Bacton Energy Hub
Supply SIG

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REVISION RECORD SHEET

Revision	Section	Description	Date
00	-	First Revision	23/08/2022
01	-	- Cross-referencing errors removed. - Section 7.3, comment added regarding requirement for a significant grid connection for Scenario B. - Added note to Figure 7.5. - A note is added to Section 7.5, to review the risk of harmonics from electrolyser rectification.	22/09/2022

CONTENTS PAGE

1.0 INTRODUCTION

1.1 BACKGROUND

In 2021 the UK North Sea Transition Authority ("NSTA", formally known as the Oil & Gas Authority) commissioned a future vision for the Southern North Sea and Bacton considering the potential role of hydrogen in supporting the delivery of Maximising Economic Recovery and Net Zero. The study area, which is described as the Bacton Catchment Area ("BCA") comprises the Southern North Sea, and the onshore areas defined by National Grid's East of England and North Thames areas.

Bacton is ideally positioned to become a significant hydrogen production facility for London and the South East. It has a number of critical advantages:

- Access to indigenous and, later, imported natural gas for blue hydrogen production.
- Access to offshore wind farm output for green hydrogen production.
- Availability of offshore structures for carbon dioxide (CO_2) and hydrogen (H_2) storage.
- Ample land for development of hydrogen production.
- Excellent gas connections to London and the Southeast of England.

These factors combine to make Bacton ideally situated for development as a low carbon hub.

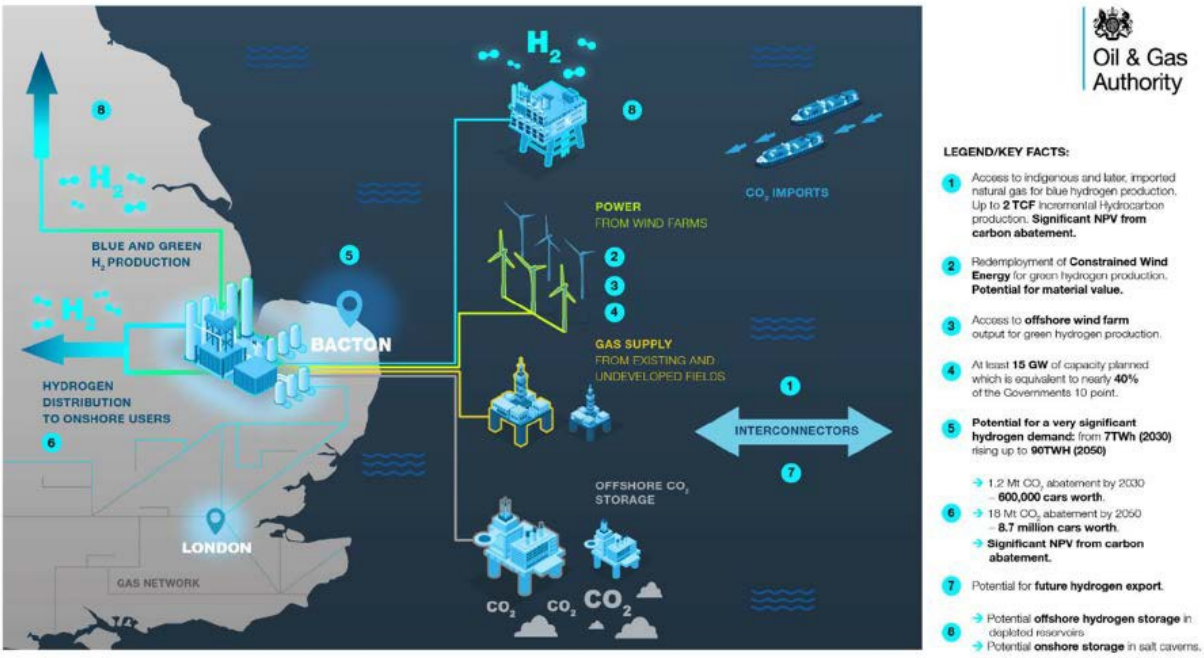


Figure 1-1 Bacton Energy Hub Potential Development Scheme

Hydrogen production at Bacton could help to decarbonise not just the study area, which comprises nearly 20% of the UK population, but also to contribute to decarbonisation in London and the South East more widely.

This development would contribute to the UK's decarbonisation targets and to the recently published "Ten Point Plan for a Green Industrial Revolution", specifically by supporting objectives 1 ("Advancing Offshore

Wind”), 2 (“Driving the Growth of Low Carbon Hydrogen”) and 8 (“Investing in Carbon Capture, Usage and Storage”).

It is recognised that there are a multitude of scenarios that are credible, however detailed scenarios will ultimately be required to be explored by the consortium in the future phases of the project. Therefore, maturing an extensive list of scenarios at this stage of the project will add little value when considering the key objective for this phase. It is not the intention of this phase of the project to define the technical specification or detailed basis of design of the hub, but rather propose a development concept supported by a scoping level design outline to help frame the potential.

1.2 OBJECTIVES AND PURPOSE

The objectives of the power supply scope are as follows:

- Review options for existing and new, renewable power, demand requirements.
- Review power demand requirements for Blue and Green hydrogen facilities, and onshore CCS facilities.
- Determine power supply source:
  - Grid supply.
  - Dedicated renewable/clean technology.

The purpose of this report is to:

- Provide a scoping level overview of the power demands associated with the Bacton energy hub scenarios.
- Provide a scoping-level overview of the potential power supply options and associated considerations.

1.3 SCOPE AND OUTPUTS

The scope of this study encompasses the power demand and supply for the entirety of the Bacton energy hub, including blue hydrogen, carbon capture and storage, desalination and green hydrogen production.

The power demand figures are based on inputs received from other parties conducting the different study scopes for the project.

The scope of the power supply study is to outline the supply strategy at a high level.

The outputs of this study are as follows:

- Power demand list and capacity sizing.
- Power supply strategy, i.e. grid, renewables, clean etc.

2.0 DEFINITIONS AND ABBREVIATIONS

2.1 ABBREVIATIONS

ACRONYMS	DESIGNATION
ATR	Auto Thermal Reformation
BCA	Bacton Catchment Area
BEH	Bacton Energy Hub
CCC	Climate Change Committee
COD	Commercial Operation Date
CTR	Cost Time Resource
GHR	Gas heated reforming
HV	High Voltage
HVAC	High Voltage Alternating Current
IRENA,	International Renewable Energy Agency
KRA	Key Resource Area
LCOE	Levelised Cost of Energy
MW	Megawatt
NSTA	North Sea Transition Authority
OHL	Overhead Line
PEL	Progressive Energy Limited
POC	Point of Connection
POX	Partial Oxidation
PSA	Pressure Swing Adsorption
REP	Report
RIIO	Ofgem's new performance based RIIO model
SAI	Saipem Ltd
SIG	Special Interest Group
SMR	Steam methane reforming
SNS	Southern North Sea
SWRO	Seawater Reverse Osmosis
TW	Terawatt
UKPN	UK Power Networks
WTG	Wind Turbine Generator

3.0 REFERENCES

Title	Reference
[Ref 1] PEL_Blue_Hydrogen_Technology_Review	31-05-22_v0.2
[Ref 2] Bacton Supply SIG - Green Hydrogen Scoping Report	J75769A-A-TN-00001 B1
[Ref 3] BEH Supply SIG - Desalination Summary Report	NEP-005-RP-001-B2
[Ref 4] Everoze Partners Limited. 2020. BROAD HORIZONS: Key resource areas for offshore wind Summary Report. s.l. : The Crown Estate, 2020.	https://www.marinedataexchange.co.uk/details/2117/2020-everoze-characterisation-of-key-resource-areas-for-offshore-wind-a-report-for-the-crown-estate/packages
[Ref 5] BROAD HORIZONS: Key resource areas for offshore wind Summary Report	https://www.thecrownestate.co.uk/media/3642/broad-horizons-offshore-wind-key-resource-area-summary-report.pdf
[Ref 6] Offshore wind operational report 2020	https://www.thecrownestate.co.uk/media/3792/offshore-wind-operational-report-1.pdf
[Ref 7] National Grid RIIO-2 business plan (2021-2026)	https://www.nationalgrid.com/electricity-transmission/about-us/planning-together/our-riio2-business-plan-2021-2026
[Ref 8] Map Data Files - Floating Wind KRA (England, Wales & NI), The Crown Estate	https://opendata-thecrownestate.opendata.arcgis.com/datasets/thecrownestate::floating-wind-kra-england-wales-ni-the-crown-estate/about
[Ref 9] CCC Sixth Carbon Budget, December 2020	HTTPS://WWW.THECCC.ORG.UK/PUBLICATION/SIXTH-CARBON-BUDGET/#DOWNLOADS
[Ref 10] UK offshore wind capacity factors, June 2022	HTTPS://ENERGYNUMBERS.INFO/UK-OFFSHORE-WIND-CAPACITY-FACTORS
[Ref 11] UKPN East Anglia substations and overhead lines	HTTPS://DGMAP.UKPOWERNETWORKS.CO.UK/SITE/?Q=DGMAPPING_EXT_OPEN
[Ref 12] FUTURE OF WIND Deployment, investment, technology, grid integration and socio-economic aspects, IRENA, October 2019	HTTPS://IRENA.ORG/-/MEDIA/FILES/IRENA/AGENCY/%20PUBLICATION/2019/OCT/IRENA_FUTURE_OF_WIND_2019.PDF
[Ref 13] SNS-Bacton Energy Hub, A Vision for the Future, Progressive Energy, 2021	REPORT FOR THE OIL & GAS AUTHORITY
[Ref 14] Norwegian Energy and Environment Consortium	HTTPS://NEEC.NO/ZEPHYR-HAS-UNVEILED-PLANS-FOR-A-1GW-PLUS-OFFSHORE-WIND-FARM-OFF-SWEDEN/
[Ref 15] UK offshore wind leasing round 4 preferred projects	https://opendata-thecrownestate.opendata.arcgis.com/apps/thecrownestate::offshore-wind-leasing-round-4-preferred-projects-viewer/explore
[Ref 16] The need for network reinforcements in East Anglia	https://www.nationalgrid.com/electricity-transmission/network-and-infrastructure/bramford-twinstead/the-need-for-network-reinforcement

4.0 BACTON ENERGY HUB SCENARIOS

A summary of the project scenarios and the work scopes of the various SIGs is shown below.

		Core Project	Build-out
Demand	**Demand Base Assumption**	Supply Driven Domestic Only	Balanced supply / demand scenario Domestic Only 70% of current domestic gas demand is met with hydrogen (by 2040)
	Maximum Demand (TWh)	7.9 TWh (2030), 58.2 TWh (2040), 90.3 TWh (2050)	7.9 TWh (2030), 58.2 TWh (2040), 90.3 TWh (2050)
	Maximum Blend %	Assumed 20% blend in 2030 increasing to 100% hydrogen in some parts of region in 2040, all 100% hydrogen in 2050	
	Phasing Description	Assumes blending into NTS by 2030. 2030 demand dominated by blend into NTS/LDZ supply for domestic/commercial; full conversion to 100% hydrogen over time	
Supply	**Supply Base Assumption (Blue, Green, Blue + Green)**	Blue Only*	Blue + Green
	Blue / Green Phasing Description	1 (or 3 depending on demand at the time) x 355MW SMR/ATR Plant, no additional investment	2030: 3 x 355 MW SMR/ATR plants 2040: 3 x 355 MW SMR/ATR + 2 x 1.8 GW upscaled SMR/ATR + 1 x 2.1 GW Electroliser 2050: 2 x 1.8 GW upscaled SMR/ATR + 1 x 2.1 GW Electroliser + 2 x 2.1 GW Electroliser plants (NB 3 x 355MW SMR/ATR retired)
	Maximum Supply from Blue Hydrogen (TWH / %?)	3 TWh – 100% of demand	9 TWh – 100% of Demand (2030), 39 TWh – 54% of demand (2040) 30 TWh – 33% of demand (2050)
	Maximum Supply from Green Hydrogen (TWH / %?)	Zero	0 TWh – 0% of demand (2030) 18 TWh – 46% of demand (2040) 54 TWh – 80% of demand (2050)
	Blue Hydrogen Feedstock Assumptions	Producing and Reserves (Requires approx. 30 mmscf/d). Availability of indigenous supply to be confirmed by SIG	Producing and Reserves + Undeveloped discoveries for Hydrogen with possible import 2040 onwards. Estimated hydrocarbon feedstock: 82 mmscf/d (2030) 356 mmscfd (2040) 274 mmscfd (2050) NB All figures to be verified by SIG, and assessment of indigenous vs imported supply
	Green Hydrogen Feedstock Assumptions	N/A	Redeployment of constrained wind power + connection to (green) grid (2040), Dedicated wind/solar plus connection to (green) grid (2050)
	Export Yes / No?	No	No
	CS Yes / No?	Yes	Yes
	Hydrogen Storage Yes / No?	No	Yes
Infrastructure	**Land requirement**	Within existing plant boundary	Blue hydrogen within existing plant boundary with potential re-use of existing plants as part of consolidate of terminals [to confirm as part of study] Expansion of plant likely required for green hydrogen [to be confirmed as part of the study]
	Blue Hydrogen Base Assumptions	Existing upstream gas pipelines available to supply natural gas to terminal over life of project. Electricity supplied from the grid for H2 generation + CO2 capture plant [to confirm no grid constraints]. Depending on technology steam / oxygen generation Desalination plant [to be confirmed]	Existing upstream gas pipelines available to supply natural gas to terminal over life of project [to be confirmed as part of study]. May require import of natural gas from Europe. Electricity supplied from the grid for H2 generation + CO2 capture plant [to confirm no grid constraints]. Depending on technology steam / oxygen generation Desalination plant [to be confirmed]
	Green Hydrogen Base Assumptions	N/A, unless local supply	Electricity supplied from green source (offshore wind). New desalination plant required. New water handling plant.
	Hydrogen Evacuation Base Assumptions	To be agreed as sensitivity on Base Case. Assume some blend of NTS + others	Current NTS (heating) – blend TBC. Transport (local) Ports Power station
	CO2 Transport and Storage Assumptions	Green field or re-use existing pipelines / storage or route to existing storage site [to be confirmed as part of study] with required injection rate of 0.8 mtpa. Assume transport of CO2 to already approved CCS (Northern Endurance) projects unlikely due to consenting issues for new onshore CO2 pipeline	New storage site and pipeline required [to be confirmed as part of study] with required injection capacity of: 2030: 2.4 mtpa 2040: 10.4 mtpa 2050: 8 mtpa
	Hydrogen Storage Base Assumption	N/A	To identify potential suitable Hydrogen storage sites (if available) – new salt caverns, existing salt caverns (e.g. Teesside) depleted hydrocarbon fields, line pack
	Export Base Assumptions	N/A	N/A
Assum?		CO2 licence application Viability of H2 plant @ Bacton Supply chain capacity building Ability to blend into grid at X%	CO2 licence application Viability of H2 plant @ Bacton Supply chain capacity building Offshore wind connection Green H2 plant Ability to blend into grid at X%

*Excludes (for now) the possibility of an "Early Production System" for Green Hydrogen
Facility retirement assumed after 20 years from first hydrogen

5.0 FACILITIES INPUTS

The following sections detail power consumption inputs from the blue, green and desalination reports which were used to establish the power demand of the different BEH scenarios.

A summary of the inputs obtained from these reports is noted below.

Table 5-1 Summary of facilities power consumption duties used in study

Facility	Process	Electrical Consumption	Reference
Blue H_2 (Inc. CCS)	SMR/ATR	79 kW_e/MW_{th}	Blue Hydrogen Report [Ref 1], 25-30MW net grid import for a 350MW_{th} unit. Note (1).
Desalination	SWRO (2-stage)	4.4 kWh_e/m^3	Desalination Report [Ref 3], Table 5-2. Note (2).
Green H_2	Alkaline Electrolyser	2,200 MW_e	Green Hydrogen Report [Ref 2], Table 4-2

Notes:
1) The electrical demand for blue hydrogen production and CCS is the net import from the grid, assuming a co-gen unit is used for the balance.
2) Electrical consumption For the desalination water for blue and green hydrogen production, i.e. for the green hydrogen this is for the electrolysers only; i.e. assuming air cooling (no cooling water requirement) [Ref 2].

Table 5-2 Desalination water requirements

Facility	Process	Water Consumption	Reference
Desalination (Blue H_2)	SWRO (2-stage)	3.0 $(m^3/d)/MW_{th}$	Desalination Report [Ref 3], Table 5-2, Note 1.
Desalination (Green H_2)	SWRO (2-stage)	4.1 $(m^3/d)/MW_e$	Desalination Report [Ref 3], Table 5-2, Note 2.

Notes:
1) Value derived from desalination report estimate, 45m3/h for a 355MWth blue hydrogen unit (feedstock and utilities).
2) Value derived from Green Hydrogen Report, water requirement for electrolysers only, assuming air cooling (no water-cooling requirement).

5.1 BLUE HYDROGEN

The Blue Hydrogen Technology Review report [Ref 1] concludes that the most appropriate technologies for deployment at the Bacton Energy Hub are the coupled Gas-Heated-Reformer plus Autothermal-Reformer and the Non-Catalytic Partial Oxidation process.

The Blue Hydrogen Report notes that these processes are comparable in terms of performance and cost.

The main inputs obtained from the Blue Hydrogen Report are noted below:

- The GHR+ATR+PSA process consumes (net grid import) 8.8MJ/kgH_2, while the POX+Methanation process consumes (net import) 5.6MJ/kgH_2. The report notes that the power consumption rates are based on a “broadly comparable basis”.

- The electrical duty of the blue hydrogen facility is based on the reported net import power from the grid for a 350MW$_{th}$ reference ATR+PSA unit.
- It was further clarified via communications with Progressive Energy that the net power import for a 350MW$_{th}$ GHR+ATR plant is in the range 25-30MW.
- The net power import from the grid is extrapolated to the upscaled units of the BEH scenarios.
- It is noted that the Blue Hydrogen report does not provide the total power demand, but only the net import from the grid, assuming a power generation unit is present within the blue hydrogen plant facilities.
- The net import power figures given include the power required for carbon capture and compression.

5.2 GREEN HYDROGEN

The 'core' project for the BEH does not include the installation of any green hydrogen production facilities.

However, green hydrogen production is part of the 'build-out' scope; where green hydrogen production would begin in 2040 with the installation of 2,200MW$_e$ electrolyser modules, followed by the installation of two more electrolysers by 2050, each rated at 2,200MW$_e$. The total installed capacity would therefore be 6,600MWe in the build-out scenario.

The green hydrogen facilities comprise the following:

- One electrolyser plant rated at 2,200MWe, installed by 2040.

The base case technology for green hydrogen production is through alkaline electrolysers as per the Green Hydrogen Technology Review Report [Ref 2].

The base case green hydrogen production assumes power import from dedicated renewable sources (e.g. offshore wind) is supplemented by power imported from the grid.

The base case scenario then considers that power from dedicated renewable sources would account for 60% of the rated capacity of the electrolysers. Therefore, the green hydrogen report considers that 40% of the 2,200MW$_e$ is to be imported from the grid.

Other scenarios, where import from the grid is less than 40% are also investigated in this report (see Section 7.3).

Water Desalination for green hydrogen:

The study assumes a two-stage pass seawater reverse osmosis process with a consumption duty of 4.4kWh/m^3, as given in the desalination review report [Ref 3].

Water Treatment Plant (Demin Plant):

- The green hydrogen production plants also require the inclusion of a water treatment facility.
- A water treatment facility works to demineralise the desalinated water before it being fed into the electrolysers.
- The electrical duty of the water treatment facilities (demineralisation) is included in the total duty of a single electrolyser plant 2,200MW$_e$.

5.3 SEAWATER DESALINATION

The green hydrogen report [Ref 2] assumes that water will be supplied by a local water authority, or from a potential desalination plant. Discussions with local water authorities show that local supply is limited in the region, thus this can be assumed unfeasible at this stage [Ref 3].

Therefore, for the purposes of power supply and demand scoping, desalination facilities are assumed to be required for both blue and green hydrogen scenarios and their power requirements are accounted for in this report.

Desalination of seawater is required for both blue and green hydrogen production.

The Desalination review report [Ref 3] shows that the power demand of the desalination process is in the range 4-4.8kWh/m^3. A value of 4.4kWh/m^3 is used in this study.

6.0 POWER DEMAND

This section presents a power demand list for the Bacton Energy Hub. The list is broken down by process and by project phase.

For each project phase, a single plant is assumed for each facility as per the BEH scenarios presented in Section 4.0.

To breakdown the scope and to distinguish between phases, these plants are numbered in the lists. However, the actual design of these facilities may entail a different configuration depending on future engineering phases and economic evaluations. Nevertheless, the electrical duties are expected to remain broadly similar.

6.1 CORE PROJECT (2030)

The power demand of the BEH for the core project is presented in the following table. In this scenario, only blue hydrogen production is assumed.

For this phase, a single 355MW_{th} blue hydrogen generation plant is envisioned. The blue hydrogen electrical duty includes the power required to capture and store carbon dioxide and this represents a net import from the grid, with further power being generated from a co-generation power plant. The blue hydrogen facility would be supported by a seawater reverse osmosis desalination plant with a nameplate capacity of 45m^3/h.

The total electrical demand is estimated to be 30MW_e.

Table 6-1 Total Electrical demand list Core project

COD	PROCESS	SUB-PROCESS	PLANT	NAMEPLATE	Demand [MW_e]
2030	Blue H_2	Production & CCS	SMR/ATR PLANT 1	355 MW_{th}	28
2030	Blue H_2	Desalination	SWRO PLANT 1	45 m^3/h	0.20

The breakdown of the electrical demand of for the 2030 build-out project is demonstrated in the following pie-chart.

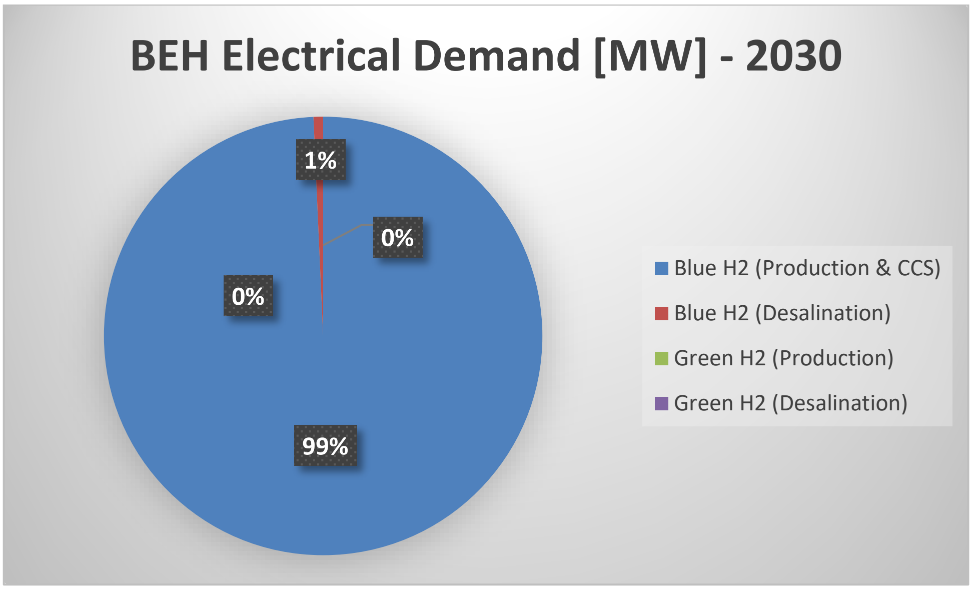


Figure 6-1 Figure 6-2 Electrical demand breakdown for BEH core 2030.

6.2 BUILD-OUT PROJECT (2030)

Similar to the core-project but with three (3) blue hydrogen plants, each rated at 355MW_{th}. The desalination plant is shown as three units to demonstrate the electrical duty associated with the blue trains. However, a single larger capacity desalination plant may be the preferred design option.

The total electrical demand of this phase is around 90MW_e.

Table 6-2 Total electrical demand list build-out 2030

COD	**PROCESS**	**SUB-PROCESS**	**PLANT**	**NAMEPLATE**	**Demand [MW_e]**
2030	Blue H_2	Production & CCS	SMR/ATR Plant 1	355 MW_{th}	28
2030	Blue H_2	Production & CCS	SMR/ATR Plant 2	355 MW_{th}	28
2030	Blue H_2	Production & CCS	SMR/ATR Plant 3	355 MW_{th}	28
2030	Blue H_2	Desalination	SWRO PLANT 1	45 m^3/h	0.20
2030	Blue H_2	Desalination	SWRO PLANT 2	45 m^3/h	0.20
2030	Blue H_2	Desalination	SWRO PLANT 3	45 m^3/h	0.20

The breakdown of the electrical demand of for the 2030 build-out project is demonstrated in the following pie-chart.

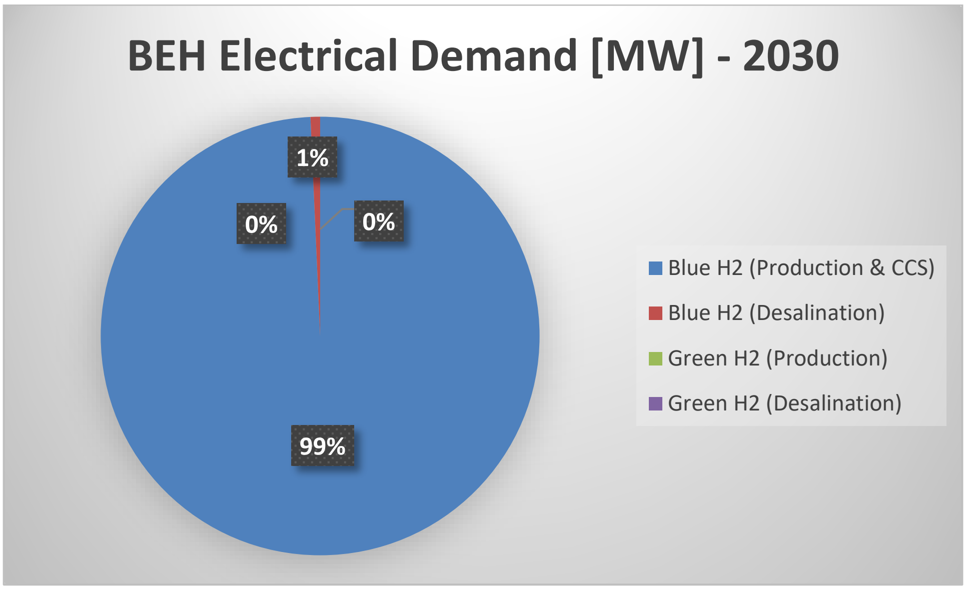


Figure 6-3 Electrical demand breakdown for BEH build-out 2030.

6.3 BUILD-OUT PROJECT (2040)

For this phase, in addition to the facilities commissioned in 2030 (Table 6-2), additional facilities are to be constructed and operated by the year 2040. The additional units comprise two (2) upscaled 1800MW_{th} blue hydrogen plants and a single 2,100MW_e green hydrogen plant.

The total electrical demand of the hub, by the year 2040, would be around 2500MW.

Table 6-3 Total electrical demand list build-out 2040

COD	PROCESS	SUB-PROCESS	PLANT	NAMEPLATE	Demand [MW_e]
2030	Blue H_2	Production & CCS	SMR/ATR Plant 1	355 MW_{th}	28
2030	Blue H_2	Production & CCS	SMR/ATR Plant 2	355 MW_{th}	28

2030	Blue H_2	Production & CCS	SMR/ATR Plant 3	355 MW$_{th}$	28
2030	Blue H_2	Desalination	SWRO PLANT 1	45 m^3/h	0.2
2030	Blue H_2	Desalination	SWRO PLANT 2	45 m^3/h	0.2
2030	Blue H_2	Desalination	SWRO PLANT 3	45 m^3/h	0.2
COD	**PROCESS**	**SUB-PROCESS**	**PLANT**	**NAMEPLATE**	**Demand [MW$_e$]**
2040	Blue H_2	Production & CCS	SMR/ATR Plant 4	1800 MW$_{th}$	141
2040	Blue H_2	Production & CCS	SMR/ATR Plant 5	1800 MW$_{th}$	141
2040	Blue H_2	Desalination	SWRO PLANT 4	228 m^3/h	1.0
2040	Blue H_2	Desalination	SWRO PLANT 5	228 m^3/h	1.0
2040	Green H_2	Production	ALKALINE ELECTROLYSER 1	2100 MW$_e$	2100
2040	Green H_2	Desalination	SWRO PLANT 6	378 m^3/h	1.7

The breakdown of the electrical demand of for the 2040 build-out project is demonstrated in the following pie-chart.

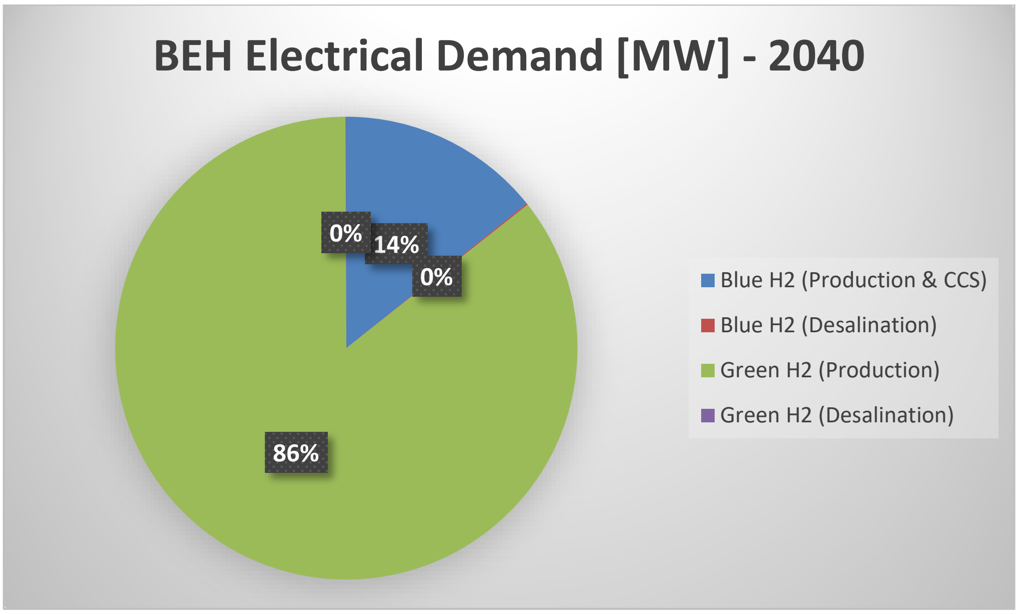


Figure 6-4 Electrical demand breakdown for BEH 2040.

6.4 BUILD-OUT PROJECT (2050)

During this phase of the build-out project, the facilities originally commissioned in 2030 are retired. While new facilities are constructed and commissioned for 2050, these being two (2) green electrolyser plants each with a capacity of 2,100MW$_e$.

The total electrical demand of the hub by 2050 would be around 6,600MW.

Table 6-4 Total electrical demand list build-out 2050

COD	PROCESS	SUB-PROCESS	PLANT	NAMEPLATE	Demand [MW$_e$]
2030	Blue H_2	Production & CCS	SMR/ATR Plant 1	355 MW$_{th}$	*0 (RETIRED)*
2030	Blue H_2	Production & CCS	SMR/ATR Plant 2	355 MW$_{th}$	*0 (RETIRED)*
2030	Blue H_2	Production & CCS	SMR/ATR Plant 3	355 MW$_{th}$	*0 (RETIRED)*
2030	Blue H_2	Desalination	SWRO PLANT 1	45 m^3/h	*0 (RETIRED)*
2030	Blue H_2	Desalination	SWRO PLANT 2	45 m^3/h	*0 (RETIRED)*
2030	Blue H_2	Desalination	SWRO PLANT 3	45 m^3/h	*0 (RETIRED)*
COD	PROCESS	SUB-PROCESS	PLANT	NAMEPLATE	Demand [MW$_e$]
2040	Blue H_2	Production & CCS	SMR/ATR Plant 4	1800	141
2040	Blue H_2	Production & CCS	SMR/ATR Plant 5	1800	141
2040	Blue H_2	Desalination	SWRO PLANT 4	228 m^3/h	1.0
2040	Blue H_2	Desalination	SWRO PLANT 5	228 m^3/h	1.0
2040	Green H_2	Production	ALKALINE ELECTROLYSER 1	2100 MW$_e$	2100
2040	Green H_2	Desalination	SWRO PLANT 6	378 m^3/h	1.7
COD	**PROCESS**	**SUB-PROCESS**	**PLANT**	**NAMEPLATE**	**Demand [MW$_e$]**
2050	Green H_2	Production	ALKALINE ELECTROLYSER 2	2100 MW$_e$	2100
2050	Green H_2	Production	ALKALINE ELECTROLYSER 3	2100 MW$_e$	2100
2050	Green H_2	Desalination	SWRO PLANT 7	378 m^3/h	1.7
2050	Green H_2	Desalination	SWRO PLANT 8	378 m^3/h	1.7

The breakdown of the electrical demand of for the 2050 build-out project is demonstrated in the following pie-chart.

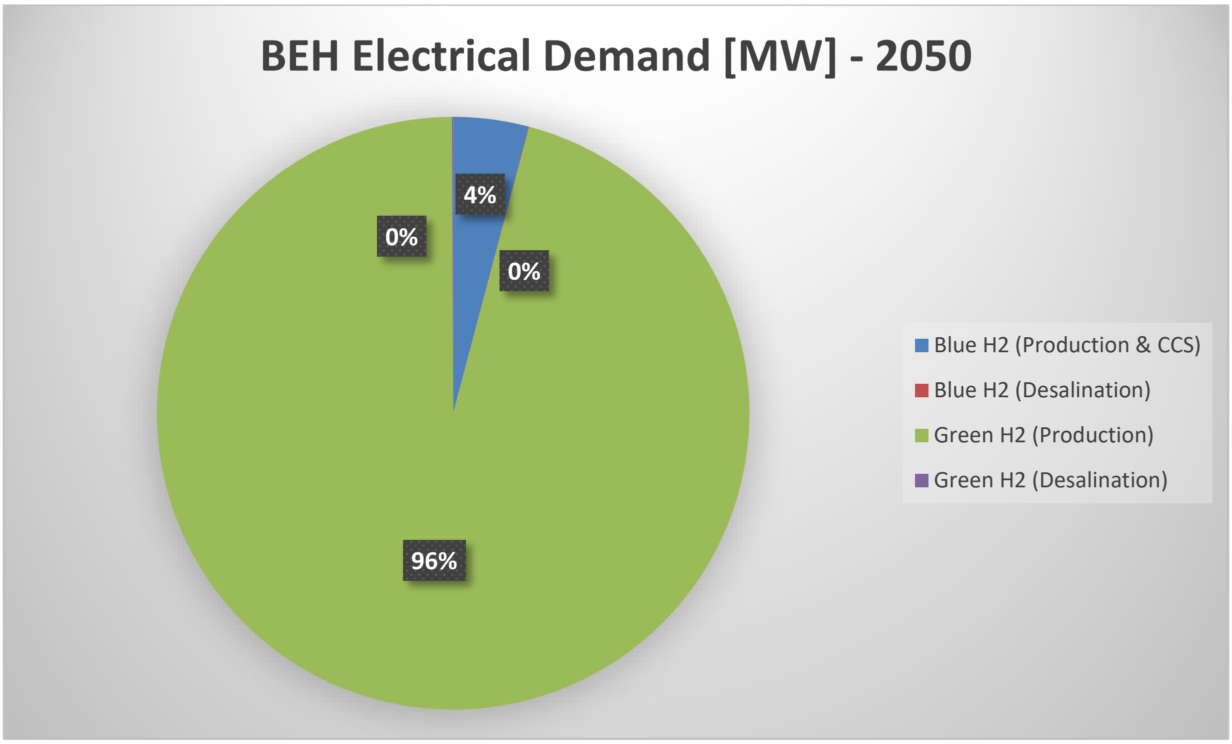


Figure 6-5 Electrical demand breakdown for BEH 2050.

7.0 POWER SUPPLY

This section presents a high-level power supply list for the electrical loads required for the different phases and scenarios of the Bacton Energy Hub.

The supply of power is split into two main sources:

- Regional power grid, supplying all of BEH except for the green hydrogen electrolysers.
- Dedicated offshore wind supplying only the green hydrogen electrolysers.

7.1 RENEWABLE SUPPLY STRATEGY

For the green hydrogen electrolysers, the bulk of the power supply is assumed to be supplied form offshore wind with a smaller supply from the local grid.

This assumption is based on several considerations:

- The fact that once electrical power has entered the grid it is generally more economical and efficient to allow this to be consumed as electrical energy by the grid users, as opposed to conversion to hydrogen.
- The large scale of the electrolysers, reaching a duty of 6.6GW by 2050, means that total supply from the grid may be unfeasible.
- Offshore wind is selected as the main source of renewable energy, since this is the largest and best positioned resource to meet the large scale demands of the electrolysers. While other types of renewable energy do exist, such as solar energy, the scale of these technologies remains relatively small in comparison to wind. The case for offshore wind is further enhanced by the location of the BEH within the Bacton catchment area near large scale offshore wind developments in the southern North Sea.
- There may be potential for power export from the dedicated windfarms into the grid in cases of surplus energy. This could be accommodated and planned with the grid operator in the early phases of the project.

7.2 OVERVIEW

An overview of the power demand, capacity and supply source for the BEH is shown below. Note that the 2030 list includes the core project scenario in the first line.

Table 7-1 Power supply list overview

COD	PROCESS	PLANT	Demand [MW_e]	SUPPLY SOURCE
2030	Blue H_2	SMR/ATR Plant 1 [355MW_{th}]	28	GRID
2030	Blue H_2	SMR/ATR Plant 2 [355MW_{th}]	28	GRID
2030	Blue H_2	SMR/ATR Plant 3 [355MW_{th}]	28	GRID
2030	Blue H_2	SWRO PLANT 1 [45m^3/h]	0.20	GRID
2030	Blue H_2	SWRO PLANT 2 [45m^3/h]	0.20	GRID

2030	Blue H_2	SWRO PLANT 3 [$45m^3/h$]	0.20	GRID
2040	Blue H_2	SMR/ATR PLANT 4 [$1800MW_{th}$]	141	GRID
2040	Blue H_2	SMR/ATR PLANT 5 [$1800MW_{th}$]	141	GRID
2040	Blue H_2	SWRO PLANT 4 [$230m^3/h$]	1.0	GRID
2040	Blue H_2	SWRO PLANT 5 [$230m^3/h$]	1.0	GRID
2040	Green H_2	ALKALINE ELECTROLYSER 1 [$2100MW_e$]	2200	OFFSHORE WIND + GRID
2040	Green H_2	SWRO PLANT 6 [$380m^3/h$]	1.7	GRID
2050	Green H_2	ALKALINE ELECTROLYSER 2 [$2100MW_e$]	2200	OFFSHORE WIND + GRID
2050	Green H_2	ALKALINE ELECTROLYSER 3 [$2100MW_e$]	2200	OFFSHORE WIND + GRID
2050	Green H_2	SWRO PLANT 7 [$380m^3/h$]	1.7	GRID
2050	Green H_2	SWRO PLANT 8 [$380m^3/h$]	1.7	GRID

7.3 GRID SUPPLY SCENARIOS

The split of power supply between offshore wind and the local grid must be determined in future phases of the project. For the current study, three scenarios have been envisioned:

Scenario A is where the green electrolysers are not supplied from the grid. In this scenario, all energy for the production of green hydrogen is sourced from dedicated offshore wind. Some level of connection to the grid is considered preferable to allow for improved operability of the electrolysers, as well as the potential for power export in cases of electrolyser down-time. Therefore, this scenario may be less preferrable.

Scenario B is where a smaller percentage of the load (taken to be 10% for this study) is supplied from the grid. In this scenario, a small proportion of the energy is supplied directly from the local grid while the offshore windfarms feed directly into the electrolysers. The smaller supply from the grid improves the operability of the plant while not overloading the local grid. The assumption of 130MW connection per electrolyser plant is only an assumption at this stage. The optimum connection capacity must be determined in further stages of the project.

It is noted that while Scenario B may be feasible, it would still require a significant grid connection for importing power from the grid and exporting surplus power from the offshore wind turbines. The connection would require significant grid upgrades.

The offshore windfarms supplying the electrolysers would sized for the rating of the plant (Build out 2050 rating 6600MW).

Scenario C is where 40% of the load is supplied from the grid. In this scenario, power from the grid is sized to be up to 880MW per 2,100MW electrolyser plant. This is the base-case scenario considered in the green hydrogen review report [Ref 2]. This scenario is considered more onerous on the grid and potentially unfeasible. In addition, it is understood that in general once electrical power has entered the grid it is more economical and efficient to use it by electrical consumption rather than convert it into hydrogen. Therefore this scenario is considered unlikely.

Table 7-2 power supply list - grid supply scenarios

Project Phase	Power from Grid to BEH	Scenario A (MW)	Scenario B	Scenario C (MW)	Power from Wind to H_2

	(except the electrolyser) (MW)		**(Base Case) (MW)**		**Electrolysers (MW)**
		"0% from Grid"	**"10% from Grid"**	**"40% from Grid"**	
Core 2030	30	0	0	0	0
Build-Out 2030	90	0	0	0	0
Build-Out 2040	370	0	130	880	2200
Build-Out 2050	290	0	400	2640	6600

The base case for grid power to the H_2 electrolysers can be considered as scenario B, where 130MW and 400MW connections are made between the grid and the electrolysers for the 2040 and 2050 build-out phases respectively. This scenario is foreseen to allow for a nominal supply of power from the grid to help stabilise the operations of the electrolysers. This is 10% of the average power anticipated from offshore wind farms, based on an optimistic 60% capacity factor.

The connection capacities (130MW by 2040 and 400MW by 2050), are considered to be feasible in terms of grid power availability and local infrastructure capacity.

7.4 POWER SUPPLY CONNECTIONS

This section presents a table of all the anticipated power connections for the various phases of the BEH. Each connection being established between the supplying substation and a receiving substation at BEH.

The connection list is presented in the Table below, with the following points of consideration to note:

- For the core project, 30MW connection, a connection request was made to UK Power Networks to determine the most appropriate point of connection substation as well as an estimate budget cost for the connection. UK Power Networks have provided this connection estimate as shown in Appendix A. The nominated point of connection substation is Earlham Grid (132kV) located about 38km from the BEH site.
- Options for the point of connection substations for the build-out phases are subject to confirmation and study by the National Grid and/or UK Power Networks. The nominated locations are only indicative.
- Grid connection supply voltage needs to be determined based on the requirements of the receiving facilities and the capacity of the grid operator.
- Windfarm connection voltage level to be confirmed by detailed studies. 400kV is considered due to busbar current carrying capacity.
- It is assumed that each offshore windfarm will be linked to the BEH via a dedicated onshore substation. Other configurations may be possible with cost benefits such as combining and linking of substations and windfarms. This must be investigated at future stages of the project.

Table 7-3 power supply connections list - grid and offshore wind to BEH

Project	Conn. #	Capac. (MW)	Supplier	Supply Substation Options	Receiving Substation	Supply voltage
2030 Core	1	30	UKPN	Earlham Grid (132kv)	BEH Main Substation	33kV – 132kV
2030 Build-out	2	90	UKPN	Earlham Grid (132kv), or Norwich Main (132kv)	BEH Main Substation	33kV – 132kV
2040 Build-out	3	290	UKPN/NG	Earlham Grid (132kv), or Norwich Main (132kv), or Norwich Main (400kv)	BEH Main Substation	33kV – 132kV
2040 Build-out	4	130	UKPN/NG	NORWICH MAIN (132kv) NORWICH MAIN (400kv)	Electrolyser 1 Substation	33kV – 400kV
2040 Build-out	5	2200	Offshore Windfarm 1	Windfarm Onshore Substation 1	Electrolyser 1 Substation	400kV
2050 Build-out	6	130	UKPN/NG	NORWICH MAIN (132kv) NORWICH MAIN (400kv)	Electrolyser 2 Substation	33kV – 400kV
2050 Build-out	7	2200	Offshore Windfarm 2	Windfarm Onshore Substation 2	Electrolyser 2 Substation	400kV
2050 Build-out	8	130	UKPN/NG	NORWICH MAIN (132kv) NORWICH MAIN (400kv)	Electrolyser 3 Substation	33kV – 400kV
2050 Build-out	9	2200	Offshore Windfarm 3	Windfarm Onshore Substation 3	Electrolyser 3 Substation	400kV

7.5 GRID SUPPLY

This section presents a number of general considerations regarding the local grid network in East Anglia and the availability of renewable power in the UK.

It should be noted that harmonics from the electrolyser rectification are not investigated in this technical note. This could be a large risk and at this scale of electrolysis will require better rectifier design development to prevent high harmonics in the power network and carry over to the grid. It is recommended that this is reviewed in the next phases of the BEH project.

7.5.1 RENEWABLE POWER IN THE GRID

Recent projections for the UK’s energy demand and supply demonstrate the potential for the local grid around Bacton to supply a considerable amount of renewable energy to supply the BEH.

The Climate Change Committee estimates that the UK’s electricity demand could reach 500TWh by 2035, and double or triple from current levels by 2050. It is estimated that variable renewables could meet the majority of this increased demand over the next 15 years; replacing coal power stations, which will all be offline by 2024, and gas generation [Ref 9].

In line with the above, a transition of electricity generation away from fossil fuels to variable renewables is forecast over the next few decades as shown in Figure 7-1, [Ref 9]. This figure demonstrates the split of power generation sources for the entire UK and not just the Bacton area. However, it can be assumed that a significant proportion of the UK's renewable energy generation would originate from offshore wind in the southern North Sea and would therefore be available for the Bacton Energy Hub.

The total energy demand of the three green Electrolysers would be around 58TWh by 2050. Considering that renewable energy in the UK grid is projected to reach around 500TWh by 2050, the Electrolysers would require about 12% of the UK's total renewable energy generation in the grid. Considering that not all of that energy would be available in the Bacton area, that percentage would be even higher. It is therefore the assumption of this study that the main source of renewable power for the green Electrolysers shall be dedicated offshore windfarms, with a smaller supplementary grid connection.

In addition, it is not considered feasible to power the Electrolysers off of constrained wind power as there levels of required power far exceed the available constrained power in the region, as stated in the SNS Bacton Report [Ref 13].

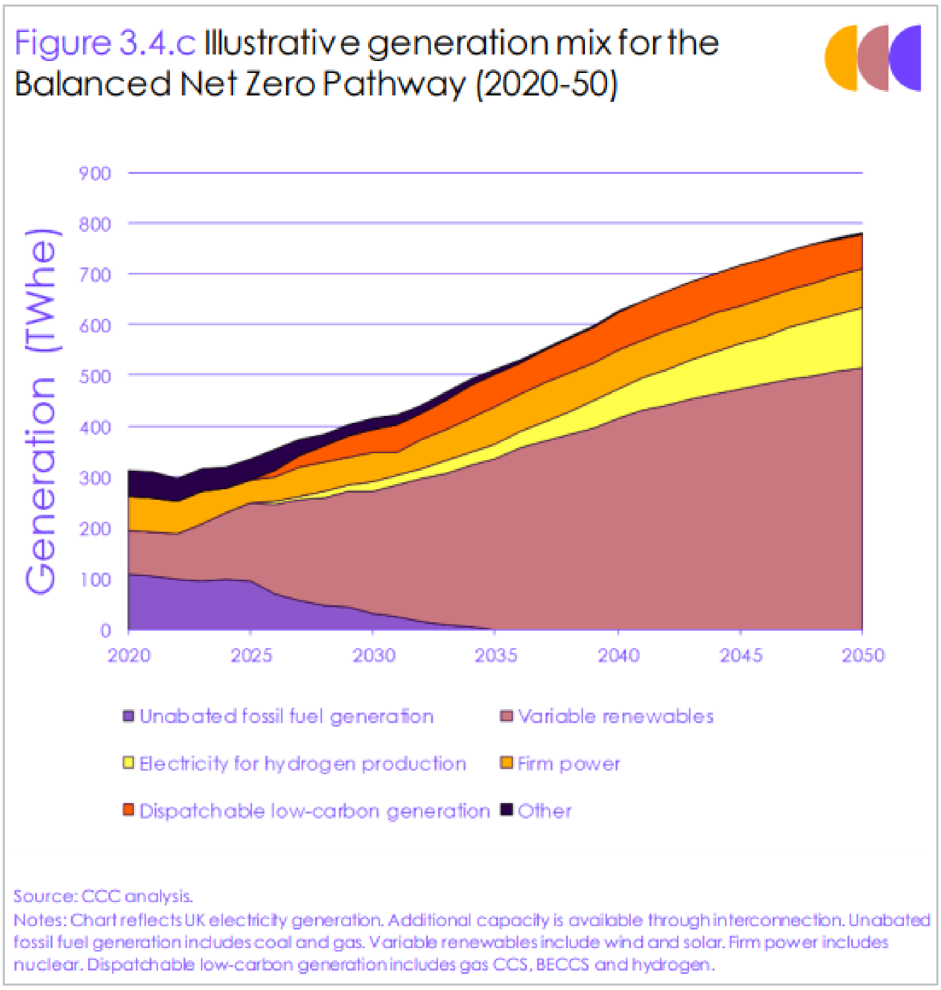


Figure 3.4.c Illustrative generation mix for the Balanced Net Zero Pathway (2020-50)

Source: CCC analysis.
Notes: Chart reflects UK electricity generation. Additional capacity is available through interconnection. Unabated fossil fuel generation includes coal and gas. Variable renewables include wind and solar. Firm power includes nuclear. Dispatchable low-carbon generation includes gas CCS, BECCS and hydrogen.

Figure 7-1 Electricity generation forecast, [Ref 9]

7.5.2 POINT OF CONNECTION (SUBSTATION) OPTIONS

Supply of electricity from the grid to the BEH could take place from a number of existing substations that are located relatively closely to the hub.

The choice of substation will depend on a number of variables including distance, available capacity, required power, infrastructure and the local demand and supply balance.

The choice of substation connection is determined by the National Grid and/or UKPN, who will conduct a study to determine the most suitable location, which would also provide the highest return on investment for the grid operator.

A request was submitted by Saipem Ltd to UK Power Networks to examine the options for the core project (30MW) to the grid. UK Power Networks have performed an initial investigation and provided an estimate budget for the 30MW connection into Bacton by 2030, this can be seen in detail in Appendix A – Connection Budget Estimate.

UK Power Networks have determined that for the core BEH project, the most appropriate Point of Connection is the Earlham Grid (132kV) substation.

This would result in a connection circuit length of ~38km. The cost of establishing this 30MW connection to the grid is £37.4m (exclusive of VAT).

For the build-out scenarios, other points of connection may be considered. A list of local substations which might considered for connection into the BEH are listed in Table 7-4 below. This is not an exhaustive list, rather it is indicative of potential options in the vicinity of BEH. An evaluation by the grid operator is required to confirm the most appropriate POC substation.

Table 7-4 Potential existing substations to supply the BEH

UKPN/NG Substations	**Voltage**	**Approx. distance**	**Comments**
Earlham Grid	132kV	25 miles	Selected by UKPN for the core project 30MW connection for the base-case, see Appendix A – Connection Budget Estimate.
Sall Grid	132kV	14 miles	Nearest 132kV SS
Great Yarmouth Grid	132kV	22 miles	
Hempton Grid	132kV	27 miles	
Norwich Main	132kV	27 miles	Nearest 132kV SS that is connected to 400kV network
Norwich Main	400kV	27 miles	Nearest 400kV SS

Note that the Knapton Primary Substation (>22kV) is not considered in the list above as it has been excluded by UKPN for the core project supply. It is assumed that this substation will not have sufficient capacity to support any of the BEH major power demands.

The locations of the above substations and associated overhead lines can be seen in Figure 7-2 below.

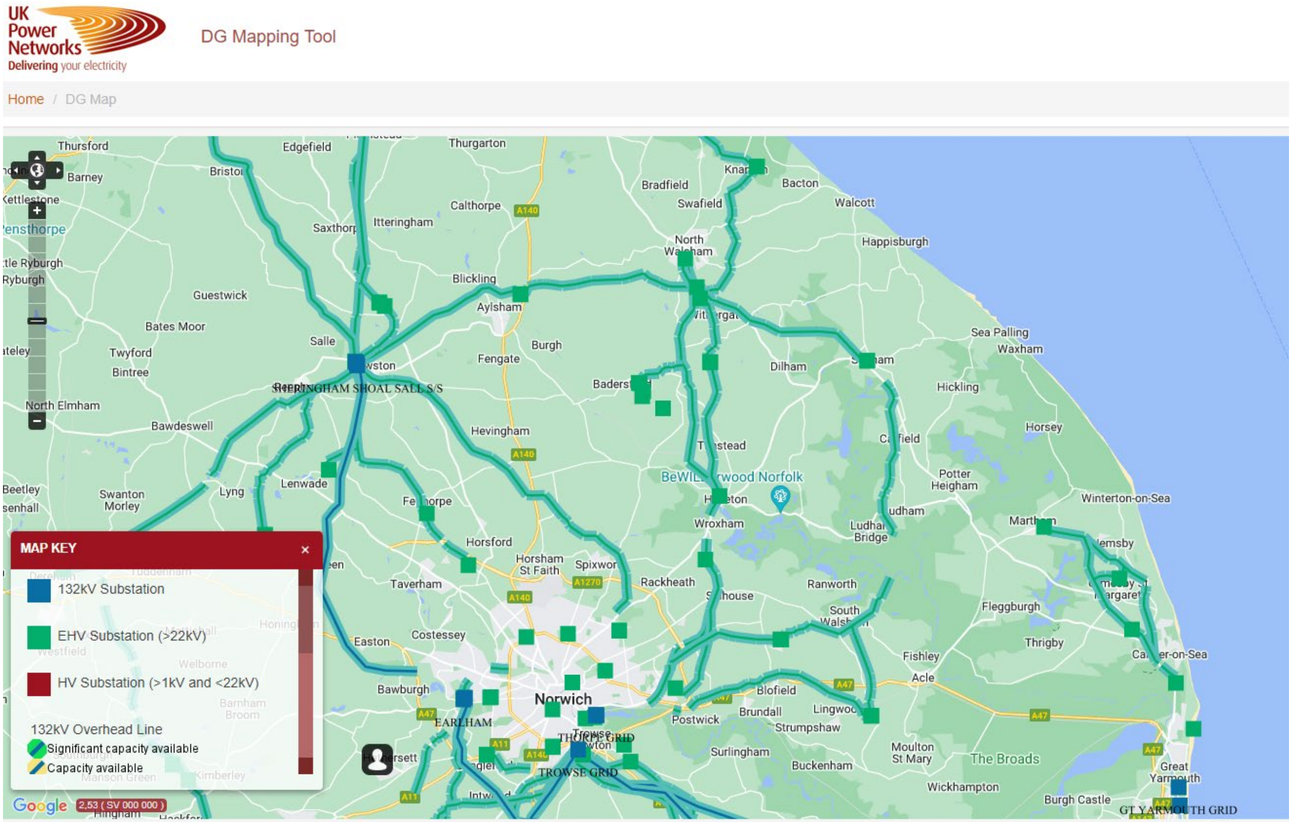


Figure 7-2 East Anglia UKPN substations and overhead lines (132kV and >22kV) [Ref 11]

7.5.3 GRID CONNECTION CONSIDERATIONS

Establishing a grid connection into the BEH is entails the following considerations:

- The grid operator’s Point of Connection (POC) substation will require a number of upgrades to accommodate the required power demand, these upgrades may include the installation of new switchgear and new cables. This will form a significant part of the cost of connection, as determined by the grid operator.
- A Point of Supply (PoS) substation may be required. This would function as the switching/transformer substation and would be located within/in close proximity to the Project. The substation will would be owned by the grid operator (National Grid or UK Power Networks) and would constitute a part of the cost of connection to the grid. It is noted that all the civil works associated with the PoS substation are to be performed by the Project at no cost to the grid operator.
- Installation of new transmission lines or upgrading them. These can either be overhead for long distances or buried for shorter connections. The transmission lines may use existing routes and towers or may be established over new infrastructure. These variables are to be studied by the grid operator and would form part of the cost of connection.
- It is assumed that the grid will have sufficient supply capacity by the indicated project timelines. The assessment of available power is conducted by the grid operator in collaboration with the Project.

- In cases of insufficient capacity in the local grid, additional work may be required to bring-in power from other parts of the network. This may include additional upgrades of lines and substations to import the power.
- The BEH development would have to bear a portion of the cost of any required network upgrades, see Appendix A – Connection Budget Estimate for an estimate budget for the core project.
- NG develops and owns the Switching Substations required to connect to HV OHL, while the Project developer owns any substation equipment upstream of the connection station.

7.5.4 EAST ANGLIA NETWORK REINFORCEMENTS

There are short- and long-term plans to upgrade and reinforce the national grid network in East Anglia. The current export capacity of the grid in East Anglia is around 3.5GW, and the network operator plans to expand this to between 10-17GW in the coming ten years, [Ref 16].

This is primarily due to the anticipated increase in power generation that will connect into the grid at this region. The increased generation would come from offshore wind, nuclear and interconnections.

National Grid ESSO expects generation in the region to increase to a range between 10GW and 17GW in the next ten years, [Ref 16]. Without network reinforcements, the network would not be able to accommodate this increase.

The planned reinforcements include rewiring lines with larger diameter conductors, installing new lines and connections, and installing power control devices.

Figure 7-3 shows the current configuration of the transmission-level power grid in East Anglia.

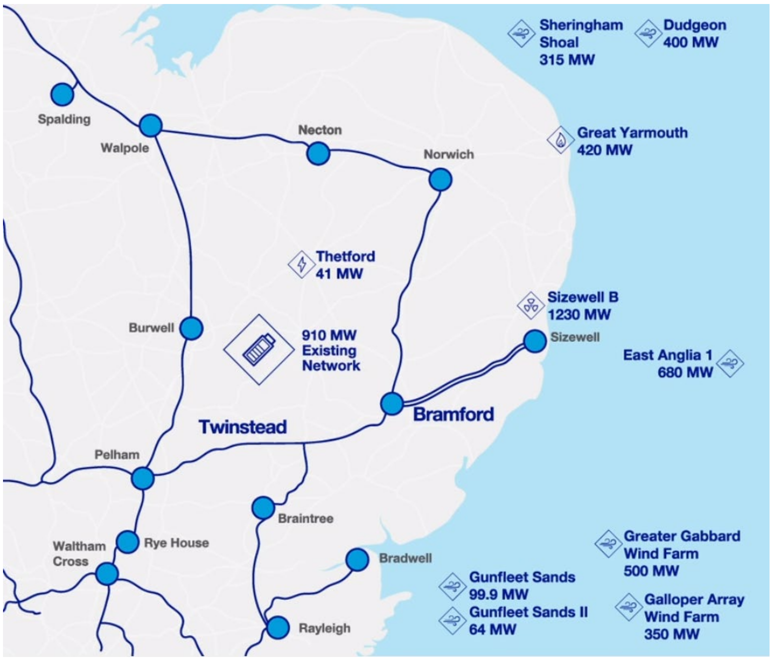


Figure 7-3 East Anglia's (400 kV) electricity transmission network was built in the 1960s [Ref 16].

7.6 Offshore Wind

The green hydrogen electrolysers require 2200MW of renewable power at full load per single plant. With a total of three plants, the total demand is 6.6GW of renewable energy.

Of the currently available options for renewable power supply, offshore wind provides the highest capacity to fulfil this level of demand.

7.6.1 Offshore Wind in Southern North Sea

The SNS area enjoys relatively high winds offshore and the area has been the focus of ongoing UK wind farm development projects. The SNS Bacton Energy Hub Report [Ref 13] shows that the BCA may have a pro-rata share of the total UK offshore wind capacity that is around 5GW by 2030, 8.5GW by 2040, and of 15GW by 2050.

These levels of power could potentially be available to power the green hydrogen electrolysers in the BEH (2.2GW by 2040 and 6.6GW by 2050).

Such a scenario can be achieved in several ways:

- SNS offshore windfarms provide power to the grid as normal, while BEH receives its demand from the local grid (e.g. via Norwich Main Substation). In such a scenario, the grid operator would install high voltage lines from its substation to BEH while a switching substation will provide the final link to BEH.
- SNS offshore windfarms would export power directly to BEH. The windfarm would provide HVAC power to BEH at 400kV. In this scenario, an additional connection to the grid may still be useful to allow for smoothing of power from the windfarms, see the Green Hydrogen Report.

Figure 7-4 below shows all current agreements and developments in the southern North Sea area.

Currently several large-scale windfarms are planned to make landfall close to the Bacton terminal. These projects then transfer their power via underground HVDC cables to the national grid at the 400kV level. A windfarm project substation is typically located close to the national grid substation to convert the power to alternating current at the required grid voltage.

While older windfarms in the SNS were located closer to shore and employed HVAC export technology, the latest proposals in development are larger in scale (multi-Gigawatts) and further in distance (up to 140km from shore) and these are planned with HVDC technology.

The conditions in the SNS also favour the utilisation of fixed-bottom foundations in the form of monopiles and jackets, [Ref 4]. Therefore, all of the developments in the SNS employ these technologies; it is not envisioned that floating wind would be required in this region.

Figure 7-4 shows that there is still significant sea area available in the region for future windfarm developments; some of this can be utilised for the development of offshore wind farms to support the BEH green electrolysers.

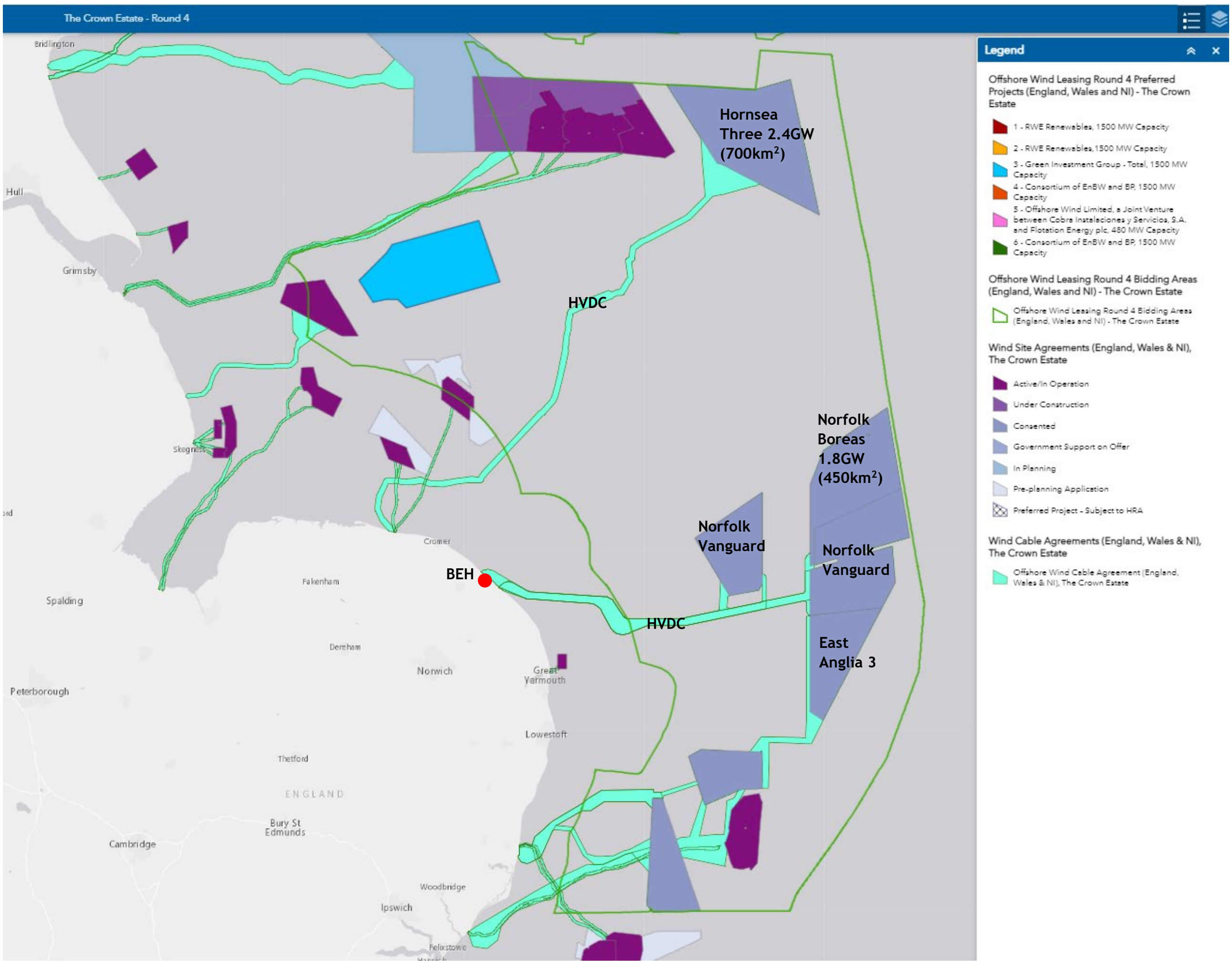


Figure 7-4 UK offshore wind leasing round 4 preferred projects [Ref 15]

7.6.2 WINDFARM CONNECTION

The base case concept for powering the electrolysers is a dual connection setup; with power from the grid and power from a dedicated offshore windfarm supplied behind the meter.

To power a single 2200MW electrolyser plant, a 2200MW windfarm would export power directly to the electrolyser substation. Connection will be made at 400kV to accommodate the large power transfer.

To supplement the wind power, the electrolyser substation is also supplied with a grid connection. The grid connection voltage will depend on how much renewable power is available for use in the grid. Where available power is low, a lower connection voltage may be considered, e.g. in the range of 33kV. If a larger capacity is available, then a connection of up to 400kV may be considered.

A demonstration of how the connections would be setup for a single 2200MW electrolyser plant is shown in Figure 7-5, this is considered indicative only.

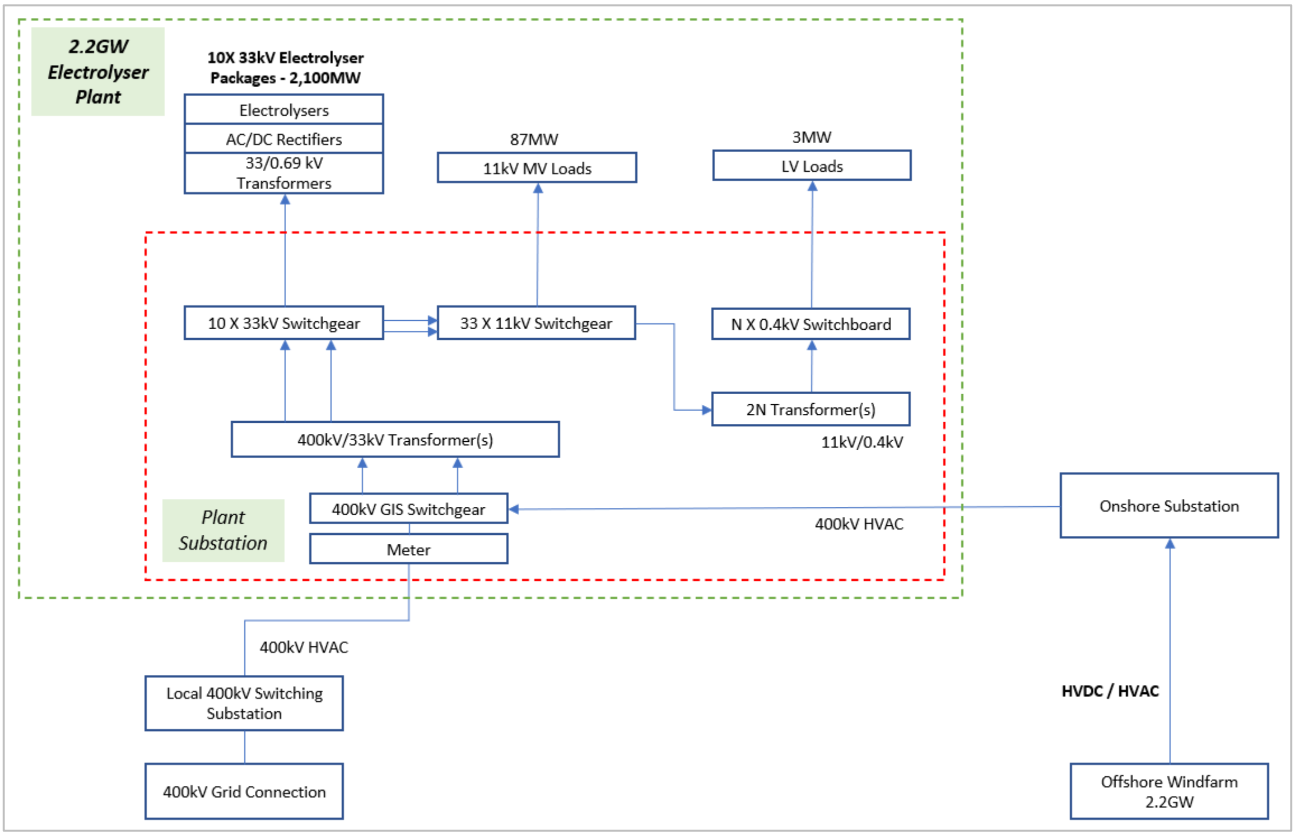


*Figure 7-5 A schematic of potential power connections to green hydrogen electrolyser plant (**Indicative Only**).*

7.6.3 Wind Farm Design

Offshore wind power is envisioned as the main supply source of renewable energy to power the green hydrogen electrolysers.

Each of the three electrolyser plants will be powered by a dedicated offshore windfarm to be located in the SNS lease area.

Wind turbine technology continues to develop with increasingly larger turbines. The larger turbines provide increased efficiencies as well as access to higher wind speeds due to higher hub heights.

By 2040, it is anticipated that at least one new generation of technology platform will be commercialised with a rated capacity in the region of 20MW. If the global offshore wind market continues to expand strongly, it is possible that a further generation of the technology will deliver turbines up to 24MW. [Ref 4]

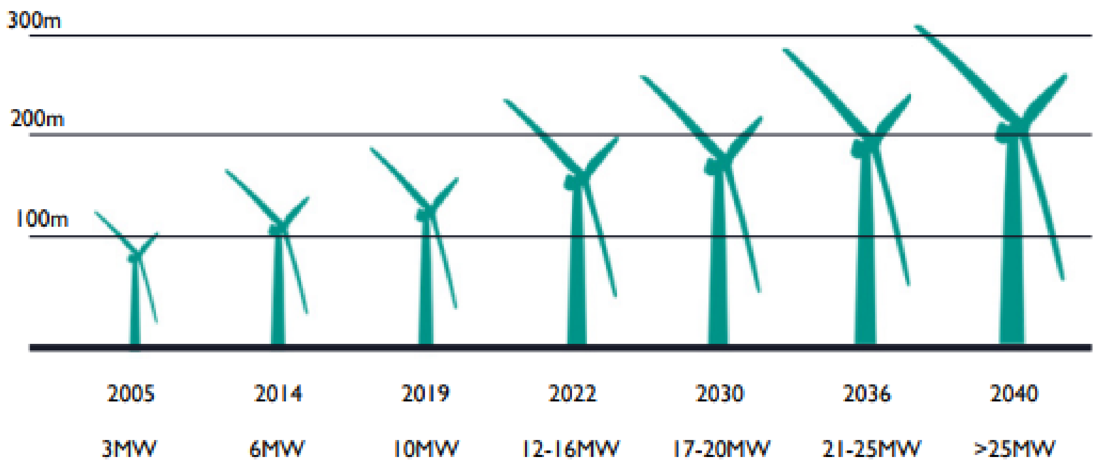


Figure 7-6 Projected turbine size development [Ref 4]

The use of larger turbines also drives an increase in capacity factors. This is due to taller towers, bigger turbines and higher average wind speeds associated with more distant offshore windfarms.

In addition, the SNS area enjoys relatively high average wind speeds compared to other regions of the world [Ref 13].

Referring to currently operating windfarms in the SNS, the East Anglia ONE windfarm (714MW, piled jackets, 7MW turbines, 45km offshore, 220kV HVAC, 400kV onshore substation) has an average calculated capacity factor of ~47%, [Ref 10]. The windfarm is one of the latest to be commissioned in the SNS, coming on in 2020.

Similarly, the much larger Hornsea One windfarm (1218MW, monopile foundations, 7MW turbines, 3 offshore substations, 120km offshore, 220 kV HVAC plus offshore Reactive Power Compensation (RPC), and onshore substation 400kV) has a capacity factor of 47% [Ref 10]. The windfarm was commissioned in 2019.

These capacity factors compare favourably to the global average for offshore wind of 43% in 2018, [Ref 12].

Globally, the weighted average capacity factor for offshore wind has increased by 8% since 2010, to 43%, and forecasts predict upcoming projects to have higher capacity factors up to 58% in 2030 and 60% in 2050, [Ref 12].

Based on the above, future windfarm developments in the SNS can be assumed to have relatively high capacity factors, for the purposes of this study the following can be assumed:

- For the 2040 build-out phase, a capacity factor of 55% is assumed.
- For the 2050 build-out phases, a capacity factor of 60% is assumed.

Figure 7-7 below shows the global historical capacity factor ranges for offshore wind with predictions for 2030 and 2050 [Ref 12].

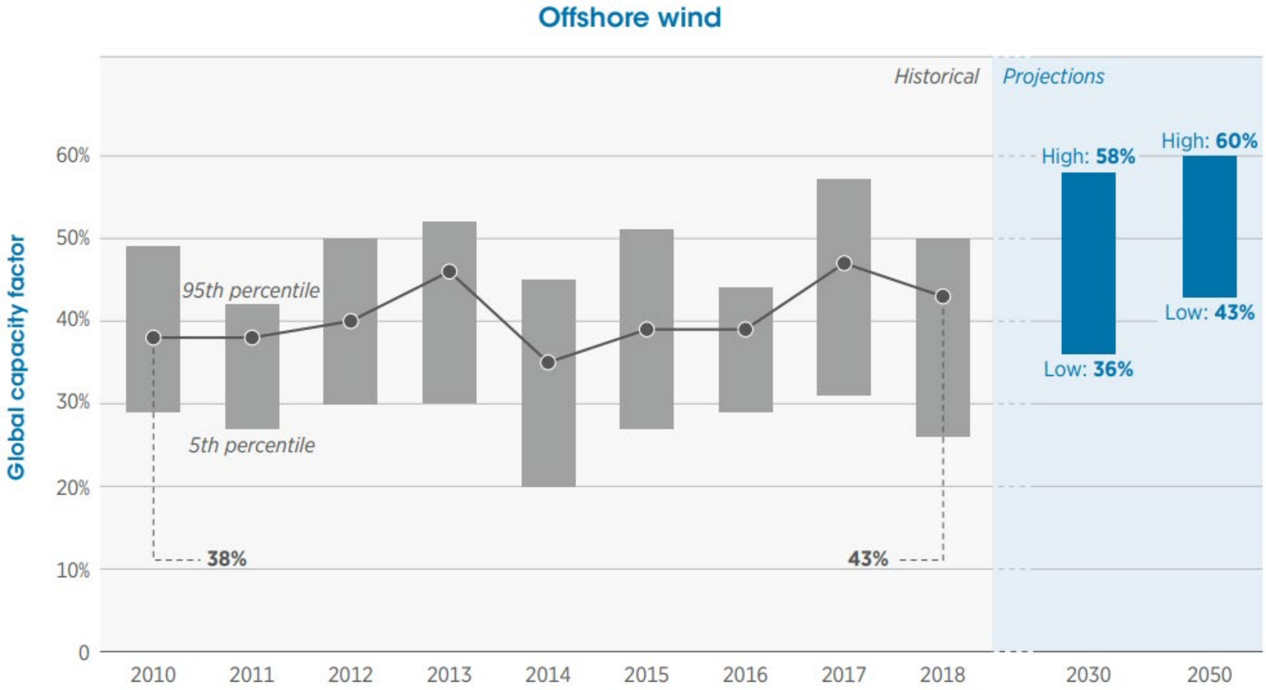


Figure 7-7 The global weighted average capacity factor for offshore wind, [Ref 12].

Based on the above information, an indicative windfarm sizing can be performed as reported in Table 7-5 below.

Indicative windfarm areas are based on an assumed spacing of 10 rotor diameters windward and 8 rotor diameters crosswind.

Table 7-5 Indicative windfarm size

Project Phase	**Windfarm**	**CAPACITY MW**	**WTG RATING MW**	**No. of WTG**	**Capacity Factor %**	**Annual Yield TWh**	**Rotor Diameter m**	**Windfarm Area km^2**
2040 Build-out	OFFSHORE WINDFARM 1	2200	20	110	55	10.6	275	500
2050 Build-out	OFFSHORE WINDFARM 2	2200	25	88	60	11.6	310	500
2050 Build-out	OFFSHORE WINDFARM 3	2200	25	88	60	11.6	310	500

7.6.4 WINDFARM CONSIDERATIONS

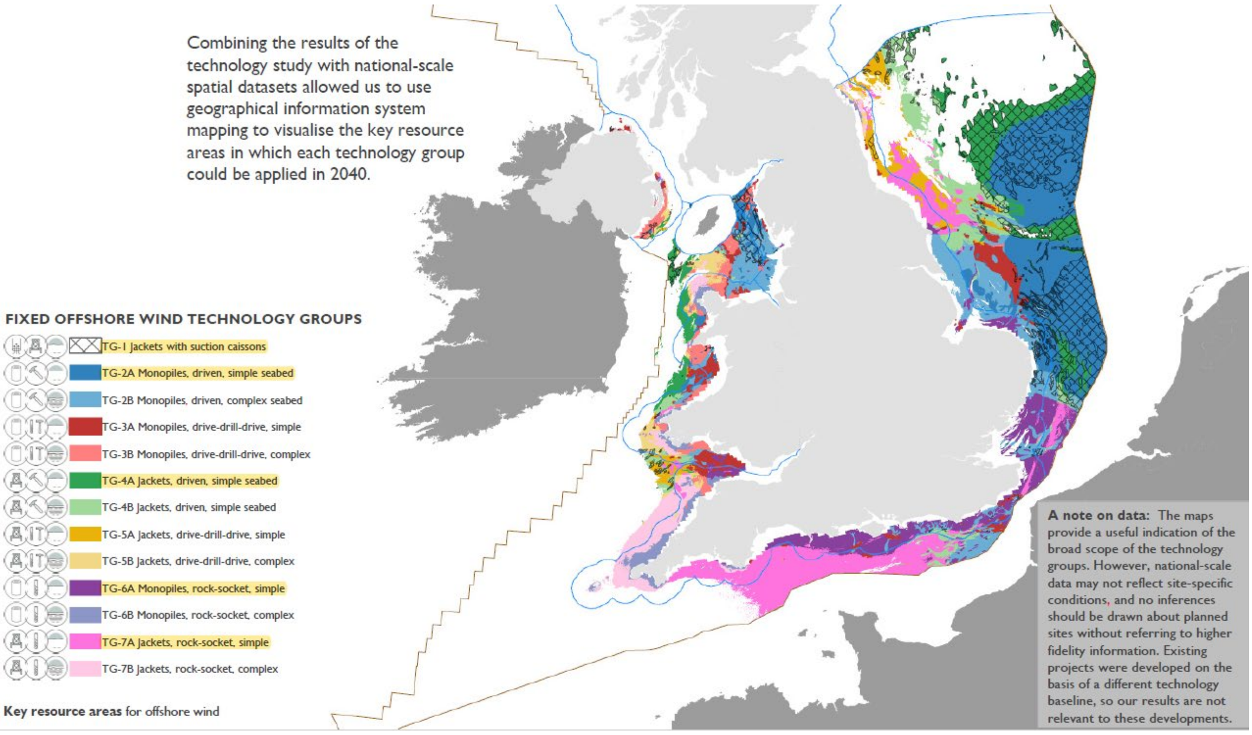
Offshore Foundations:

Offshore wind developments in the southern North Sea are dominated by fixed-bottom foundations, either using monopiles or jackets. It can be reasonably assumed that any future developments in the area will also use fixed foundations.

The water depth criteria for employing monopiles versus jackets can be considered as follows [Ref 4]:

- Monopiles for 10-45m water depth.
- Jacket structures for 45-70m water depth (20-70m, with suction caissons).

The majority of the SNS region is suitable for fixed-bottom foundations of different types, see Figure 7-8, [Ref 4].



Combining the results of the technology study with national-scale spatial datasets allowed us to use geographical information system mapping to visualise the key resource areas in which each technology group could be applied in 2040.

A note on data: The maps provide a useful indication of the broad scope of the technology groups. However, national-scale data may not reflect site-specific conditions, and no inferences should be drawn about planned sites without referring to higher fidelity information. Existing projects were developed on the basis of a different technology baseline, so our results are not relevant to these developments.

Figure 7-8 Fixed Offshore Wind Technology Areas [Ref 4]

Transmission Technology:

The distance of an offshore windfarm to shore impacts cable and installation costs as well as potential electrical line losses. The distance therefore plays a role in the determination of the most economic transmission technology, i.e. choice of HVAC versus HVDC.

Newer windfarm developments in the SNS, including those currently in planning, are becoming more distant from shore, with recent developments such as Hornsea 3 having an offshore cable corridor length of 163km. While the Norfolk Boreas windfarm has an offshore cable corridor of 72km.

Future developments in the region can be expected to have similar distances to shore, see Figure 7-4.

The choice of HVDC vs. HVAC depends on the export distance from the windfarm substation to the interconnection point. For longer distances, HVAC exhibits reactive resistances in the export cables leading to energy losses. HVDC does not exhibit such losses but does require additional investment in infrastructure.

Therefore, HVDC becomes cost effective (in terms of LCOE) at distances from 80-150km, [Ref 12]. The production capacity of the windfarm would then dictate the number of cables and the optimum voltage to export power to shore.

APPENDIX A – CONNECTION BUDGET ESTIMATE

Registered Office
Newington House
237 Southwark Bridge Road
London SE1 6NP

Company:
UK Power Networks
(Operations) Limited

Registered in England and Wales No: 3870728

Mr N Kubba
Saipem Ltd
Saipem House
12-42, Wood Street
KINGSTON UPON THAMES
Surrey
KT1 1TG

Date: 11 August 2022

Our Ref: 8600026253 / QID 3000041060

Dear Mr Kubba,

Site Address: Paston Road NORWICH NR12 0JE

Budget estimate

I am writing to you on behalf of Eastern Power Networks plc the licensed distributor of electricity for the above address trading as and referred to in this Quote as “UK Power Networks”. Thank you for your recent enquiry regarding the above premises.

I am pleased to be able to provide you with a budget estimate for the Works for 30MVA import.

It is important to note that this budget estimate is intended as a guide only. It may have been prepared without carrying out a site visit or system studies. No enquiry has been made as to the availability of consents or the existence of any ground conditions that may affect the ground works. It is not an offer to provide the connection and nor does it reserve any capacity on UK Power Networks’ electricity distribution system.

Description of work included:

PoC Voltage: 132kV
Circuit Length: ~38km
P0C Location: Earlham Grid 132 kV
PoS Voltage: 132kV

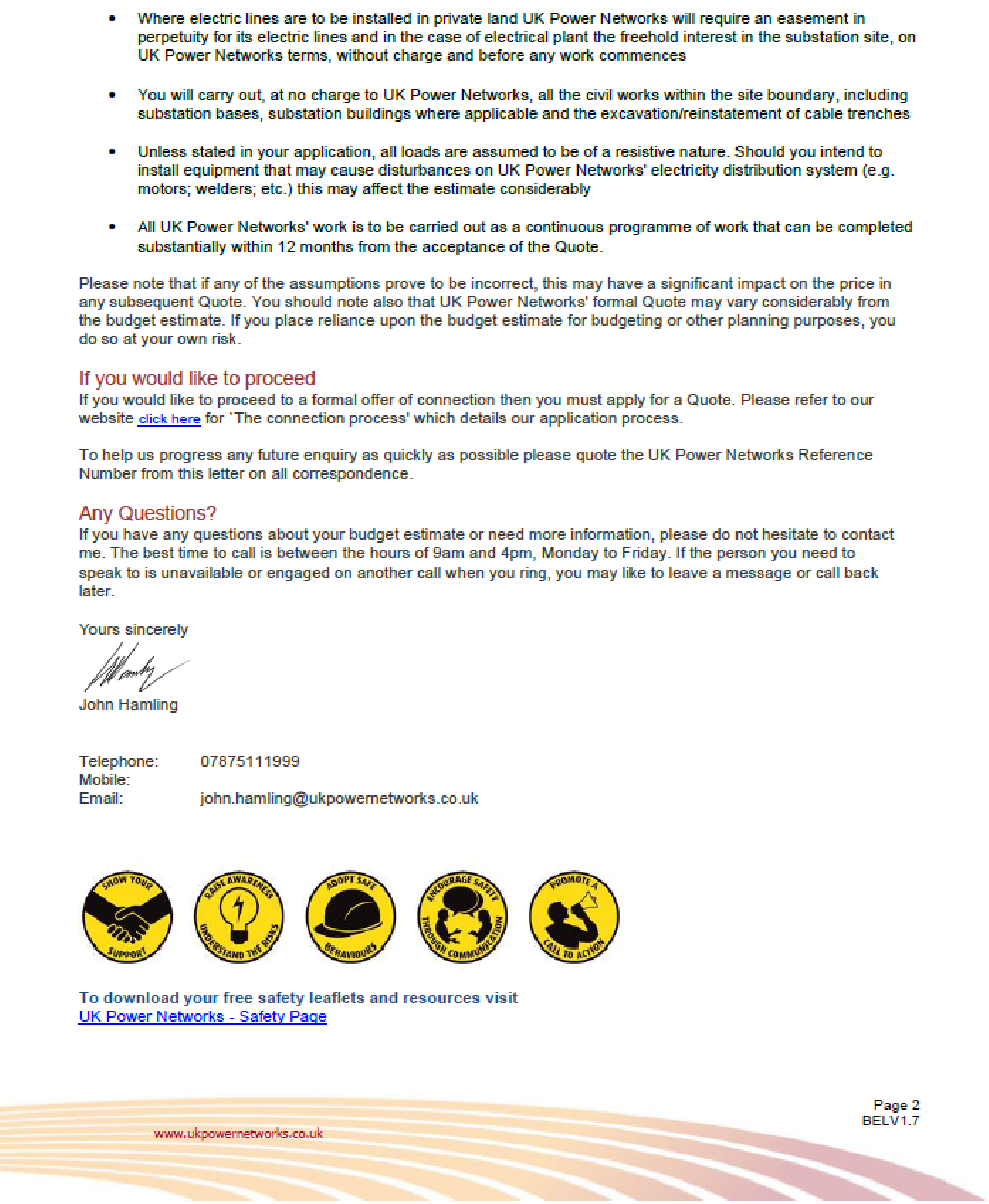
Price

£37,400,000.00 (exclusive of VAT)

Assumptions

This budget estimate is based on the following assumptions:

- The most appropriate Point of Connection (POC) is as described above.
- A viable cable or overhead line route exists along the route we have assumed between the Point of Connection (POC) and your site
- In cases where the Point of Connection (POC) is to be at High Voltage, that a substation can be located on your premises at or close to the position we have assumed



- Where electric lines are to be installed in private land UK Power Networks will require an easement in perpetuity for its electric lines and in the case of electrical plant the freehold interest in the substation site, on UK Power Networks terms, without charge and before any work commences
- You will carry out, at no charge to UK Power Networks, all the civil works within the site boundary, including substation bases, substation buildings where applicable and the excavation/reinstatement of cable trenches
- Unless stated in your application, all loads are assumed to be of a resistive nature. Should you intend to install equipment that may cause disturbances on UK Power Networks' electricity distribution system (e.g. motors; welders; etc.) this may affect the estimate considerably
- All UK Power Networks' work is to be carried out as a continuous programme of work that can be completed substantially within 12 months from the acceptance of the Quote.

Please note that if any of the assumptions prove to be incorrect, this may have a significant impact on the price in any subsequent Quote. You should note also that UK Power Networks' formal Quote may vary considerably from the budget estimate. If you place reliance upon the budget estimate for budgeting or other planning purposes, you do so at your own risk.

If you would like to proceed

If you would like to proceed to a formal offer of connection then you must apply for a Quote. Please refer to our website click here for `The connection process' which details our application process.

To help us progress any future enquiry as quickly as possible please quote the UK Power Networks Reference Number from this letter on all correspondence.

Any Questions?

If you have any questions about your budget estimate or need more information, please do not hesitate to contact me. The best time to call is between the hours of 9am and 4pm, Monday to Friday. If the person you need to speak to is unavailable or engaged on another call when you ring, you may like to leave a message or call back later.

Yours sincerely

John Hamling

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Page 2
BELV1.7

APPENDIX B – POWER SUPPLY CTR

CTR
Cost, Time, Resource

Project: BEH Supply SIG	**Contract No.:**	**Work Order No.:**
Contractor:		
Customer:		
Planned Start:	**Planned Finish:**	**Duration:**
CTR No.: 004	**Title:** **Hydrogen Facility Power Demand**	**Date:** **Rev:** **By:**

Objective:

Review options for existing and new renewable power demand requirements

Activity Description:

Review power demand requirements for Blue and Green hydrogen facilities, onshore CCS facilities.

Determine source:

- Grid supply
- Dedicated renewable/clean technology

Input Requirements:

Supplier data for Hydrogen facilities, desalination facilities and CCS Facility.

Output/Deliverables:

Power demand list and capacity sizing

Power demand strategy – Grid, renewables, clean etc.

Notes/Assumptions:

Prepared By:	**Checked By:**
Name:…………………………………………	**Name:**…………………………………………
Signature:…………………………………..	**Signature:**…………………………………..
Date:……………………………………………	**Date:**……………………………………………