Annex 6.2

Streamlined Carbon Footprint of Transport Associated with the Development of Offshore Wind Farm

(ERM)

CONTENTS

1 INTRODUCTION

1.1.1 Able UK Ltd (Able) is proposing to develop a port facility for the manufacture of marine energy components including off-shore wind turbines (OWT). The facility would also be a transportation hub for various off-shore wind farm sites. The port - the Able Marine Energy Park (AMEP) – will be situated on the Humber Estuary, near Immingham, North Lincolnshire. If the AMEP site is not consented, there are two generic alternatives that could deliver an equal amount of capacity for OWT production as AMEP and its supply chain.

This assessment examines AMEP along with a supply chain of 100 towers from Able Seaton Port and 100 sets of blades from Tyne Renewable Energy Park (*Figure 1.1)*. This is done so as to provide a production output which can be easily compared against alternatives.

1.1.2 The alternatives are:

- an equivalent quantum of development on a number of sites along the east coast of Britain (*Figure 1.2)*; and
- an equivalent quantum of development partly based in the UK and partly based on the continent (*Figure 1.3*).

1.1.3 Whilst these two broad alternatives could themselves have a number of specific alternatives within their scope, one reasonable option for each has been developed in order to make an informed comparison of relevant environmental impacts. These two alternatives are described and justified below.

The Alternative Distributed UK Manufacturing Sites

1.1.4 This scenario is based on the premise that Greenport Hull and the Port of Sheerness are likely to proceed in any event and so these sites are not included in the consideration of an alternative to AMEP since it is taken that they will proceed as well.

1.1.5 Taking into account the need for manufacturing to be in relative proximity to the Round 3 Sites, in particular Dogger Bank, Hornsea and Norfolk, and the size of land parcel necessary for production, the following spread of development is considered reasonable.

- Bathside Bay is the largest alternative undeveloped port location on the east coast of Britain and can provide 114 ha of land for manufacturing. This site could support 2 nacelle manufacturers (400 nacelles per year) and two blade manufacturers (400 sets of blades per year) with a supply chain producing 100 000 T of components per year. It will also be assumed to have four dedicated construction quays that will provide for the construction of 400 OWTs per annum.

- The other sites closest to the Round 3 zones that could support some manufacturing lie on the Tyne and the Tees. It is assumed that Able Seaton Port (ASP) will be the base for a nacelle manufacture (200 nacelles per year) and a supply chain producing 50 000 T of components per year. Half of the nacelles will be exported to Great Yarmouth; 100 OWTs shall be constructed at ASP. Able Middlesbrough Port will support a tower manufacturer producing 200 towers per year and the Tyne will provide a base for a blade manufacturer producing 100 blade sets per year.

- Methil in Scotland is already a base for foundation manufacturing and it can produce the 50 foundation structures that AMEP plans to produce. This scenario assumes that it can further support a tower manufacturer producing 300 towers per year.

The Alternative Distributed Continental Manufacturing Sites

1.1.6 This scenario is based on the premise that only limited manufacturing facilities are ultimately located in the UK with the balance of manufacturing being based in continental Europe. Again, since Greenport Hull and the Port of Sheerness are assumed to proceed, these sites are not considered an alternative to AMEP.

1.1.7 Taking into account the need for manufacturing to be in relative proximity to the Round 3 Sites, in particular Dogger Bank, Hornsea and Norfolk, and the size of land parcels necessary for production, the following spread of development is considered reasonable in this scenario.

- Eemshaven in Holland has a large parcel of potential development land. This site could support a nacelle manufacturer (200 nacelles per year) and a blade manufacturers (200 sets of blades per year) with a supply chain producing 100 000 T of components per year.

- Bremerhaven in Germany has existing manufacturing facilities and has plans to develop more land for manufacturing. This site could also support a nacelle manufacturer (200 nacelles per year) and a blade manufacturer (200 blade sets per year).

- The UK sites that could support manufacturing lie on the Tyne and the Tees. Able Middlesbrough Port will support a tower manufacturer producing 200 towers per year and the Tyne will provide a base for a blade and a nacelle manufacturer producing 100 blade sets and 200 nacelles per year.

- Methil in Scotland is already a base for foundation manufacturing and this scenario further assumes that it can produce the 50 foundation structures that AMEP plans to produce. It is also assumed to support a tower manufacturer producing 300 towers per year.

- The Port of Great Yarmouth will provide a base for the construction of 200 OWTs per year. The balance of construction activity is assumed to be undertaken at Harwich and on the Tees where 200 and 100 OWTs respectively, will be assembled annually.

In terms of considering the difference in environmental impact between the three alternatives, one important aspect is the variation between the sea transportation that would be required in each case. This report assesses the carbon footprint of sea transportation that each alternative imparts, in order to gauge which of them has the lowest associated environmental impact with respect to carbon emissions. To this end, a carbon footprint assessment was undertaken by Environmental Resources Management Limited (ERM), following a streamlined method. A 'streamlined' method identifies elements of the carbon footprint that can be omitted or where surrogate or generic data can be used without significantly affecting the accuracy of the results. System boundaries are noted in *Section 2.5*.

1.1.8 The method, results and conclusions of the streamlined carbon footprint assessment are presented in this short report.

1.1.9 The remainder of this report is set out as follows:

- project approach;
- inventory;
- data quality and limitations;
- results;
- conclusions; and
- references.

2 *PROJECT APPROACH*

2.1.1 This section outlines the project aims and the method used for this assessment.

2.2 *PROJECT AIMS*

2.2.1 The aim of this project is to establish the carbon footprint of transporting OWTs and their components by sea via routes proposed in three scenarios. Further to this aim, comparison between the three alternative scenarios is required to establish which is the most desirable, in terms of minimising the carbon emissions associated with sea transport.

2.3 *PROJECT SCOPE*

2.3.1 The scope of this streamlined assessment is to calculate the carbon footprint associated with the sea transportation of OWTs and their components from manufacturing bases to wind farm sites for three scenarios:

- AMEP Supply Chain;
- Alternative A - Distributed UK Manufacturing Sites; and
- Alternative B - Distributed Continental Manufacturing Sites.

2.3.2 Within each of these three scenarios, the final stage of transportation is to the following three wind farm sites in the North Sea:

- Dogger Bank – 1 800 wind turbines / 9 GW capacity;
- Hornsea – 800 wind turbines / 4 GW capacity; and
- Norfolk – 1 440 wind turbines / 7.2 GW capacity.

2.3.3 The streamlined assessment uses primary data, such as fuel use and transportation distances from Able, as well as secondary data, such as greenhouse gas (GHG) emissions factors from trusted sources.

2.3.4 The study allows a comparison of the carbon footprint of sea transportation for the three scenarios.

2.4 FUNCTIONAL UNIT

2.4.1 In life cycle assessment (LCA) and carbon footprinting, environmental impacts are represented in terms of a metric known as the functional unit. The functional unit represents a quantified environmental impact as a function of the desired output of a process and ideally allows for a straightforward comparison between similar processes.

2.4.2 The functional unit for this study has been defined as the transportation by sea of all components required for 500 complete 5 MW OWTs and 50 foundations from their manufacturing bases to Dogger Bank, Hornsea and Norfolk wind farms and the transportation by sea of 100 excess nacelles to a construction port within the UK. This represents the potential annual production capacity for AMEP.

2.5 SYSTEM BOUNDARY

2.5.1 This streamlined carbon footprint focuses on sea transportation of OWTs and their components from manufacturing bases to wind farm sites and does not consider the entire life cycle (ie cradle to grave) of wind turbines. In this respect, looking at the wider context, it can be said that the burdens associated with raw material acquisition, manufacturing, installation, decommissioning and end of life are assumed to be the same in each scenario and have been excluded.

2.5.2 The following life cycle stages have been included in the carbon footprint assessment:

- sea transportation of components required to construct 500 5 MW OWTs from their manufacturing base to construction ports;
- sea transportation of 500 complete 5 MW OWTs from construction ports to wind farm sites in the North Sea;
- sea transportation of 50 foundations from their manufacturing base to wind farm sites in the North Sea; and
- sea transportation of 100 excess nacelles from their manufacturing base to a construction port within the UK.

2.5.3 The following life cycle stages have been excluded from the carbon footprint assessment:

- extraction and transportation of all raw materials required to manufacture wind turbine components;
- manufacturing of wind turbine components and complete wind turbines;
- any packaging required for wind turbine components or complete wind turbines;
- the sea transportation of 450 foundations from their manufacturing base to wind farm sites in the North Sea (this remains identical in each scenario and was therefore excluded);
- installation of wind turbines;
- operation phase (including maintenance);
- waste at all stages of the life cycle; and
- decommissioning and end of life.

2.5.4 In addition, the following aspects have been excluded, which cover more than one life cycle stage:

- capital goods (eg manufacturing of vessels used to transport turbines); and
- human energy inputs.

2.6 CARBON FOOTPRINT CALCULATION

2.6.1 Data collected from Able and other (secondary) sources were used to model the carbon footprint of each scenario in the LCA software SimaPro. This software tool allows releases of GHGs associated with a particular process to be quantified, including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Total emissions of individual GHGs are subsequently normalised to CO_2 equivalents, using global warming potentials, which take into consideration the ability of each gas to absorb infra red radiation and its lifetime in the atmosphere over a certain period of time (usually 100 years). The resulting metric is a quantity of carbon dioxide equivalents (CO_2e).

2.6.2 The carbon footprint calculation process of this study began by using primary data provided by Able on fuel type, fuel consumption, return trips, affect of loading on fuel consumption and typical vessel utilisation to model the inputs and outputs associated with transporting one tonne of goods one kilometre. This metric is known as a tonne kilometre (tkm) emission factor. Secondary data from Defra (2010) on the inputs and outputs associated with the life cycle (ie extraction, refining, transportation and combustion) of marine diesel oil was also used in creating this metric.

2.6.3 The next step involved applying the tkm emission factors for loaded and empty vessels to data provided by Able on transportation distances and masses of OWTs and their components. This was carried out for each transportation stage of each scenario.

2.6.4 An impact assessment was subsequently carried out on each of the scenarios using the latest (2007) 100 year global warming potentials from the Intergovernmental Panel on Climate Change (IPCC), where all IPCC gases were considered. All carbon footprints presented in this study are measured in tonnes of carbon dioxide equivalents (t CO_2e).

3 *INVENTORY*

3.1.1 This section provides a description of the data collected, which was used in this study to model sea transportation, as per the system boundary.

3.2 *OFFSHORE WIND TURBINES AND COMPONENTS*

3.2.1 The masses of components required for a 5 MW OWT were provided by Able (as per The Crown Estate report, '*A guide to an Offshore Wind Farm*'), and are as follows:

- Tower (T) = 200 tonnes;
- Blade set (B) = 45 tonnes;
- Nacelles (N) = 150 tonnes;
- Slewing rings, flanges etc = 20 tonnes;
- Total OWT = 415 tonnes; and
- Foundation (F) = 600 tonnes.

3.2.2 In accordance with the functional unit of this study, each scenario comprises the transportation of:

- 500 OWTs (comprising the nacelle, blades and tower);
- 50 foundations; and
- 100 excess nacelles.

3.2.3 The number of movements of towers, blade sets and nacelles are dependant on the transportation scenario in each case.

3.2.4 In addition, the masses of components required for an 8 MW OWT were also provided by Able (as per The Crown Estate report, '*A guide to an Offshore Wind Farm*'), and are as follows:

- Tower (T) = 400 tonnes;
- Blade set (B) = 75 tonnes;
- Nacelles (N) = 300 tonnes;
- Slewing rings, flanges etc = 20 tonnes;
- Total OWT = 795 tonnes; and
- Foundation (F) = 800 tonnes.

3.2.5 The sensitivity of results to both increased utilisation and increased fuel consumption due to loading was assessed by repeating the carbon footprint calculation for 8 MW turbines. The same functional unit was used, where complete turbine and component masses reflected those of 8 MW wind turbines ie the transportation by sea of all components required for 500 complete 8 MW OWTs and 50 foundations from their manufacturing bases to Dogger Bank, Hornsea and Norfolk wind farms and the transportation by sea of 100 excess nacelles to a construction port within the UK.

3.3 VESSELS

3.3.1 Data on an example vessel that will be used to transport turbines was provided by Able. This vessel – the MV Adventurer – is purpose built for installing OWT components and foundations. It typically consumes 2.1 tonnes of marine diesel oil per hour when fully loaded and 1.9 tonnes per hour when empty. It travels at 12 knots when fully loaded and 13 knots when empty. Therefore, it will consume 94.5 kilograms of marine diesel oil per kilometre when fully loaded and 78.9 kilograms per kilometre when empty.

3.3.2 In addition, Able also provided data on an example vessel used to transport OWT components from the manufacturer to construction port. This vessel typically consumes 1.1 tonnes of marine diesel oil per hour when fully loaded and 1 tonne per hour when empty. It travels at 14 knots when fully loaded and it is assumed it travels at 15 knots when empty. Therefore, it will consume 42.4 kilograms of marine diesel oil per kilometre when fully loaded and 36.0 kilograms per kilometre when empty.

3.3.3 An important consideration needed to allocate total GHG emissions of the vessel to a tonne of goods being transported is the vessel utilisation. The manufacturer of MV Adventurer (1), MPI Offshore, states that it has a maximum deadweight of 7 095 tonnes. However, Able indicates that a vessel will only typically carry five OWTs (as components or assembled), which, in the case of 5 MW turbines, is equivalent to 2 075 tonnes. Also, the vessel used to transport components is known to have a maximum deadweight of 10 000 tonnes but will only carry 12 nacelles, ten tower sections or 16 blades, which weigh 1 800 tonnes, 2 000 tonnes and 240 tonnes, respectively (in the case of 5 MW turbines). The relatively low utilisation of the vessel by mass can by explained by taking into account the high probability of a vessel reaching its maximum capacity by volume before it reaches its maximum capacity by mass (ie with this load, the vessel is constrained by volume). The

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(1) http://www.mpi-offshore.com/equipment-1/new-builds/

sensitivity of vessel utilisation has been assessed in this study to determine if a greater or lower utilisation affects the final conclusions.

3.3.4 In addition to the impact that loading has on the allocation of total impact to a tonne of goods; there is also an impact on overall fuel consumption. Using data on the utilisation of vessels (by mass), fuel consumption in each case was interpolated from values for fully loaded and empty vessels. The utilisation of a construction vessel transporting 5 MW OWTs was calculated to be 29%. The utilisation of vessels transporting nacelles, tower sections and blades (used for 5 MW turbines) from the manufacturer to construction port was calculated to be 18%, 20% and 2.4%, respectively.

3.4 *AMEP SUPPLY CHAIN SCENARIO*

3.4.1 *Table 3.1* below provides a summary of all transportation stages required for the AMEP Supply Chain scenario. Distances provided by Able are one-way distances and consider shipping lane routes and extra travel required within the wind farm sites.

Table 3.1 Summary of AMEP Supply Chain scenario

Transportation Stage	One-way Distance (Nautical Miles / Kilometres)	Items Transported	Total Mass of Items Transported (tonnes)
AMEP to Dogger Bank	117 / 217	200 OWTs	83 000
AMEP to Harwich	150 / 278	100 nacelles	15 000
AMEP to Hornsea	46 / 85	100 OWTs	41 500
AMEP to Hornsea	46 / 85	50 foundations	30 000
AMEP to Norfolk	108 / 199	200 OWTs	83 000
Able Seaton Port (ASP) to AMEP	105 / 194	100 towers	20 000
Tyne to AMEP	133 / 246	100 blade sets	4 500

3.5 *ALTERNATIVE A - DISTRIBUTED UK MANUFACTURING SITES*

3.5.1 *Table 3.2* below provides a summary of all transportation stages required for the alternative A scenario - distributed UK manufacturing sites. As above, distances provided by Able are one-way distances and consider shipping lane routes and extra travel required within the wind farm sites.

Table 3.2 *Summary of Alternative A scenario - distributed UK manufacturing sites*

Transportation Stage	One-way Distance (Nautical Miles / Kilometres)	Items Transported	Total Mass of Items Transported (tonnes)
ASP to Bathside Bay	240 / 444	100 towers	20 000
ASP to Great Yarmouth	170 / 315	100 nacelles	15 000
ASP to Hornsea	106 / 196	100 OWTs	41 500
Bathside Bay to Dogger Bank	202 / 374	200 OWTs	83 000
Bathside Bay to Norfolk	53 / 98	200 OWTs	83 000
Methil to Bathside Bay	340 / 630	300 towers	60 000
Methil to Dogger Bank	191 / 354	50 foundations	30 000
Tyne to ASP	28 / 52	100 blade sets	4 500

3.6 ALTERNATIVE B - DISTRIBUTED CONTINENTAL MANUFACTURING SITES

Table 3.3 below provides a summary of all transportation stages required for the alternative B scenario - distributed continental manufacturing sites. As above, distances provided by Able are one-way distances and to the centre of each site, considering shipping lane routes.

Table 3.3 *Summary of alternative B scenario - distributed continental manufacturing sites*

Transportation Stage	One-way Distance (Nautical Miles / Kilometres)	Items Transported	Total Mass of Items Transported (tonnes)
ASP to Dogger Bank	124 / 230	100 OWTs	41 500
ASP to Great Yarmouth	170 / 315	100 towers	20 000
Bremerhaven to Great Yarmouth	270 / 500	200 blade sets	9 000
Bremerhaven to Great Yarmouth	270 / 500	200 nacelles	30 000
Eemshaven to Harwich	220 / 407	200 blade sets	9 000
Eemshaven to Harwich	220 / 407	200 nacelles	30 000
Great Yarmouth to Dogger Bank	175 / 324	100 OWTs	41 500
Great Yarmouth to Hornsea	101 / 187	100 OWTs	41 500
Harwich to Norfolk	53 / 98	200 OWTs	83 000

Transportation Stage	One-way Distance (Nautical Miles / Kilometres)	Items Transported	Total Mass of Items Transported (tonnes)
Methil to Dogger Bank	191 / 354	50 foundations	30 000
Methil to Great Yarmouth	290 / 537	100 towers	20 000
Methil to Harwich	340 / 630	200 towers	40 000
Tyne to ASP	28 / 52	100 blade sets	4 500
Tyne to ASP	28 / 52	200 nacelles	30 000

4 *DATA QUALITY AND LIMITATIONS*

4.1.1 This section provides a description of limitations of the study, data quality and the main assumptions required.

4.1.2 While the results provide a high-level understanding of the carbon footprint associated with sea transportation for each scenario, they are not intended to be taken as a detailed assessment of OWTs.

4.1.3 This study only considers the carbon footprint of sea transportation. It does not purport to provide an understanding of the differences in environmental impact between each scenario.

4.1.4 A suitable amount of primary data (eg fuel consumption and transportation distances) was collected from Able. The amount of primary data allowed carbon footprint results to be more representative of the scenarios under investigation than if the study had drawn heavily on secondary data. Overall, data can be considered of reasonable quality.

4.1.5 Where data gaps exist in carbon footprint assessment it is often necessary to make assumptions, as was the case in this study. The assumptions made are considered reasonable and used information sources provided by Able (as per The Crown Estate report, '*A guide to an Offshore Wind Farm*). *Table 4.1* below lists the main assumptions required for this study.

Table 4.1 Main assumptions

Assumption	Justification
On the return leg, all vessels will return to the port they departed from.	Able confirmed this is the most probable situation.
On the return leg, all vessels will return completely empty. Therefore, all associated emissions were allocated to goods transported on the outward journey on a mass basis.	Able confirmed this is the most probable situation.
All vessels on their outward leg are assumed to be loaded with the equivalent of five 5 MW turbines, with a mass of 2 075 tonnes.	Able stated that typically a vessel will carry the equivalent of five 5 MW turbines (complete or as components), which have a mass of 2 075 tonnes. A sensitivity analysis was also carried out to assess to impact on results if vessels were assumed to have a greater or smaller utilisation.
Emissions associated with gas oil are similar enough to marine diesel oil for the emissions factor for gas oil to be used as a proxy for marine diesel oil.	Defra recommend that the emissions factor for gas oil should be used to model the carbon footprint of marine diesel oil.
The typical speed of an empty vessel used to transport OWT components was assumed to be 15 knots.	A fully loaded vessel travels 14 knots, therefore it is reasonable to assume an empty vessel will travel 1 knot faster.

5.1.1 This section provides the carbon footprint results of this study. Results for each scenario are presented per transportation stage and split out between outward and return legs. In addition, a comparison between each of the scenarios and results of sensitivity analyses, are presented here.

5.2 *AMEP AND SUPPLY CHAIN SCENARIO*

5.2.1 *Table 5.1* below provides a summary carbon footprint results for the AMEP scenario. Results are broken down by transportation stage and by outward and return legs of the journey.

Table 5.1 Carbon footprint results of AMEP scenario

Transportation Stage	**Items Transported**	**Carbon Footprint of Outward Leg (tCO_2e)**	**Carbon Footprint of Return Leg (tCO_2e)**	**Total Carbon Footprint (tCO_2e)**
AMEP to Dogger Bank	200 OWTs	2 959	2 798	5 757
AMEP to Harwich	100 nacelles	352	341	693
AMEP to Hornsea	100 OWTs	582	550	1 132
AMEP to Hornsea	50 foundations	421	397	818
AMEP to Norfolk	200 OWTs	2 719	2 571	5 290
Able Seaton Port (ASP) to AMEP	100 towers	297	286	583
Tyne to AMEP	100 blade sets	683	680	1 363
ANNUAL TOTAL	**500 OWTs, 50 foundations, 100 nacelles, 100 towers and 100 blade sets**	**8 013**	**7 623**	**15 636**

5.3 *ALTERNATIVE A - DISTRIBUTED UK MANUFACTURING SITES*

5.3.1 *Table 5.2* below provides a summary carbon footprint results for the alternative B scenario - distributed UK manufacturing sites. Results are broken down by transportation stage and by outward and return legs of the journey.

Table 5.2 Carbon footprint results of alternative A scenario - distributed UK manufacturing sites

Transportation Stage	**Items Transported**	**Carbon Footprint of Outward Leg (tCO_2e)**	**Carbon Footprint of Return Leg (tCO_2e)**	**Total Carbon Footprint (tCO_2e)**
ASP to Bathside Bay	100 towers	678	654	1 332
ASP to Great Yarmouth	100 nacelles	399	386	785
ASP to Hornsea	100 OWTs	1 341	1 267	2 608
Bathside Bay to Dogger Bank	200 OWTs	5 109	4 831	9 940
Bathside Bay to Norfolk	200 OWTs	1 341	1 267	2 608
Methil to Bathside Bay	300 towers	2 881	2 782	5 663
Methil to Dogger Bank	50 foundations	1 746	1 651	3 397
Tyne to ASP	100 blade sets	144	143	287
ANNUAL TOTAL	**500 OWTs, 50 foundations, 100 nacelles, 400 towers and 100 blade sets**	**13 639**	**12 981**	**26 620**

5.4 *ALTERNATIVE B - DISTRIBUTED CONTINENTAL MANUFACTURING SITES*

5.4.1 *Table 5.3* below provides a summary carbon footprint results for the alternative B scenario - distributed continental manufacturing sites. Results are broken down by transportation stage and by outward and return legs of the journey.

Table 5.3 *Carbon footprint results of alternative B scenario - distributed continental manufacturing sites*

Transportation Stage	Items Transported	Carbon Footprint of Outward Leg (tCO_2e)	Carbon Footprint of Return Leg (tCO_2e)	Total Carbon Footprint (tCO_2e)
ASP to Dogger Bank	100 OWTs	1 568	1 483	3 051
ASP to Great Yarmouth	100 towers	480	464	944
Bremerhaven to Great Yarmouth	200 blade sets	2 773	2 761	5 534
Bremerhaven to Great Yarmouth	200 nacelles	1 267	1 227	2 494
Eemshaven to Harwich	200 blade sets	2 259	2 250	4 509
Eemshaven to Harwich	200 nacelles	1 032	1 000	2 032
Great Yarmouth to Dogger Bank	100 OWTs	2 213	2 093	4 306
Great Yarmouth to Hornsea	100 OWTs	1 277	1 208	2 485
Harwich to Norfolk	200 OWTs	1 341	1 267	2 608
Methil to Dogger Bank	50 foundations	1 746	1 651	3 397
Methil to Great Yarmouth	100 towers	819	791	1 610
Methil to Harwich	200 towers	1 921	1 854	3 775
Tyne to ASP	100 blade sets	144	143	287
Tyne to ASP	200 nacelles	132	127	259
ANNUAL TOTAL	**500 OWTs, 50 foundations, 600 nacelles, 400 towers and 500 blade sets**	**18 972**	**18 319**	**37 291**

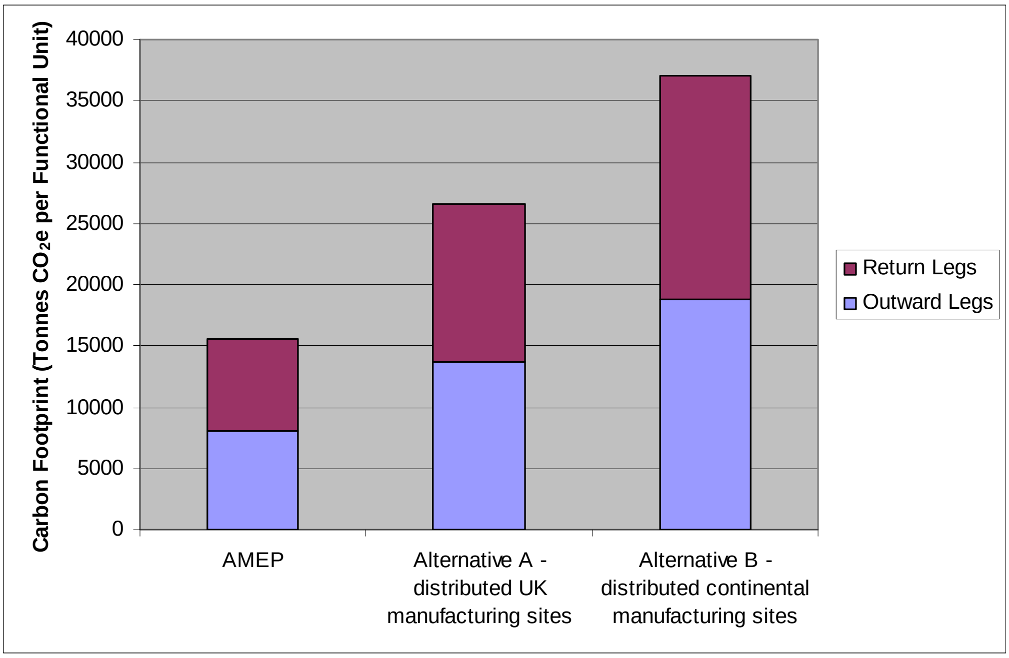
5.5 COMPARISON BETWEEN SCENARIOS

5.5.1 *Table 5.4* and *Figure 5.1* below provides a summary of carbon footprint results for all scenarios. Results are broken down by outward and return legs of all transportation stages combined.

Table 5.4 Carbon footprint results of all scenarios

Scenario	Items Transported	Carbon Footprint of all Outward Legs (tCO_2e)	Carbon Footprint of All Return Legs (tCO_2e)	Total Carbon Footprint (tCO_2e)
AMEP	500 OWTs, 50 foundations, 100 nacelles, 100 towers and 100 blade sets	8 013	7 623	15 636
Alternative A - distributed UK manufacturing sites	500 OWTs, 50 foundations, 100 nacelles, 400 towers and 100 blade sets	13 639	12 981	26 620
Alternative B - distributed continental manufacturing sites	500 OWTs, 50 foundations, 600 nacelles, 400 towers and 500 blade sets	18 972	18 319	37 291

Figure 5.1 Annual Carbon footprint results of all scenarios



5.5.2 From *Table 5.4* and *Figure 5.1* the following points are evident.

- The AMEP scenario has the lowest carbon footprint for sea transportation of all the scenarios;
- The carbon footprint for sea transportation for the AMEP scenario is 41% lower than that of the alternative A scenario and 58% lower than that of the alternative B scenario;

- Alternative A scenario has a lower carbon footprint for sea transportation than alternative B;

- Alternative B has the highest carbon footprint for sea transportation of all the scenarios;

- For each scenario, the carbon footprint of the return leg is lower than that of the outward leg (by the same proportion in each scenario);

- The total carbon footprint of the AMEP scenario is equivalent manufacturing of 900 cars or the operation of 6 000 cars for one year(2);

- The difference between the carbon footprint of the AMEP scenario and that of alternative A (ie the saving) is equivalent to manufacturing of 600 cars or the operation of 4 200 cars for one year(2); and

- The difference between the carbon footprint of the AMEP scenario and that of alternative B (ie the saving) is equivalent to manufacturing 1 300 cars or the operation of 8 300 cars for one year(2).

Sensitivity Analysis One – The Impact of Wind Turbine Size on Results

5.5.3 This study modelled the sea transportation of 5 MW OWTs. However, Able also provided information on the masses of components required for larger OWTs; the largest being 8 MW turbines. Therefore the sensitivity of results to wind turbine size and the impact on vessel utilisation and vessel loading was assessed to determine if this affects the overall conclusions.

5.5.4 Turbine size affects the overall fuel consumption of the vessel (ie the greater the mass of the load the more fuel will be consumed). However, as each vessel type is constrained by volume rather than mass, much greater utilisation of vessels is possible when transporting 8 MW turbines and components in comparison to 5 MW turbines and components.

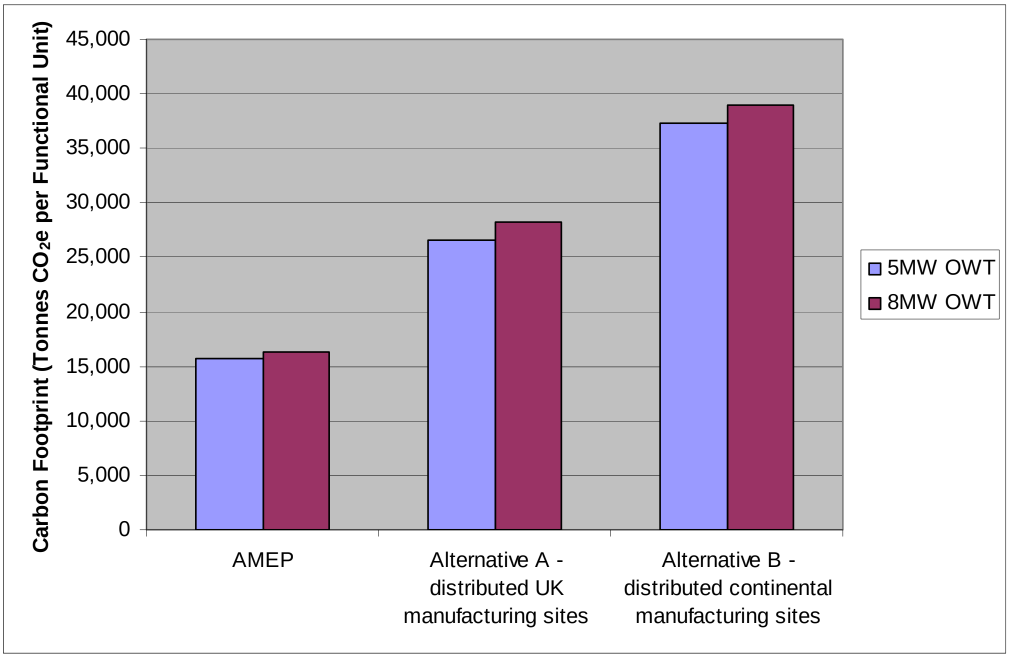
5.5.5 *Table 5.5* and *Figure 5.2* below show the carbon footprint of all scenarios, for the sea transportation of both 5 MW turbines and components and 8 MW turbines and components, in accordance with the functional unit.

(2) Goodal (2007) *How to live a low-carbon life*, Earthscan: London

Table 5.5 *Carbon footprint results of all scenarios, considering the sensitivity of wind turbine size on results*

Scenario	**Total Carbon Footprint (tCO_2e) – 5 MW turbines and components**	**Total Carbon Footprint (tCO_2e) – 8 MW turbines and components**
AMEP	15 636	16 245
Alternative A - distributed UK manufacturing sites	26 620	28 278
Alternative B - distributed continental manufacturing sites	37 291	38 944

Figure 5.2 *Carbon footprint results of all scenarios, considering the sensitivity of wind turbine size on results*



5.5.6 From *Table 5.5* and *Figure 5.2* the following points are evident.

- The sea transportation of 8 MW turbines and components results in a slightly larger carbon footprint in comparison to that of the sea transportation of 5 MW turbines and components.

- This is due to the increase in mass resulting in an increase in fuel consumption.

- Represented on a 'per tonne of goods transported', the carbon footprint of transporting 8 MW turbines and components is lower than transporting 5 MW turbines and components, which is due to the increased vessel utilisation achieved.

Sensitivity Analysis Two – The Impact of Vessel Utilisation on Results

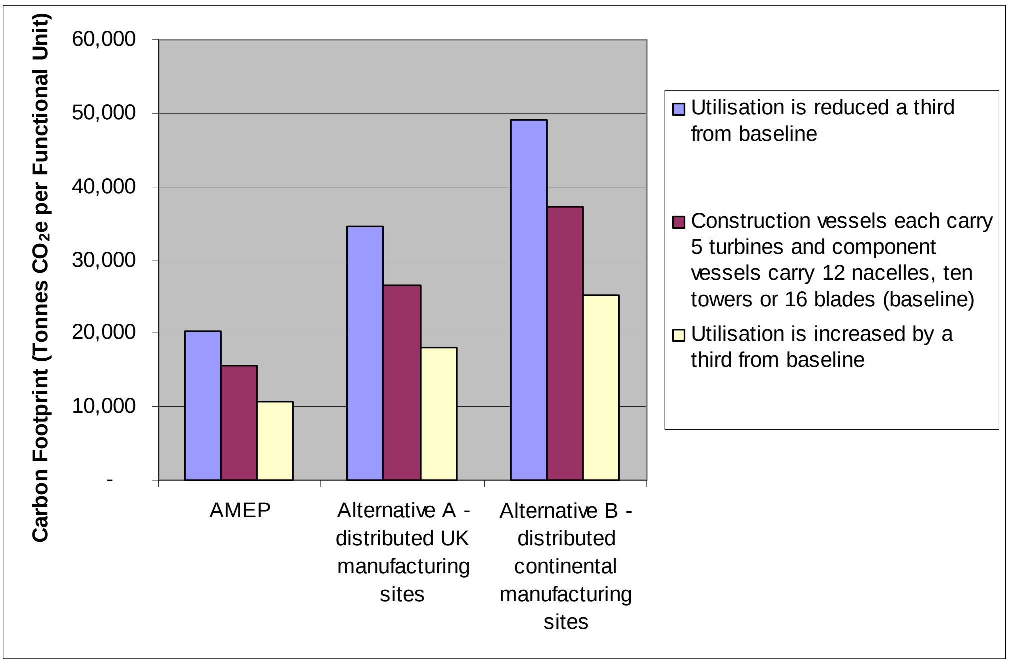
5.5.7 In this study, for the outward journeys of vessels used to transport OWTs it was assumed they were loaded with the equivalent of five 5 MW turbines, with a mass of 2 075 tonnes. Also, the vessels used to transport components from manufacturers to construction ports were assumed to be loaded with 12 nacelles, or ten tower sections, or 16 blades. These assumptions were made based on information Able provided on typical loading of vessels. As the maximum deadweight of construction and component vessels is known to be 7 095 tonnes and 10 000 tonnes, respectively, the sensitivity of vessel utilisation has been assessed in this study to determine if a greater or lower utilisation affects the final conclusions.

5.5.8 *Table 5.6* and *Figure 5.3* below show the carbon footprint of all scenarios, where the vessel utilisation has been both increased and decreased by a third (ie 33%) and compared with the baseline.

Table 5.6 Carbon footprint results of all scenarios, considering the sensitivity of vessel utilisation on results

Scenario	**Total Carbon Footprint (tCO_2e) – where utilisation is reduced by a third from baseline**	**Total Carbon Footprint (tCO_2e) – where construction vessels each carry 5 turbines and component vessels carry 12 nacelles, ten towers or 16 blades (baseline)**	**Total Carbon Footprint (tCO_2e) – where utilisation is increased by a third from baseline**
AMEP	20 311	15 636	10 693
Alternative A - distributed UK manufacturing sites	35 653	26 620	18 167
Alternative B - distributed continental manufacturing sites	49 113	37 291	25 165

Figure 5.3 *Carbon footprint results of all scenarios, considering the sensitivity of vessel utilisation on results*



5.5.9 From *Table 5.6* and *Figure 5.3* the following points are evident.

- The smaller the load (ie lower the utilisation) that vessels are assumed to have the higher the carbon footprint associated with sea transportation.

- The absolute difference in carbon footprint between scenarios increases with decreasing load/utilisation.

- This does not affect the relative difference in carbon footprint between scenarios (ie in each case, the AMEP scenario is 41% lower than that of the alternative A scenario and 58% lower than that of the alternative B scenario).

6 CONCLUSIONS

6.1.1 This section provides the conclusions of this study.

6.1.2 This streamlined study established the carbon footprint of transporting 5 MW OWTs and their components by sea via routes proposed in three alternative scenarios. It also allowed comparison between the three alternative scenarios and established the most desirable, in terms of minimising the environmental impact of carbon emissions.

6.1.3 The following key conclusions can be drawn from the study.

- The carbon footprint for sea transportation for the AMEP scenario is the lowest, being 41% lower than that of the alternative A scenario and 58% lower than that of the alternative B scenario.

- This is due to the greater quantity of movements of components in both of the alternative scenarios by comparison to AMEP scenario.

- The sensitivity of turbine size does not affect the above conclusions.

- The sensitivity of vessel utilisation does not affect the above conclusions, providing the utilisation is the same for each scenario.

- Return legs are lower in carbon footprint than that of the outward leg due to the fact less fuel is consumed when the vessel is empty.

7 REFERENCES

7.1.1 Defra (2010) *2010 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting*. Defra: London

7.1.2 Intergovernmental Panel on Climate Change (2007) *IPCC Fourth Assessment Report: Climate Change 2007 (AR4)*. IPCC: Geneva

7.1.3 Vattenfall (2010) *Vattenfall Wind Power Certified Environmental Product Declaration of Electricity from Vattenfall's Wind Farms*. Vattenfall: London

KEY

200T	-	Manufacturing base for 200 No. Towers.
200B	-	Manufacturing base for 200 No. Blade sets.
200N	-	Manufacturing base for 200 No. Nacelles.
50F	-	Manufacturing base for 50 Foundations.
500OWT	-	Assembly and transportation of Offshore Wind Turbines.
1,800OWT	-	Estimated number of OWT's to be installed in a zone or constructed at a port.
100nm	-	Shipping distance is 100 nautical miles.

Notes

1. This is an indicative scenario for the installation of 500 OWTs from the AMEP site over one year.
2. All distance from AMEP to the wind farm zones are to the centre of the zone.
3. The number of OWT's needed for each wind farm zone assume 5MW turbines.

Rev	Date	Comments	Drw	Chk	App
D	28/07/11	General Amendments	JH	RC	RC
C	26/07/11	Title Amended	JH	RC	RC
B	30/06/11	OWT No.s added	PP	RC	PMS
A	07/06/11	Preliminary Issue	PP	RC	PMS

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Project: ABLE Marine Energy Park

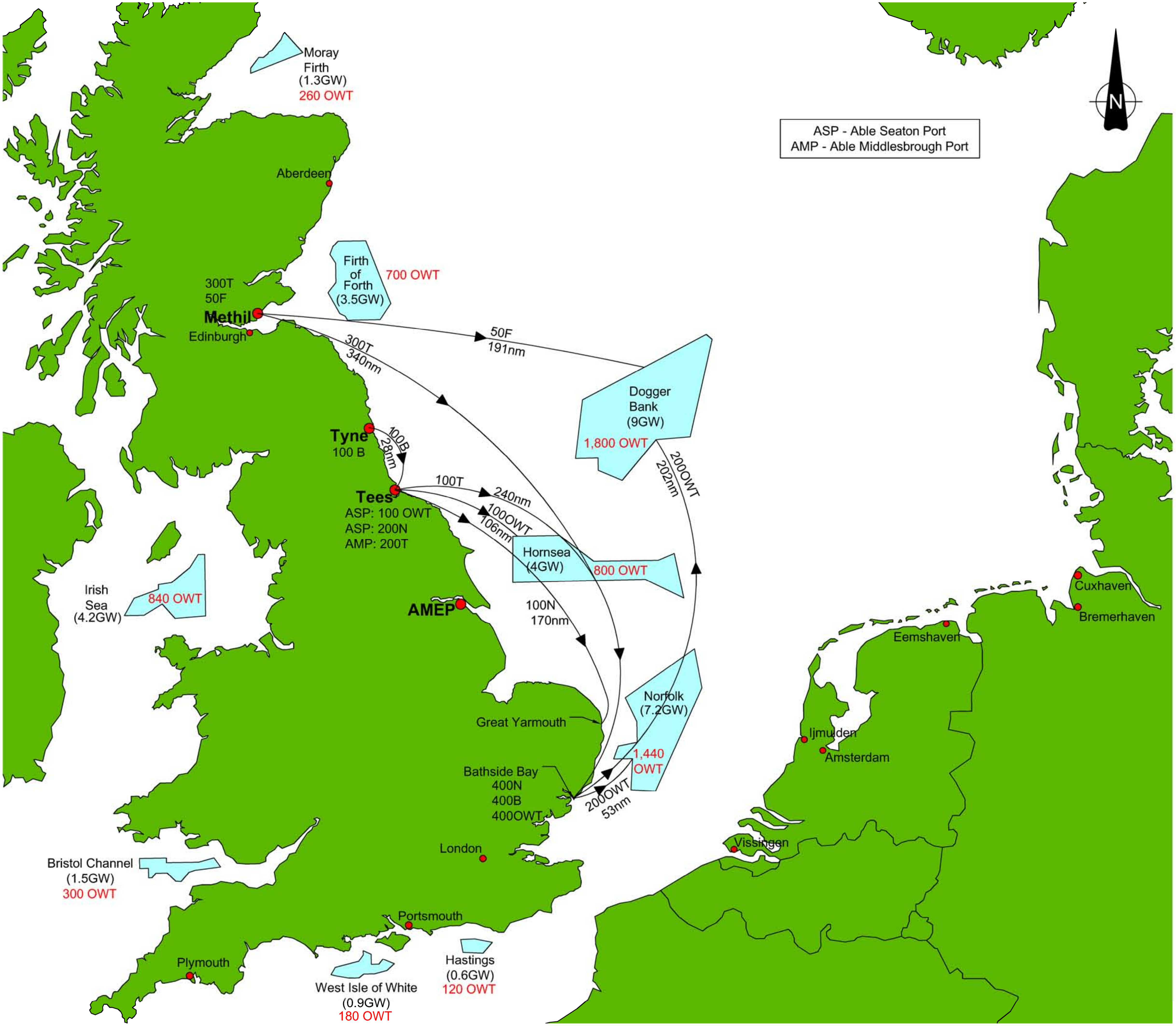
Client: ABLE Humber Ports Ltd

Title: AMEP Supply Chain

Scale:	Drawn	Checked	Approved
N.T.S@A3	P Parsley	R Cram	PMS
Date	07/06/2011	07/06/2011	07/06/2011

Drawing No. Figure 1.1

Revision: D



KEY

200T - Manufacturing base for 200 No. Towers.

200B - Manufacturing base for 200 No. Blade sets.

200N - Manufacturing base for 200 No. Nacelles.

50F - Manufacturing base for 50 Foundations.

500OWT - Assembly and transportation of Offshore Wind Turbines.

1,800OWT - Estimated number of OWT's to be installed in a zone or constructed at a port.

100nm - Shipping distance is 100 nautical miles.

Notes

1. This scenario represents an alternative to the development of AMEP. ABP Hull and the port of Sheerness are not included in the scenario as they are not alternatives to AMEP but will be required as well to satisfy European demand.
2. All distances from construction ports to the wind farm zones are to the centre of the zone.
3. The number of OWT's needed for each wind farm zone assume 5MW turbines.

Rev	Date	Comments	Drw	Chk	App
D	29/07/11	Title Amended	JH	RC	RC
C	27/07/11	Title Amended	JH	RC	RC
B	30/06/11	Layout Changed	PP	RC	RC

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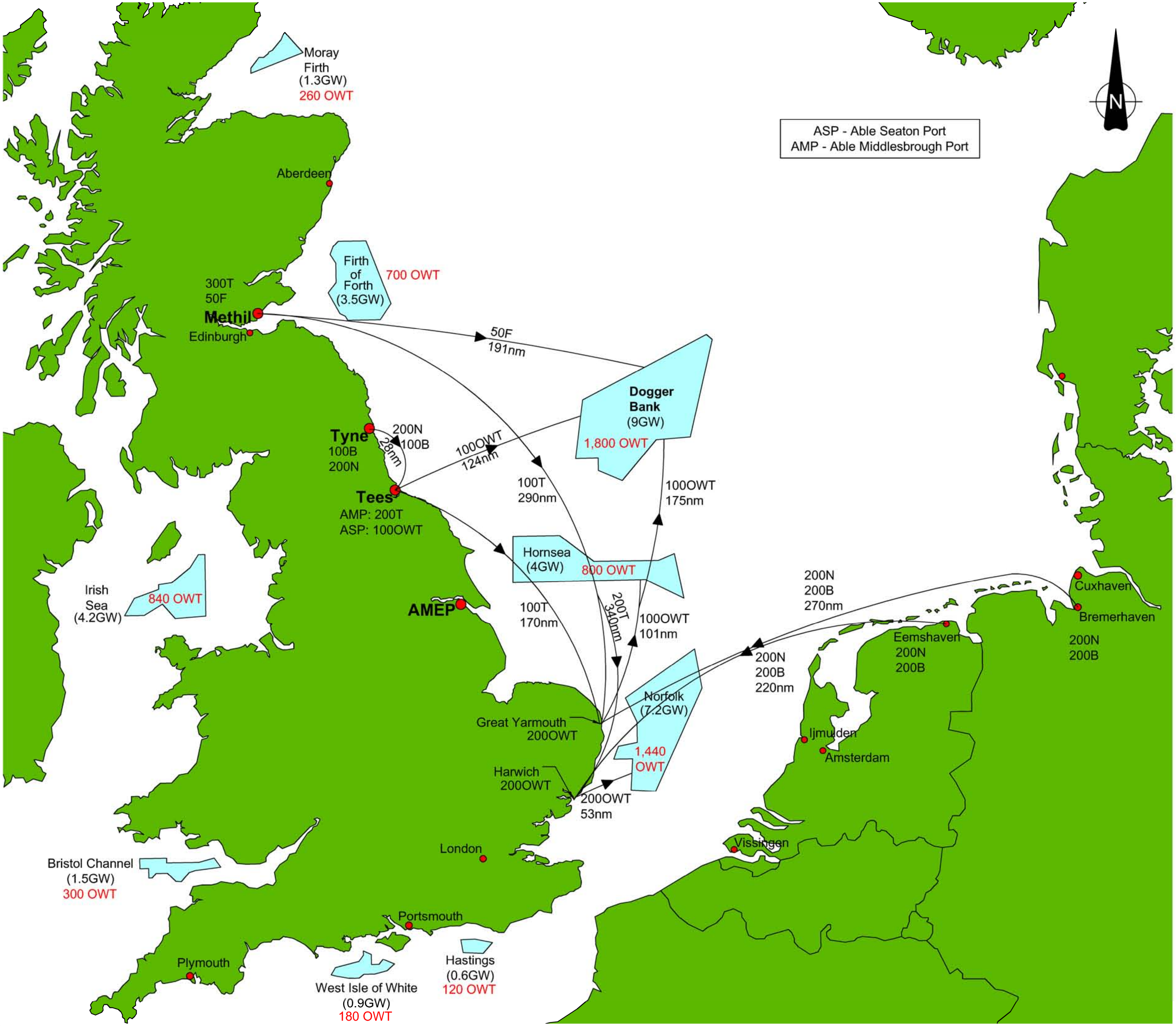
Client: ABLE Humber Ports Ltd

Title: Alternative A - Distributed UK Manufacturing Sites

Scale:	Drawn	Checked	Approved
N.T.S@A3	P Parsley	R Cram	R Cram
Date	07/06/2011	07/06/2011	07/06/2011

Drawing No. Figure 1.2

Revision: D



KEY

200T	-	Manufacturing base for 200 No. Towers.
200B	-	Manufacturing base for 200 No. Blade sets.
200N	-	Manufacturing base for 200 No. Nacelles.
50F	-	Manufacturing base for 50 Foundations.
500OWT	-	Assembly and transportation of Offshore Wind Turbines.
1,800OWT	-	Estimated number of OWT's to be installed in a zone or constructed at a port.
100nm	-	Shipping distance is 100 nautical miles.

Notes

1. This scenario represents an alternative to the development of AMEP. ABP Hull and the port of Sheerness are not included in the scenario as they are not alternatives to AMEP but will be required as well to satisfy European demand.
2. All distances from construction ports to the wind farm zones are to the centre of the zone.
3. The number of OWT's needed for each wind farm zone assume 5MW turbines.

Rev	Date	Comments	Drw	Chk	App
E	28/07/11	General Amendments	JH	RC	RC
D	26/07/11	Title Amended	JH	RC	RC
C	13/07/11	Text Alterations	JH	JM	RC

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Client: ABLE Humber Ports Ltd

Title: Alternative B - Distributed Continental Manufacturing Sites

	Drawn	Checked	Approved
Scale: N.T.S@A3	P Parsley	R Cram	R Cram
Date	07/06/2011	07/06/2011	07/06/2011

Drawing No. Figure 1.3

Revision: E