100	13,110	12,120	14,100	13,110	12,120
B7aDB1234H2L012	16,100	15,110	14,120	16,100	15,110	14,120
B7aDB1234H23L012	15,800	14,810	13,820	15,800	14,810	13,820
B7aDB1234H123L012	16,700	15,710	14,720	16,700	15,710	14,720
B8DB1234H123L0123	15,600	14,390	13,180	15,600	14,390	13,180
B8DB1234H123EA1L0123	16,800	15,590	14,380	16,800	15,590	14,380
B8DB1234H123EA34L0123	17,100	15,890	14,680	17,100	15,890	14,680
B8DB1234H123EA134L0123	17,700	16,490	15,280	17,700	16,490	15,280
B9DB1234H123L0123	13,500	12,500	11,500	13,500	12,500	11,500
B9DB1234H123EA1L0123	14,700	13,700	12,700	14,700	13,700	12,700
B9DB1234H123EA34L0123	15,000	14,000	13,000	15,000	14,000	13,000
B9DB1234H123EA134L0123	15,600	14,600	13,600	15,600	14,600	13,600
B7DB1234L01	11,800	10,920	10,040	11,800	10,920	10,040
B7aDB1234L01	12,900	11,910	10,920	12,900	11,910	10,920
B8DB1234H123L012	15,100	13,890	12,680	15,100	13,890	12,680
B9DB1234H123L012	13,000	12,000	11,000	13,000	12,000	11,000
SC1	5,900	5,310	4,720	5,900	5,310	4,720
EC1	9,400	8,460	7,520	5,500	4,950	4,400
EC3	3,600	3,240	2,880	3,600	3,240	2,880
EC5	7,600	6,840	6,080	7,300	6,570	5,840
NW1	6,400	5,760	5,120	5,600	5,040	4,480
NW2	6,700	6,030	5,360	4,900	4,410	3,920
NW3	7,200	6,480	5,760	5,400	4,860	4,320
NW4	7,700	6,930	6,160	5,000	4,500	4,000
B15Rev	8,000	7,200	6,400	8,000	7,200	6,400
SC1Rev	5,900	5,310	4,720	5,900	5,310	4,720

CENTRAL2030 Radial + Onshore	Gone Green			Slow Progression		
Model Boundary	Winter	Spr/Aut	Summer	Winter	Spr/Aut	Summer
B6	11,000	9,900	8,800	11,000	9,900	8,800
B10	5,900	5,310	4,720	5,900	5,310	4,720
B12	8,300	7,470	6,640	7,200	6,480	5,760
B13	5,500	4,950	4,400	5,500	4,950	4,400
B14	10,800	9,720	8,640	10,800	9,720	8,640
B15	8,000	7,200	6,400	8,000	7,200	6,400
B17	5,500	4,950	4,400	7,100	6,390	5,680
DB1	1,000	1,000	1,000	1,000	1,000	1,000
DB2	1,000	1,000	1,000	1,000	1,000	1,000
DB3	1,000	1,000	1,000	1,000	1,000	1,000
DB4	1,000	1,000	1,000	1,000	1,000	1,000
H1	1,000	1,000	1,000	1,000	1,000	1,000
H2	1,000	1,000	1,000	1,000	1,000	1,000
H3	1,000	1,000	1,000	1,000	1,000	1,000
EA1	1,200	1,200	1,200	1,200	1,200	1,200
EA3	1,200	1,200	1,200	1,200	1,200	1,200
EA4	800	800	800	800	800	800
B7DB23	10,200	9,180	8,160	10,200	9,180	8,160
B7DB1234	12,200	11,180	10,160	12,200	11,180	10,160
B7aDB23	11,100	9,990	8,880	11,100	9,990	8,880
B7aDB1234	13,100	11,990	10,880	13,100	11,990	10,880
B8DB1234H12	14,200	12,780	11,360	14,200	12,780	11,360
B8DB1234H123	15,200	13,780	12,360	15,200	13,780	12,360
B9DB1234H12	12,000	10,800	9,600	12,000	10,800	9,600
B9DB1234H123	13,000	11,800	10,600	13,000	11,800	10,600
SC1	5,900	5,310	4,720	5,900	5,310	4,720
EC1	9,400	8,460	7,520	5,500	4,950	4,400
EC3	3,600	3,240	2,880	3,600	3,240	2,880
EC5	7,600	6,840	6,080	7,300	6,570	5,840
NW1	6,400	5,760	5,120	5,600	5,040	4,480
NW2	6,700	6,030	5,360	4,900	4,410	3,920
NW3	7,200	6,480	5,760	5,400	4,860	4,320
NW4	7,700	6,930	6,160	5,000	4,500	4,000
B15Rev	8,000	7,200	6,400	8,000	7,200	6,400
SC1Rev	5,900	5,310	4,720	5,900	5,310	4,720

Appendix 3 – Constraint Bid Volumes by Offshore Zone

The optimisation process in the ELSI model adopted for this analysis does not allow accurate reporting of constraint costs by boundary. This is because some actions can resolve more than one constraint hence allocation is indeterminate, hence it is not possible to identify the location of corresponding Offer actions.

However, ELSI can track where Bid actions are taken and the volumes. This offers insight into the volume of lost generation by network designs for each of the offshore zones (Dogger Bank, Hornsea and East Anglia). The model results are shown below. All values are negative owning to the model nomenclature for Bid actions.

Gone Green background and 17.2GW Wind Capacity

GONE GREEN	GONE GREEN	GONE GREEN	GONE GREEN	GONE GREEN	GONE GREEN	GONE GREEN	GONE GREEN	GONE GREEN
	TEC 30 Radial: counterfactual	TEC 30 Option 10a	TEC 30 Option 10c	TEC 30 Option 13a	TEC 30 Option 13c	TEC 30 Option 15a	TEC 30 Option 15c	TEC 30 Radial plus onshore
Zone	Average TWh pa.	Average TWh pa.	Average TWh pa.	Average TWh pa.	Average TWh pa.	Average TWh pa.	Average TWh pa.	Average TWh pa.
Dogger Bank Sub Total	-0.671	-0.878	-0.620	-0.512	-0.437	-0.157	-0.259	-0.652
Hornsea Sub Total	-0.369	-0.185	-0.253	-0.085	-0.129	-0.049	-0.089	-0.382
East Anglia Sub Total	-0.380	-0.459	-0.506	-0.345	-0.241	-0.274	-0.322	-0.376
Totals	**-1.420**	**-1.523**	**-1.378**	**-0.942**	**-0.807**	**-0.480**	**-0.669**	**-1.409**
Total GB Bids (TWh)	-14.587	-12.119	-5.330	-5.919	-5.537	-4.665	-4.834	-7.802

Gone Green background and 10GW Wind Capacity

GONE GREEN	GONE GREEN	GONE GREEN	GONE GREEN	GONE GREEN	GONE GREEN	GONE GREEN	GONE GREEN	GONE GREEN
	Central Radial: counterfactual	Central Option 2a	Central Option 2c	Central Option 3a	Central Option 4a	Central Option 5a	Central Option 5b	Central plus onshore
Zone	Average TWh pa.	Average TWh pa.	Average TWh pa.	Average TWh pa.	Average TWh pa.	Average TWh pa.	Average TWh pa.	Average TWh pa.
Dogger Bank Sub Total	-0.600	-0.096	-0.484	-0.343	-0.313	-0.082	-0.245	-0.600
Hornsea Sub Total	-0.212	-0.083	-0.104	-0.265	-0.146	-0.067	-0.029	-0.212
East Anglia Sub Total	-0.241	-0.075	-0.131	-0.241	-0.305	-0.054	-0.035	-0.241
Totals	**-1.053**	**-0.254**	**-0.718**	**-0.849**	**-0.764**	**-0.203**	**-0.309**	**-1.053**
Total GB Bids (TWh)	-12.177	-5.122	-5.502	-5.901	-5.148	-4.577	-6.026	-6.332

Slow Progression background and 17.2GW Wind Capacity

SLOW PROG.	SLOW PROG.	SLOW PROG.	SLOW PROG.	SLOW PROG.	SLOW PROG.	SLOW PROG.	SLOW PROG.	SLOW PROG.
	TEC 30 Radial: counterfactual	TEC 30 Option 10a	TEC 30 Option 10c	TEC 30 Option 13a	TEC 30 Option 13c	TEC 30 Option 15a	TEC 30 Option 15c	TEC 30 Radial plus onshore
Zone	Average TWh pa.	Average TWh pa.	Average TWh pa.	Average TWh pa.	Average TWh pa.	Average TWh pa.	Average TWh pa.	Average TWh pa.
Dogger Bank Sub Total	-0.663	-0.857	-0.620	-0.512	-0.437	-0.157	-0.259	-0.652
Hornsea Sub Total	-0.369	-0.185	-0.253	-0.085	-0.129	-0.049	-0.089	-0.382
East Anglia Sub Total	-0.380	-0.458	-0.394	-0.345	-0.177	-0.272	-0.234	-0.376
Totals	**-1.413**	**-1.501**	**-1.266**	**-0.942**	**-0.743**	**-0.478**	**-0.582**	**-1.409**
Total GB Bids (TWh)	-14.497	-7.539	-3.936	-9.001	-7.345	-5.138	-4.536	-6.779

Slow Progression background and 10GW Wind Capacity

SLOW PROG.	SLOW PROG.	SLOW PROG.	SLOW PROG.	SLOW PROG.	SLOW PROG.	SLOW PROG.	SLOW PROG.	SLOW PROG.
	Central Radial: counterfactual	**Central Option 2a**	**Central Option 2c**	**Central Option 3a**	**Central Option 4a**	**Central Option 5a**	**Central Option 5b**	**Central plus onshore**
Zone	Average TWh pa.	Average TWh pa.	Average TWh pa.	Average TWh pa.	Average TWh pa.	Average TWh pa.	Average TWh pa.	Average TWh pa.
Dogger Bank Sub Total	*-0.600*	*-0.096*	*-0.484*	*-0.314*	*-0.313*	*-0.082*	*-0.245*	*-0.600*
Hornsea Sub Total	*-0.212*	*-0.083*	*-0.104*	*-0.265*	*-0.146*	*-0.067*	*-0.029*	*-0.212*
East Anglia Sub Total	*-0.241*	*-0.075*	*-0.132*	*-0.241*	*-0.305*	*-0.054*	*-0.035*	*-0.241*
Totals	**-1.053**	**-0.254**	**-0.720**	**-0.820**	**-0.764**	**-0.203**	**-0.309**	**-1.053**
Total GB Bids (TWh)	-11.044	-4.635	-2.200	-6.478	-4.124	-5.106	-3.596	-4.523

The results show that IOTP(E) Bid volumes range from 0.2TWh to 1.5TWh pa. within a total national Bid volume ranging from 2.2TWh to 14.6TWh depending on the design and generation background.

Many of the designs with integration lead to lower IOTP(E) Bid volumes and lower GW Bid volumes overall, than the corresponding radial design. This suggests that integration can reduce the impact to consumers by providing secondary routes for the generation to reach the market.

Whilst the operational cost of these IOPT(E) constraint actions cannot be identified from the model, they would be comparatively expensive since the Bid value reflects lost renewable subsidies as well as the value of the energy.

Appendix 4 – An Alternative Appraisal of Design Present Values

The appraisal methodology detailed in Chapter 5 revolves around measuring changes relative to a counterfactual position. An alternative to this is to seek to minimise the total Present Value of all costs (both investment and constraints) and simply regard the counterfactual base case (radial links to shore) as one of the possible designs. The rationale for this is that all these costs and welfare benefits will ultimately be borne by the consumer, hence the objective is to minimise the sum total of them.

The table below shows the total cost NPVs for each design group for each scenario. The lowest cost options indicate least cost to the consumer for that scenario.

Total NPV Cost by Group (£m)	10GW Wind, Gone Green	17.2GW Wind, Gone Green	10GW Wind, Slow Progress	17.2GW Wind, Slow Progress
Radial Designs	17,056	22,103	14,327	20,986
Radial plus onshore	12,068	16,860	10,517	15,480
Bootstrap 1 GW	10,146	21,233	9,303	17,675
Hybrid bootstrap 2 GW	10,561	14,665	8,104	13,576
Hybrid offshore 1 GW	10,963	14,981	9,909	16,986
Hybrid offshore 2 GW	N/A	13,717	N/A	14,509
Integrated 1 GW	10,629	13,986	10,373	13,999
Integrated 2 GW	10,116	13,884	7,938	13,315

Regret analysis can be utilised in a same way as it was in Chapter 5. This time we are comparing each design with the least cost option. Grouping these by similar technology/design as previously gives the following regret measures: -

Options / Scenarios: Regrets (£m)	10GW Wind, Gone Green	17.2GW Wind, Gone Green	10GW Wind, Slow Progress	17.2GW Wind, Slow Progress	Worst Regret (£m)
Radial Designs	6940	8386	6389	7671	8386
Radial plus onshore	1952	2165	2579	2165	2579
Bootstrap 1 GW	30	7517	1365	4360	7517
Hybrid bootstrap 2 GW	445	949	166	261	949
Hybrid offshore 1 GW	848	1264	1971	3671	3671
Hybrid offshore 2 GW	NA	0	NA	1194	1194
Integrated 1 GW	514	270	2434	684	2434
Integrated 2 GW	0	168	0	0	168

The Least Worst Regret continues to be the integrated designs with larger links. This is consistent with the other assessment approach and adds some resilience to the findings.