Translating known market prospects into spatial requirements and implications for ports infrastructure

A draft report to Halcrow Group by Douglas-Westwood Ltd

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1.1 Development Background

1.1.1 Why Offshore Wind?

Onshore wind is cheaper than offshore wind. Planning, development, construction and maintenance is both more economical and easier to accomplish onshore than offshore. So why move offshore?

By going offshore, wind farms can be larger and more productive. Whilst we are starting to see the development of 100 MW-plus onshore developments, they are highly contentious due to their sheer size in terms of number of turbines, and the height of the turbines. To be most cost efficient it is advantageous to use the largest available turbines, as a set capacity can be achieved with fewer turbines. Unfortunately, it is not always practical to do this because of planning guidelines and local opposition to projects. A wind farm of several hundred megawatts onshore will nearly always have to be built away from settlements because of the visual impact it causes. Indeed the planning limitations placed on onshore wind farms (height of turbines, number of turbines, etc.) means that to build large projects, offshore is becoming the most viable location.

Large onshore wind farms will of course still be built. The US has never shied away from developments of several hundred megawatts, but most are built in remote areas. Similarly in Scotland, which has one of the best natural resources in the world, we are now seeing projects winning approval for over 100 MW. There is, however, a limit to development on such a scale.

When the offshore industry develops further, wind farms of many hundreds of megawatts will be installed out of sight far offshore. These locations benefit from high wind speeds, and give higher and more consistent electricity output than onshore or nearshore locations.

At the present time offshore wind cannot survive without financial support, whether that be feed-in tariffs or subsidies, etc. The tipping point will come when farms of 5 MW class turbines are installed offshore, for it is with turbines this size that offshore wind can become cost effective and obtain true commerciality.

Whilst a long way off, by using turbines of this size and above enormous projects can be built that rival traditional fossil fuel power stations in terms of capacity. Projects of over 1 GW are already being planned in the UK and Germany. Douglas-Westwood Limited's *World Offshore Wind Database* lists 19 separate projects of 1 GW or over that have been announced and are under development. The largest project identified at present is one of 17.5 GW planned off Germany.

1.1.2 Development History

There are 22 operational offshore wind farms in the world today. The 387 installed turbines in these projects provide a total of 798 MW. The first offshore wind turbines were installed at Vindeby off the Danish island of Lolland in 1991. The most recent project is the 90 MW wind farm off Barrow due for completion in Spring 2006.

Denmark was an early pioneer but is losing its market lead to the UK which has an excellent collection of future prospects and the most structured approach to development. Germany has excellent prospects but the highly technical nature of them means development here will not pick up until the end of the decade. The UK will soon become the market leader in terms of installed capacity.

The first ten years of the industry saw small projects being built in very shallow-water nearshore locations. These wind farms in most cases used onshore turbine models with slight adaptations. These 'demonstration' projects have paved the way for the more recent projects that are of a much larger size.

The biggest offshore wind farm yet installed is the Nysted development off Denmark which was completed in 2003. Just as this project dwarfs those built ten years previously, within another decade projects will be installed that are many times greater in size than today's offshore wind farms.

Current projects are typically 100 MW in size and we are beginning to see the installation of several of this sized projects being installed each year in countries such as the UK and the Netherlands.

1.1.3 Reasons for Growth

Until 2004, Europe had been the only world region to install offshore wind farms until two turbines were installed off Japan in 2004. The huge growth off Europe is due to several reasons:

- **A well-developed onshore industry** – Europe leads the world in terms of installed onshore wind capacity. Germany (15 GW) has twice the installed capacity of the US (6.6 GW); Spain (7 GW) and Denmark (3.5 GW), are also large markets.

- **Natural resource** – Europe has the best offshore wind resource in the world, with ideal moderate wind speeds along a very long coastline.

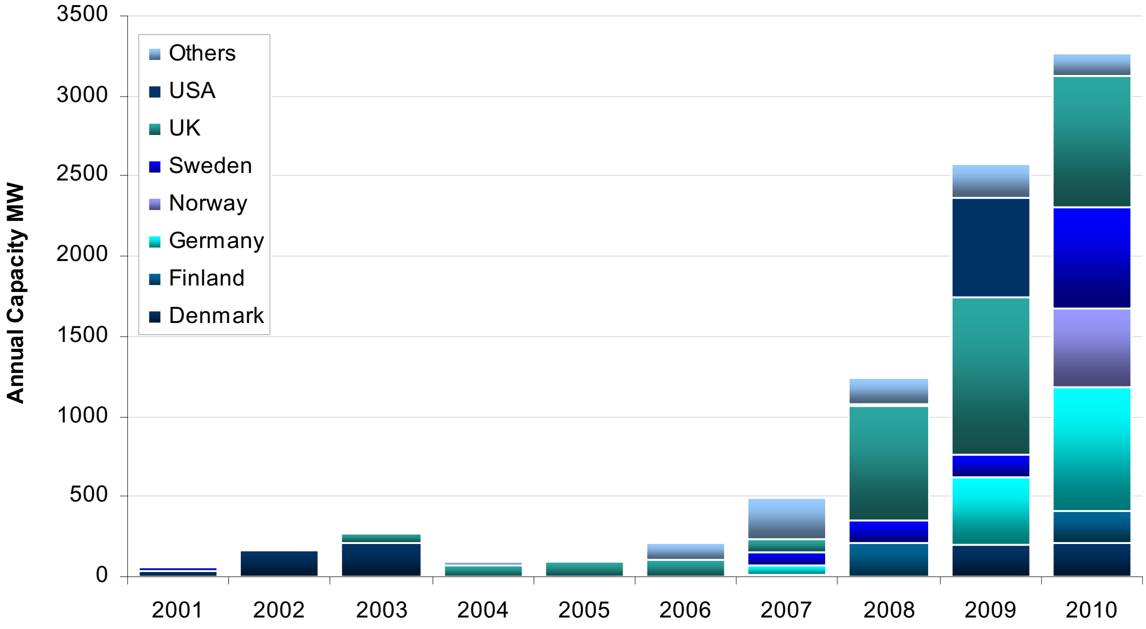
- **Suitable locations** – Many countries in Europe (Denmark, the UK, Sweden, etc.) have optimal locations for offshore wind farms with a multitude of shallow-water, benign, near-shore sites. These are ideal for developments, especially for the beginning of the offshore wind industry – these are locations where it is easier and cheaper to install. As the industry progresses and the technology and experience develops, other locations become increasingly viable (for instance the deeper waters off Germany).

- **Governmental support** – To encourage offshore wind development, the governments of several European countries actively stimulated the market by offering subsidies and grants to developers. This support has been tremendously important in establishing wind farms to the present day, and will continue to be important throughout the period of this report. The UK has been especially active in promoting development.

Other world regions are lacking one or more of the above factors. At this stage of the offshore wind industry, planning policies need to be in place and must be supported financially through governmental incentives.

1.2 Global Market Overview

1.2.1 Forecast Global Capacity



MW	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2006-2010
Denmark	40	163	213.4	0	0	0	0	0	200	215	**415**
Finland	0	0	0	0	0	0	10.8	207	0	200	**418**
Germany	0	0	0	4.5	4.3	4.5	62	0	418	764.5	**1249**
Norway	0	0	0	0	0	0	3	0	0	490	**493**
Sweden	21	0	0	0	0	0	72	144	138	640	**994**
UK	0	0	60	60	90	100	90	711	992	815	**2708**
USA	0	0	0	0	0	0	0	10	612	0	**622**
Others	0	0	0	27	0	108	258	165	218	137	**885**
Total	61	163	273	91	94	213	495	1237	2578	3261	**7784**

In the five year period to 2010, a total of 7,784 MW of offshore wind capacity is planned for construction worldwide. Looking back to 2001, the initial growth that the first years of the decade saw is visible. After 2003, installation rates dropped and between then and now the only real activity has been the installation of the UK's first offshore wind projects.

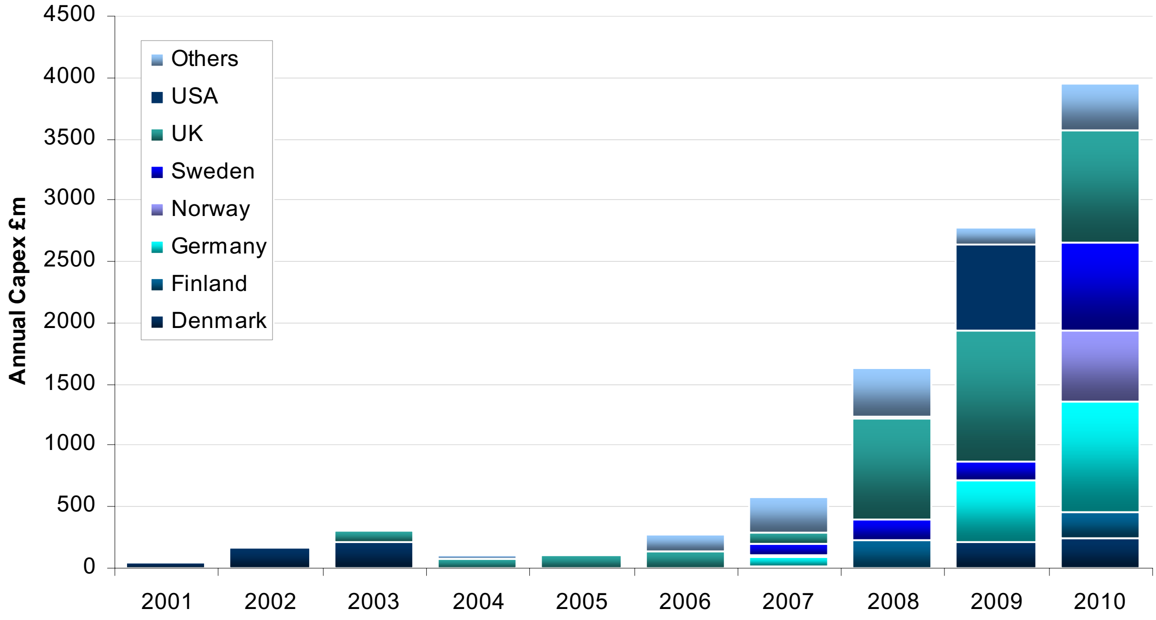
The UK is taking time to grow having experienced setbacks on projects which have caused delays. For the near, mid and long-term future however, the UK has the greatest market potential and is expected to be the dominant player in the industry throughout the period. Round One projects are currently being installed in the UK and will be for several more years. Additionally, from 2008 the first of the large 'Round Two' projects will be built which will have a significant effect on the UK's total capacity.

Germany has the greatest number of projects at a planning stage but relatively few of these are likely to be brought online before the end of the decade because development offshore Germany is technically difficult and the projects here plan to use the very highest capacity turbines which are not yet in production.

Whilst the Netherlands has two mid-sized projects nearing construction longer term prospects are currently unclear. Denmark only has two projects forecast, both effectively extensions to two completed in 2002 & 2003. We expect to see new players such as Sweden and Norway make significant progress towards the end of the decade.

Additionally, the North American and Asian markets hold a lot of potential for the future, but in the USA development is cautious because of untested planning routes – once these are overcome the market could expand rapidly.

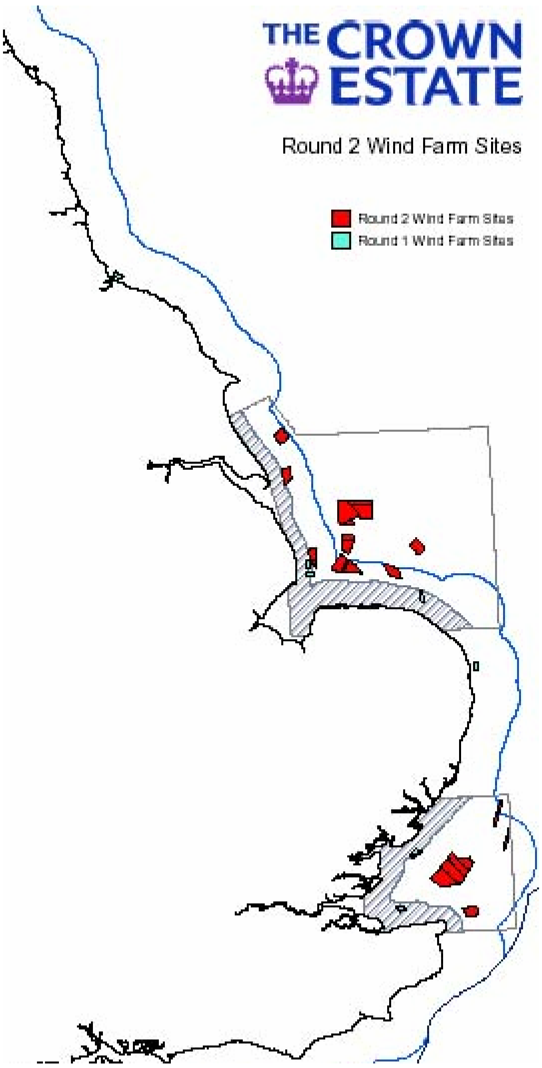
1.2.2 Forecast Global Capital Expenditure



£m	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2006-2010
Denmark	44	171	219						219	241	460
Finland							12	226	0	219	458
Germany				5	5	6	82	0	501	892	1481
Norway							12	0	0	583	595
Sweden	20						85	170	152	723	1130
UK			78	74	106	137	105	831	1057	912	3041
USA								11	713		724
Others				30		130	286	400	139	384	1338
Total	64	171	298	109	111	272	583	1638	2782	3954	**9228**

In terms of capital expenditure, the installations forecast will attract a total spend of over £9 billion across the next five years, with the UK market valued at over £3 billion. Offshore wind will exceed £1 billion per year from 2008. Note that the above forecast associates spend with the year the project is completed whilst this expenditure is often split between years on some large projects.

2 East of England – The Offshore Wind Market



The East of England region is located between two of the UK's three developmental areas for offshore wind, The Thames Estuary and The Greater Wash. Although in some cases the locations of the planned projects in these two areas are geographically distant from the physically defined East of England region (Bedfordshire, Cambridgeshire, Essex, Hertfordshire, Norfolk and Suffolk) they fall within its area of influence. East of England companies will be tendering for contracts for these projects and the region's ports are well suited to some or all of the requisite construction work.

In servicing related industries in recent decades, particularly the oil and gas industry, the East of England has developed a capability to support the majority of future offshore wind activity within the region. Indeed, it is widely believed that the region has the experience, skills and expertise present within the supply chain to support all aspects of the development and operations phases of an offshore wind farm. The only perceived weakness of the region is seen to be an absence of manufacturing capacity. Specific areas of regional strength have been identified to be: project management, offshore engineering, environmental consultancy, insurance, surveys, and operation and maintenance developed particularly within the cluster of offshore expertise located within Great Yarmouth and Lowestoft.

The East of England has a total of approximately 6 GW of capacity planned which will come from some 1,300 turbines (exact capacity and numbers depend on turbine sizes chosen). Total capital expenditure for all Round One and Two projects is forecast to reach approximately £7.4 billion.

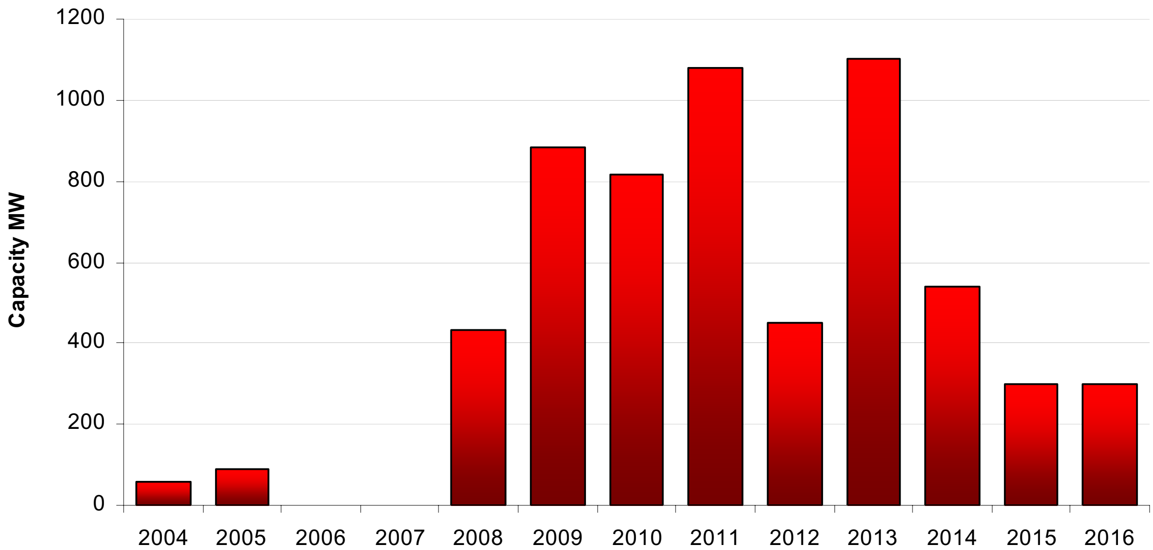


Figure 2-1: Forecast Offshore Wind Capacity in the East of England

Table 2-1: Offshore Wind Farms in the East of England

Project Name	Year	Capacity MW
Scroby Sands	2004	60
Kentish Flats	2005	90
Cromer	2008	108
Gunfleet Sands	2008	108
Inner Dowsing	2008	108
Lynn	2008	108
Gunfleet Sands phase II	2009	64
Lincs	2009	250
London Array - phase 1	2009	270
Thanet	2009	300
Greater Gabbard phase 1	2010	300
London Array - phase 2	2010	200
Sheringham Shoal	2010	315
Greater Gabbard phase 2	2011	200
Humber Gateway	2011	300
London Array - phase 3	2011	330
Docking Shoal phase I	2011	250
Docking Shoal phase II	2012	250
London Array - phase 4	2012	200
Dudgeon East	2013	300
Race Bank phase I	2013	500
Westernmost Rough	2014	240
Triton Knoll phase I	2013	300
Triton Knoll phase II	2014	300
Triton Knoll phase III	2015	300
Total		**5,716 MW**

Scroby Sands was commissioned in 2004 and was the first offshore wind farm built in the East of England. Local companies secured a significant proportion of the value of the work undertaken on the project.

Over the next 15 years there is a huge potential market off the East of England which the ports of Great Yarmouth and Lowestoft must try and service through the construction and operations & maintenance phases.

Many of the larger projects are split into multiple phases across several years. This approach is good for ports as it lessens the burden placed upon them but also can help ensure work over a long period of time.

There is a huge number of projects in prospect and Great Yarmouth and Lowestoft are well placed to secure some of this work. They do, however face competition on some projects from ports elsewhere in the country. It is therefore impractical to second guess which projects will use the ports but by looking at requirements of the industry and the capabilities of the ports it is possible to analyse the extent of the role the two ports may come to play in the development of the UK's offshore wind sector. Location is an important factor but by no means the only one. In their present state, the ports of Great Yarmouth and Lowestoft cannot offer a full service to all the forthcoming projects, particularly when those projects become very large, but there is still time remaining to develop the ports so that they may capture their maximum potential. There is more than enough activity in prospect for the two ports to gain work in the industry from 2008 to 2015.

3 The Role of Ports in Offshore Wind

3.1 Background

Ports play a central role in the offshore wind industry, being key to a number of important activities from transport, through construction, to operations & maintenance. The expenses resulting from these activities range from at least 10% and up to 20% of the total costs of an offshore wind farm and are one of the decisive factors for the successful planning, realisation and economical operation of projects.

A significant proportion of the content for Scroby Sands derived from the use of Lowestoft and Great Yarmouth as logistical bases for the project.

The range of activities that ports can undertake includes:

- Transport & delivery of major turbine components, foundations and cabling
- Storage of major turbine components, foundations and cabling awaiting installation
- Pre-assembly work for some major components
- Vessel loadout – turbines, foundations and cables
- Daily logistics support of construction support
- Servicing – operations & maintenance.

When planning projects, availability of suitable ports is of key importance to wind developers.

A complex network of connections and transhipment points for transport, storing, assembling, testing and handling must be developed to support the offshore wind industry and ports are fundamental to this. New transport chains and logistic systems will be developed continuously for offshore wind projects, particularly if the projects are to be realised successively and in the number planned.

Task sharing between locations in the supply chain is dependent on their logistic systems. For example, for the Arklow Bank project, the nacelles were pre-assembled in Salzbergen, transported to the port of Brake in several heavy loads and then shipped from Brake to the Irish port of Rosslare (base port for the main modules). The other modules (rotor blades, tower and foundations) were transported from other ports.

The East of England is a key location for offshore wind development and the seven suitable regional ports including Great Yarmouth and Lowestoft can attain significant value from it. Below, key requirements are examined for the range of services ports can provide for the offshore wind industry. Lowestoft and Great Yarmouth ports are examined to ascertain which services they are able to provide. The report also looks at how the ports can improve and best present their services to the industry to ensure they capture the maximum value in the future.

3.1.1 Logistics and Pre-Assembly

The first role ports can play in the timeline of constructing an offshore wind farm is operating as a logistics base for the project. This would typically involve the port taking delivery of major components, beginning with the foundations. Storage of the foundations would be required until installation of them begins (one foundation every two days is the approximate installation rate).

The major turbine parts would arrive at a central port ready for installation. This usually comprises the nacelle of the turbine, turbine blades, and the towers (in two or three sections). Some pre-assembly work may be carried out onshore, such as attaching two of each turbine's blades to the rotor unit (the final blade is installed at sea to aid transportation) and the rotor unit to the nacelle.

Management of component deliveries and storage is fundamental to a port's effectiveness. A port may be unable to store all foundation and turbine components simultaneously, so balancing the delivery and installation process becomes very important. Allocations must be made for periods where installation cannot take place, such as a period of bad weather or a vessel failure.

Whilst projects are typically installed all in the same year, some projects adopt a multi-season installation whereby the foundations are installed one year, with the turbines being installed the next year, once there are good weather conditions.

Whilst an individual port is capable of handing small wind farms, as projects get larger in size, with higher numbers of increasingly large turbines and foundations, project managers will likely chose to use multiple ports to service the logistics and construction of a wind farm if an individual port is not capable of storing and managing a sufficiently high amount of components. There is therefore great scope for co-operation and co-ordination between the ports of Lowestoft and Great Yarmouth.

The use of ports as logistics bases is further decided by how project developers plan the offshore installation phase.

3.1.2 Offshore Installation

Standardised carriers will, to a large extent, not be used for offshore wind energy modules. Modules such as rotor blades, nacelles, and towers are purchased in several parts of Europe or the world, are assembled in coastal areas and then loaded on specialist ships or more standard barges which take them out to sea for construction. Following on from the potential logistics systems above, all wind farm installation concepts which have been foreseen so far are based on one of the following methods:

1. Single modules are transported with barges and installed offshore with jack-up-platforms or crane barges. This can be undertaken from either a single central port, or the use of multiple ports.
2. Transport and installation take place with the help of special ships, e.g. A2Sea. (suited to a single port, or two ports – one for foundations, and a second for turbines).
3. Assembling complete units at a port and transporting them offshore with special ships for one-piece installations.

In the second case the transportation and installation ship are the same and work by carrying entire turbines in their main component parts to the offshore location for installation. Industry leading contractors can carry between four and six entire turbines on a single vessel. This is the approach that has commonly been undertaken on the UK's existing projects. There is scope for ports to work together on a job, particularly on the larger projects in the future which will require considerable storage space. One port could work with foundations and another on turbines – as these are always installed separately. On very large projects multiple ports may be needed to conduct the same activity simultaneously, in which case multiple installation vessels would operate.

In case of the first and second installation ideas, existing ports come into consideration, although the forward-looking concepts of the third option make new demands on a port's infrastructure and superstructure, which are currently not included in long-term port strategies. This third method of installation has not been trialled but many companies are interested in the potential application of such a system as it requires less time installing offshore, resulting in considerable savings.

Logistics management is a key skill and ports have to integrate carefully with the project developer's construction schedule which can be highly flexible. Effective management is a valuable service with deliveries incoming from across Europe, and a multitude of installation, transportation and service vessels operating from the port. Offshore wind farm construction can be problematic, such as weather delays or other unforeseen circumstances extending the time ports have to store components and act as the installation base. For example, on one project foundation installation was held up by three months, resulting in turbine installation falling back to the winter when turbine installation is difficult, further extending the schedule.

Where a port only has to provide a service to one wind farm a delay of 3 months in construction is manageable, but when ports are contracted for multiple projects in a season (as may be the case for Lowestoft and Great Yarmouth in the future) port operators need to plan carefully.

3.1.3 Further Services

Ports can also gain value from the operations and maintenance phase of a project. Once constructed, offshore wind farms are expected to function for at least 20 years. Similar to the onshore farms, the offshore wind farms are run with 24-hour-monitoring and control systems. Once the East of England has several wind farms installed ports will see a significant increase in activity taking place. In extreme cases such as at Horns Rev, turbines had to be disassembled and taken onshore for modification, then needed re-installing.

Special ships will most likely be used for continuous maintenance and small repairs. All required work must be planned in detail, as carrying out maintenance far offshore is highly weather dependent. Complex repairs are also only possible during this time and require the usage of floating cranes or other special equipment, which may not always be available.

The central position in relation to the offshore wind farms will be an important decision criterion. The port has to provide sufficient quaysides and halls which provide an adequate possibility to handle and to store spare parts.

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4 Spatial Requirements for Offshore Wind

Land use requirements will be considered in two cases, standard and extended. In the standard case we will assume that the port serves as a storage, loading and offloading base for the construction of an offshore wind farm. In the extended case we will assume that the port is developed to more fully support the offshore wind industry and offer a fuller range of component production/assembly.

Firstly the basic attributes for servicing the industry will be stated, then the spatial requirements for the standard and extended cases examined. A further section looks at vessel access requirements.

Where suitable the difference between requirements for current projects will be compared with the likely requirements of future projects which are far larger in size.

4.1 Basic Requirements

It is important to note that the location of ports, shipping plants, or modules must meet the requirements of the operating sea barges and special ships, in addition to offering adequate handling and interim storage capacities for large modules.

Long-term prospects need to be certain for ports to commit to infrastructure improvements that would improve their capability to service the offshore wind industry. The emergence of offshore wind has been characterised by project delays and although long-term prospects are very good, particularly off the UK, it must be stressed that up-to-date market intelligence is invaluable and that further project delays are inevitable.

Construction site logistics which flow smoothly are crucial for a project'ssuccess. Daily maintenance of ancillary vehicles used for the foundation, cabling, surveying, tug boat positioning, and staff change must be guaranteed. When settling the project, small and medium ports near to the respective wind farms can be used as a base as well.

The following requirements are desirable:

- Direct connection to water deep enough for seagoing vessels
- Berthing, dispatch and manoeuvring facilities for large floating cranes and special ships
- Loading possibilities for all plant modules (foundations, nacelles, rotor, blades, towers, cable reels, etc.)
- Quaysides for final installation of wind energy plants directly within waters deep enough for seagoing vessels in order to make the take-over with adequate transport ships possible
- Quaysides for simultaneous ship dispatch, related to the installation and module delivery via inland water-ways (n/a for EoE ports) or sea-shipping
- Areas used for interim storage and pre-assembly of plants and plant modules
- Reliable and efficient transport connections on the onshore and offshore side
- Good shipping possibilities to and from European countries
- Proximity to road and rail networks, and to an airport with direct European connections
- Sectoral expertise and project management experience of local port and logistic service providers
- Qualified local staff
- Sufficient industrial areas, if required for the construction of production lines for final assembly, direct connection to water.

4.2 Standard Land Use Requirements

The key land use requirements for the standard use of a port effectively concern storage space and its availability together with loading and unloading facilities. Some specific sizes and weights are given below for the main components that ports would be expected to handle in standard circumstances. Manoeuvrability of components at the site is a key requirement and can be problematic given the size and weights of some parts.

The floor space required for the final assembly at quayside depends mainly on the plant and on which modules are to be mounted in which way. The required floor space decreases naturally if the modules are shipped over several ports or directly from the production site to the construction site. However, the required floor space may increase if the plants cannot be taken offshore for construction, for example because of bad weather, and the incoming deliveries cannot be limited. Bearing in mind these points it should be assumed that for today's moderate sized wind farms, no port is ever likely to see all components belonging to one project having to be stored simultaneously before they get installed offshore.

Nacelles

Nacelle storage and handling capacity is dependent on the turbine models used. Below we have split nacelle weights and sizes by turbine capacity but it should be noted that some high-capacity modern turbines can be smaller and lower-weight than older lower-capacity turbines. The opposite is also true. We will assume that nacelles arrive fully assembled with just blades/rotor assembly, etc. left to fit. As previously mentioned, logistics management means that a port would not normally be required to store all nacelles at any one time, the staggered delivery schedule would reduce land use requirements identified below.

- Current generation turbines with a weight of approximately 200 tonnes and a compact nacelle of 4m x 4m x 8m.

  A single 90 MW project currently typical of UK offshore would have 30 turbines of around this size and weight. Required 'floor space' for each nacelle would be a minimum of 32m^2 and the storage volume would be approximately 128m^3 per nacelle. Maximum storage volume for all 30 nacelles would therefore be 3,40m^3 and would require an area of 960m^2 although stacking of nacelles may be possible which would reduce floor space needed.

- Next generation turbines with a weight of approximately 400 tonnes and a larger nacelle of 8m x 5m x 18m.

  Larger turbines in the 4-6 MW category will start to be used for offshore projects towards the end of the decade, especially on the UK's Round Two developments. Whilst less turbines are obviously needed to meet a certain capacity, these wind farms are in the region of 250 MW to 1 GW in size. We will look at requirements for a 250 MW project (many larger projects will be divided into phases of around this size).

  A 250 MW project/phase might use 50 turbines of this larger size. Required ground area for each nacelle would be 144m^2 and the storage space would be approximately 720m^3 per nacelle. Maximum storage volume required for 50 nacelles would therefore be 36,000m^2 and would require an area of 7,200m^2 although stacking of nacelles may be possible which would reduce floor space needed.

Figure 4-1: Stacked Nacelles with Blades

Figure 4-2: Nacelles on the Quay-Side

Blades

Examples of space requirements are below for two different blade lengths which approximately match current generation turbines (around 3 MW) and next generation turbines (around 5 MW).

- Current blades have a length of approximately 45m, a profile width of 4.5m and a weight of 10 tonnes. With three blades per turbine, a typical project of 90 MW off the East of England and the current time would require 90 blades of this size. Blades can be tilted to slightly reduce storage space so such a blade would require an estimated 90m^2 of storage space.

- Next generation blades have a length of approximately 60m, a profile width of 6m and a weight of 20 tonnes. A typical future project of 250 MW off the East of England would require 150 blades of this size. Estimated storage space for one blade is 180m^2.

Figure 4-3: Blade Storage

There are a number of potential factors further affecting storage and loading/unloading of blades. In many cases nacelles will be loaded onto construction vessels from the port with the rotor assembly and two blades attached, with the third blade(s) loaded onto the vessel individually. This method then requires fewer crane lifts at the construction site. This means that sufficient space and facilities must be available at the port to allow the assembly of two blades onto nacelles and the manoeuvring of the nacelles with blades onto vessels.

Towers

The towers used in offshore wind farms are of up to 80 metres in length but usually are built, transported and stored in two or three sections. At their widest point at the base, towers are 7 metres in diameter, shrinking to 4 metres at the top. Total tower weight can amount to as much as 600 tonnes, although it is more frequently in the range of 100-200 tonnes. Towers can be stored on end to reduce lay-down space, but with three sections per tower, they can be space intensive. Bottom sections have storage space requirement of approximately 38m^2 each, mid sections 28m^2 each and top sections 20m^2 each. Each tower, therefore, has a storage requirement of approximately 86m^2.

Foundations

- **Monopile** foundations will be the most common foundation type used for projects in the area around the East of England as they are most suited to water depths of 10-25 metres and most sites fall within this range. Monopiles weigh approximately 200-500 tonnes, have a length of 40-60 metres and a diameter of 6-7 metres. Storage space per monopole is estimated at 280-420 m^2.

- **Tripod** foundations are more suited to deeper waters of 25 metres or deeper or where seabed conditions require them. The main tube could be a 300 tonne structure of around 30 metres length with a 7 metre diameter. Support tubes have a weight of 150-200 tonnes, a typical length of 15 metres and a diameter of 7 metres. An assembled tripod foundation could have a bottom width of 35 metres, be up to 40 metres in height and have a weight in the region of 600 tonnes. Storage space for a typical tripod foundation is estimated at 2,000m^2.

- **Jacket** foundations are larger structures which are common in the oil and gas industry. Some offshore wind projects will use jacket foundations but they will only be common in very deep waters of around 40 metres where high structural strength is needed. As such, Great Yarmouth and Lowestoft are unlikely to need to handle them for offshore wind for the foreseeable future because projects in this region rarely have a water depth greater than 30 metres. An average jacket would require 2,500m^2 storage space.

  Lowestoft, however, has manufactured jackets in the past for the oil & gas industry so it could prove to be a potential location for manufacturing.

4.2.1 Summary of Standard Land-Use Requirements

The table below shows land use requirements for all components for a current offshore wind farm and in comparison, a typical future project.

It must be stressed that the phased nature of construction and logistics management greatly lessens storage requirements. These figures should just be used as an indication.

Table 4-1: Summary of Standard Land-Use Requirments

	90 MW 'Round One' Project 30x 3 MW turbines	**250 MW 'Round Two' Project** 50 x 5 MW turbines
	Nacelles	
Number of turbines	30	50
Turbine capacity	3 MW	5 MW
Nacelle size	4x4x8 metres	8x5x18 metres
Storage space	32m^2	120m^2
Total storage space	960m^2	7,200m^2
Nacelle weight	70-200 tonnes	250-400 tonnes
Total weight	2,100-6,000 tonnes	12,500-20,000 tonnes
	Blades	
Blade size	45m long x 4.5m widest point	60m long x 6m widest point
Storage space	90m^2	180m^2
Total storage space	8,100m^2	27,000m^2
Blade weight	10 tonnes	20 tonnes
Total weight	900 tonnes	3,000 tonnes
Number of blades	90	150
	Towers	
Tower size	70m x 7m (2-3 sections)	85m x 7m (2-3 sections)
Storage space	86m^2	86m^2
Total storage space	2,580m^2	4,300m^2
Tower weight	100-150 tonnes	150-200 tonnes
Number of complete towers	30	50
Total weight	3,000-4,500 tonnes	7,500-10,000 tonnes
Total maximum 'topsides' storage area required	11,640m^2	32,020m^2
	Foundations	
Foundation type	Monopile	Monopiles or Tripods
Foundation size	40m x 7m	60m x 7m
Storage space	280m^2	420m^2
Total storage space	8,400m^2	21,000m^2
Foundation weight	200-300 tonnes	300-500 tonnes
Number of foundations	30	50
Total weight	6,000-9,000 tonnes	15,000-25,000 tonnes
Total weight of components	12,000-20,400 tonnes	38,000-58,000 tonnes
Total storage area required	20,040m^2	53,020m^2

Note that some components can be stacked to save storage space. The above figures are estimations and there is a broad range of turbines, foundations, towers, etc. that could be used which would alter these numbers.

4.2.2 Standard Storage Capacities for Areas of Land

Table 4-2: Storage Capabilities for Given Areas

	Current Technology Maximum storage capacity*		**Future Technology** Maximum storage capacity*	
Space	**Topsides**	**Foundation**	**Topsides**	**Foundations**
5,000m^2	15	18	7	12
10,000m^2	30	36	14	24
20,000m^2	60	72	20	48
40,000m^2	120	144	40	96

*refers to number of total units – for topsides this is 1 nacelle, 1 tower and 3 blades

The table above estimates potential storage capabilities for different sized areas for current and future offshore wind farm technologies. Remembering that the incoming and outgoing deliveries will be strategically managed this indicates that from a land area of 5,000m^2, a port could operate a reasonable offshore wind activity.

Also note that foundations are usually all installed before turbine installation work begins. If a single season installation is planned, even a relatively small area of port could undertake both work packages one after the other for small projects.

4.3 Extended Land Use Requirement

With the notable exception of several companies, the East of England lacks manufacturing capability. Whilst the ports could be developed to house manufacturing capability for foundations, towers, etc. a realistic view should be taken as to whether Lowestoft and Great Yarmouth are best suited to achieving this goal given the more established supply bases of continental Europe and the north of England and Scotland.

An intermediary step is pre-assembly where some final work on components is undertaken at a port. The range of work can vary considerably from basic and low-value to some more highly skilled activities where value can be gained.

Turbine pre-assembly, for example, could vary from simply fitting the rotor and two blades, to a more comprehensive activity where internal components are fitted in the port's vicinity, which would necessitate the turbine manufacturer establishing an assembly plant at the port.

Whilst the regions ports will most often receive almost fully completed foundations, the most ideal solution would be the establishment of a foundation manufacturer locally. An intermediary solution would be tubular sections being shipped to a port and the welding work being done on site there.

At present the ports are best placed to act in logistics and storage, but working to gain any attainable pre-assembly work possible.

4.3.1 Turbines

Turbine assembly – typical assembly plant is 6,000m^2, half of which is covered assembly space, half storage/transport space. Such a sized plant would have an expected output of 50-75 next generation nacelles or 100-150 current generation nacelles per year.

This is work that is suited to Great Yarmouth and Lowestoft and there is much ongoing effort to try and convince major turbine manufacturers to set up a plant in the area. From a manufacturer's point of view they have to be certain of the future turbine market for 3-5 years.

4.3.2 Foundations

Monopile foundation production – the manufacturing of monopile foundations and turbine towers is an activity that can be conducted from the same facility as the work is essentially rolling steel and welding (towers use thinner steel so monopile manufacturers have the ability to make them). A typical plant would be 20-25,000m^2 and would be able to produce in the region of 200 towers and 30 monopile foundations per year (towers for on/offshore wind and monopiles for offshore). Additional storage space would be required in addition to the above.

Tripod/Jacket foundation production – the manufacturing of tripods and/or jackets requires a much greater space due to the size of the foundations. For a plant manufacturing 50 tripod foundations per year and 30 jackets per year, space requirements are estimated at 25,000m^2, the majority of which is storage space. Land for production/storage would need to be sheltered and capable of bearing 5-10 tonnes per m^2. A major manufacturer would perhaps want a site up to twice this size to double capacity and make production more economical.

It should be noted that the East of England region has extremely few projects that are planning to use tripods (usually used for waters >30m) and no projects planning to use jackets (waters of >40m).

4.3.3 Towers

Tower production – a typical UK tower manufacturing plant would have the capacity to produce 175 towers per year under a two shift pattern. Full 24-hour production could reach 250 towers per year. Such a plant would have in the region of 100 employees. Tower manufacturers may also produce monopile foundations but due to the thicker steel used in foundations this is not always the case.

Tower production is one of the more likely manufacturing activities that the EOE region could attract.

4.3.4 Blades

Blade production – typical factory size is 12,000m^2 which could produce in the region of 150 blades per year for current generation turbines. For the larger next-generation turbines with 60m+ blades, production capacity is estimated at 50 blades per year. A factory of this size would employ approximately 150 people.

4.4 Vessel Access Requirements

In order to evaluate the current situation of the ports, reference data from some offshore wind transport and installation ships have been used as a basis. Based upon this, it is possible to present a view on how local ports will be able to cope with the type of vessels commonly used in the industry.

Table 4-3: Sizes of some Offshore Wind Vessels

	M/V Sea Installer	**M/V Resolution**	**Jumping Jack**	**Vagrant**
Length	140.6m	130.5m	91.0m	43.5m
Breadth	29.6m	38.0m	33.0m	22.5m
Depth	4.9m	2.3m		4.2m
Operational water depth	45m	30m	37m	approx 40m

From looking at typical installation vessels, the following technical requirements can be described:

- Water depth at the quayside and in connection to the sea: 5-10 m (at low tide)
- Berth length: 80-160 m
- In the case of locks: width between fenders 25-40 m (not the case at Lowestoft or Great Yarmouth)
- 24-hour access for construction vessels and barges
- Number of berths: it must be assumed that several berths (at least two) are required, since the simultaneous dispatch of installation and maintenance ships and incoming ships / barges delivering modules has to be possible
- Development possibilities of quay loading have to be examined within the project. Heavy lattice boom cranes with floor loading of 30 tons/square metre (LR 1350, 350 tons/6 metre throat depth) up to 80 tons/square metre (Demag 8800, 442 tons/29 meter throat depth) may have to be used.

4.4.1 Long-term Development Factors

Ports planning expansion against the background of the offshore development are suggested to take the following leading premises into account:

- Planning of a port should be based on a long-term enterprise and a secured quantity structure
- Upgrading should occur step by step and in line with demand
- An economical and competitive port enterprise is warranted
- Ideally, minimal investments needed in infrastructure and superstructure
- Identifying measurements aimed at minimising investment risks, e.g. multi-purpose development so that the port is not wholly dependent on offshore wind in the event of severe project delays.
- Evidence of third party usability of the port's infrastructure should be taken into consideration in case of investment or development plans. Upgrading to a so called multi-purpose-terminal would secure the development possibilities within traditional commodities, such as container, high & heavy, automotive, steel and other project cargos and minimise utilisation risks.

5 Lowestoft and Great Yarmouth

5.1 Lowestoft

Lowestoft lies in the direct neighbourhood of Great Yarmouth, and has similar offshore business traditions and advantages which are brought by the experiences of numerous participants on this site. Lowestoft is one of the very few European ports with offshore wind expertise.

A wide range of facilities is available at Lowestoft for handling containers, bulk and general cargoes. The port is a major centre for servicing the offshore oil, gas and rapidly-expanding renewable-energy industries. Rig structures and modules are fabricated at facilities located in both the port's inner and outer harbours. Extensive ship-repair facilities, including a dry dock and slipways, are also located at the port.

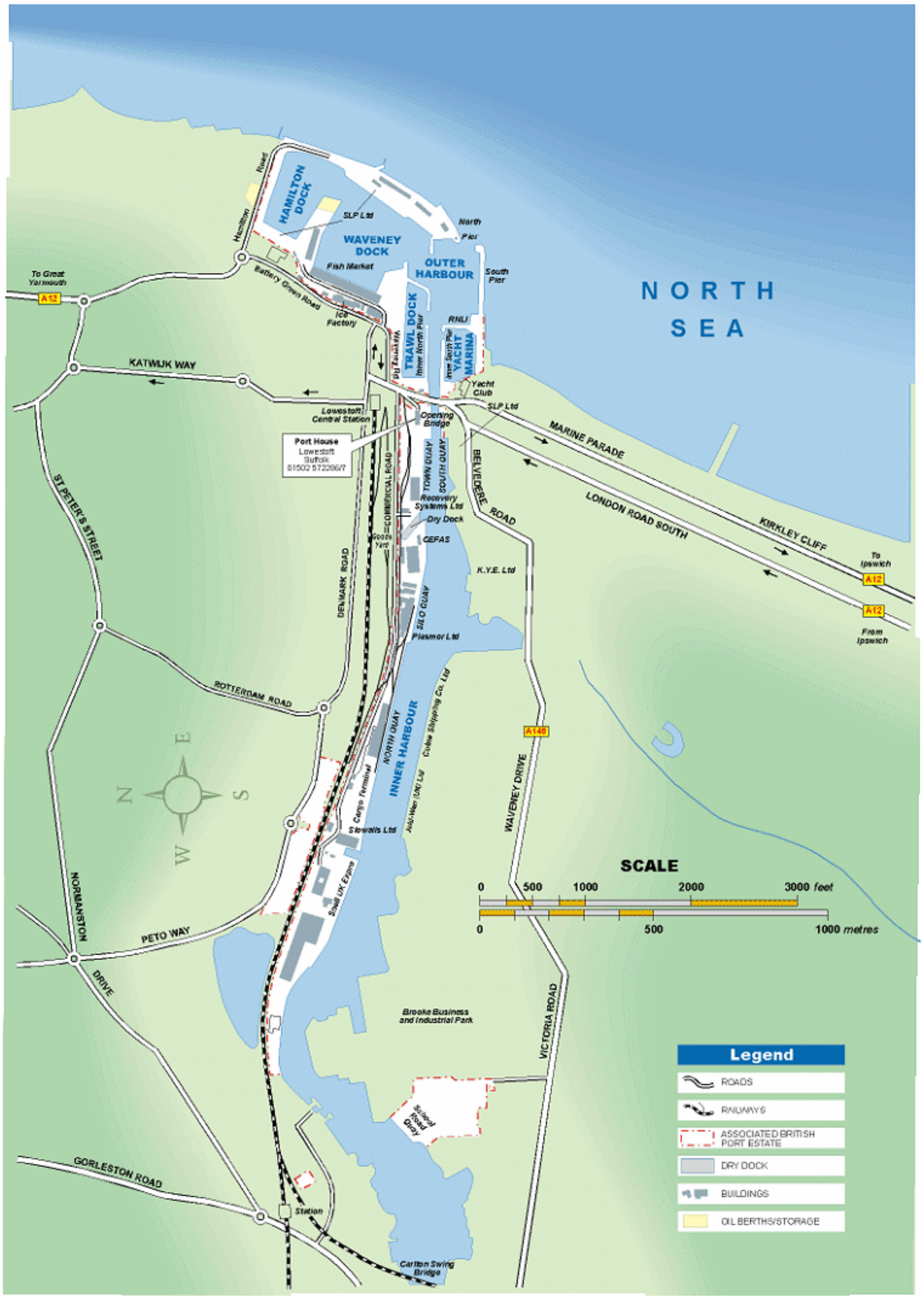

Figure 5-1: Plan of Lowestoft Port

Table 5-1: Berthing Information – Port of Lowestoft

Dock/Quay	Maximum Size of Vessel		
	Length	Beam	Draught
Outer Harbour Docks	125 m	35 m	5.5 m
Entrance Channel & Inner Harbour	125 m	22 m	6 m

However, the technical requirements of this port for a continuous and plentiful turnover of plant modules also seem to be restricted. Of benefit would be the realignment of activity at Lowestoft, where a more efficient use of the potential synergies between its Inner and Outer harbours would greatly enhance its viability for use within future offshore wind developments.

Lowestoft is an important oil and gas port for the North Sea and is increasingly becoming active in the renewable energy sector. SLP Engineering is one local company that is a major manufacturer of topside deck structures and jackets. Through subsidiary SLP Energy it has entered the wind industry.

A wide range of facilities is available at Lowestoft for handling containers, bulk and general cargoes. Rig structures and modules are fabricated at facilities located in both the port's inner and outer harbours. Extensive ship-repair facilities, including a dry dock and slipways, are also located at the port. Four modern transit sheds provide 10,000 sq m of storage space. Wide areas of open storage are also available. The port has a fleet of offshore standby/supply vessels operated by Seacor Marine (International) Ltd.

Figure 5-2: Top-Down View of Wind Farm Components

The port of Lowestoft proved its offshore wind capability capability on the Scroby Sands project. For this first wind farm in the region, Lowestoft was used as the construction and storage base for the topsides (towers, nacelles and blades).

The picture to the left shows approximately 20 full turbines stored at the port ready to be transported to the construction site.

Figure 5-3: Tower Storage at Lowestoft

This alternative view of the quay-side area shows some of the lower tower sections being stored in a vertical position.

Figure 5-4: Moving Upper Tower Section

This photograph shows how the tower sections were moved by lorry to the quayside. Manoeuvrability is a key requirement given the length and weight of some of the components.

5.2 Great Yarmouth

The port, which is operated by Great Yarmouth Port Authority, handles a range of general cargo, mostly for distribution within the region. Great Yarmouth is also the principal UK base for the offshore oil and gas industry in the Southern North Sea. The offshore experience of the participants here is based on their long-term function as an offshore supply port. However, the limited facilities are not currently suitable for larger commercial vessels. It has experience in the offshore wind industry as the monopile foundations of the Scroby Sand project were handled here.

Great Yarmouth is a sizable regional port containing some six thousand metres of commercial quays on both sides of the river Yare, adjoining the large port/industrial area known as South Denes. Under the current conditions (seaport infrastructure and sea connection), the turnover of large amounts of large modules and dispatching large ship units with frequent arrivals (transhipment function) seems only conditionally possible. In light of this, further development of the port appears necessary, although the framework for the port development as a multi-purpose port should be taken into consideration.

On either side of the river Yare, fully-lit outdoor storage areas are available, including the Atlas Terminal. Atlas also has a range of warehouses on site that are adapted for a variety of purposes. Further open storage is also available adjacent to the Ocean Terminal and East Quay for short-term storage and for longer periods, the fully walled area known as the Tent Site with 7.2 acres is available. The Port Authority has two warehouse complexes, one on either side of the river, at Berth 9 and Berth 25.

The Port Authority has adapted quays and working practices so that vessels can access the port at almost any state of the tide. Indeed this was one of the deciding factors back in the '60s as there are no locks or bridges to negotiate in the main area of the harbour and with a rise and fall in the tide of less than 2 metres movement around the river to collect the various items for delivery offshore is easily achieved.

The river port cannot accommodate ships above 125 metres length or 5.5 to 6 metres draught. To overcome this, and to develop further the trading operation of the port, an Outer Harbour is proposed.

5.2.1 EastPort

Great Yarmouth has long been planning the construction of an Outer Harbour. This development, known as EastPort, whilst primarily being undertaken for a passenger ferry to IJmuiden in the Netherlands, would also make the port an extremely capable construction base for the larger Round Two offshore wind projects by enabling larger cargo vessels to use the port.

The Outer Harbour will also reclaim significant amounts of underused land in Great Yarmouth. It is hoped that this would help boost redevelopment and renewal of the area's infrastructure and offer new employment opportunities.

Construction must be complete by 2008 for the project's finance to be issued. There is, however, some doubt within industry as to whether this timescale is realistic (although it should be noted that many of the UK's Round Two projects, for instance, are themselves facing delays).

The Outer Harbour would be a great asset for Great Yarmouth and would make the port the most suitable location for offshore wind work.

However, construction work would prove extremely disruptive to port activities and as such the port could lose out on offshore wind work until EastPort construction is completed. Taking a realistic view of the timetable for the works is, therefore, extremely important.

5.3 What Extent of the Market can Lowestoft & Great Yarmouth Supply?

5.3.1 Estimated Total Spatial Requirement – EOE Offshore Wind

The chart uses the figures in the table previously presented to estimate total land use requirements for all future offshore wind farm projects in the East of England Region, which includes all projects in the Thames Estuary and the Greater Wash strategic areas.

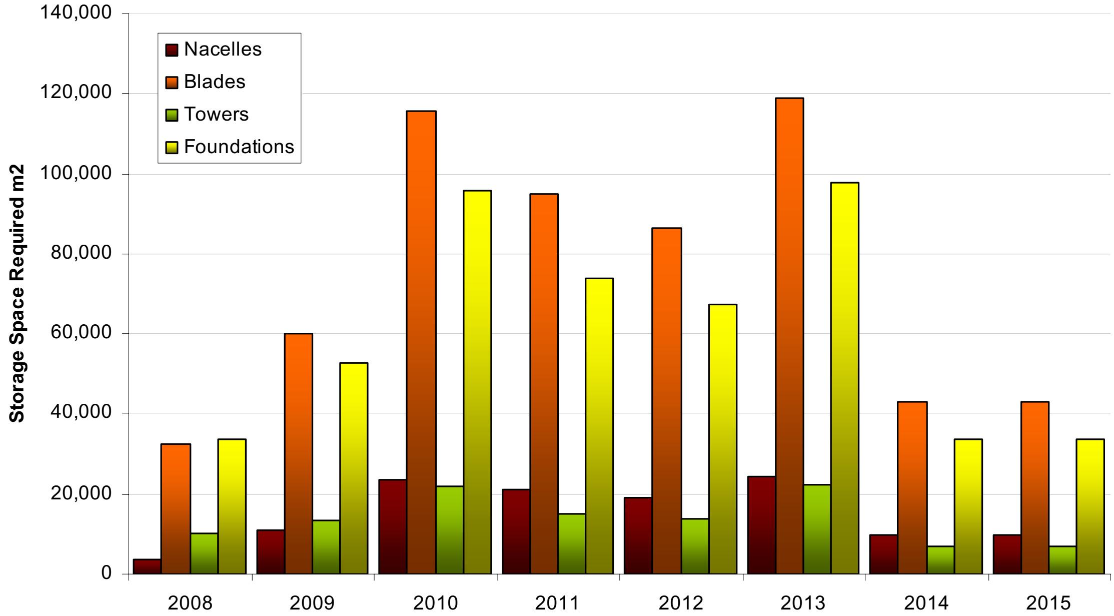

Figure 5-5: Estimated Spatial Requirements for all EOE Offshore Wind Farms

Table 5-2: Estimated Spatial Requirements for all EOE Offshore Wind Farms

Data	2008	2009	2010	2011	2012	2013	2014	2015	Total
Nacelles	3,840	10,800	23,416	21,120	19,200	24,160	9,600	9,600	121,736
Blades	32,400	59,940	115,830	95,040	86,400	118,800	43,200	43,200	594,810
Towers	10,320	13,416	22,016	15,136	13,760	22,360	6,880	6,880	110,768
Foundations	33,600	52,920	95,900	73,920	67,200	98,000	33,600	33,600	488,740
Total	80,160	137,076	257,162	205,216	186,560	263,320	93,280	93,280	1,316,054

It is estimated that land use requirements will total between 80,000m^2 and 263,000m^2 each year between 2008 and 2015. In total, the anticipated offshore wind farms in the region will require a total lay-down space of 1.3 million m^2.

5.3.2 Other Competing Ports

Immingham

- Located centrally to the Greater Wash development area
- Outer harbour suitable for offshore wind
- Inner harbour a restraining feature
- Currently handles bulk cargo and steel
- 200,000m^2 of covered storage
- Extensive open storage
- Not actively targeting offshore wind as a market.

Immingham is geographically the most suitable port for offshore wind farms in the Greater Wash area of the UK and has much potential. The port does not appear to be targeting offshore wind in the same manner as, say, Lowestoft or Great Yarmouth.

Felixstowe:

- Largest container port in the UK
- Used for Kentish Flats
- Owned by Hutchingson Port Holdings Group, subsidiary of HPH – the worlds' largest ports investor, developer and operator
- Large quay-side and berths
- Ideal for offshore wind
- BUT clashes with container business
- Further container expansion already planned
- Natural links with Ipswich – located inland with river access.

Felixstowe is a very capable port which could undertake a large portion of offshore wind activities but large scale offshore wind work would clash with its existing business. It is expected that it will continue to target offshore wind but it is unlikely to become a 'superport' for the industry.

Ipswich

- Multi-purpose port
- Meets basic requirements for offshore wind
- Compatibility of existing activities with offshore wind is unknown
- Sea connection via river Orwell – accessible for vessels
- 65,000m2 of covered storage
- Some open storage available
- Natural links with Felixstowe – which is at mouth of river Orwell.

Ipswich is a good facility and working in partnership with Felixstowe could offer a very strong package to the offshore wind industry.

Harwich:

- Close to Felixstowe & Ipswich
- Specialises in ferry and roll-on-roll-off traffic
- Any offshore wind activity must be compatible with this existing business
- Operated by HPH – the worlds' largest ports investor, developer and operator.

Harwich is less likely to be undertaking much offshore wind work as other ports present a more suitable package. Offshore wind work may impede the port's other activities.

Tilbury:

- Located in the mouth of the Thames
- Suited to southern Thames Estuary Projects
- Distant from Greater Wash projects
- Excellent links to London & Europe
- Big import potential
- Large and capable site.

Tilbury could prove to be an excellent port for the UK's 2nd round projects in the Thames Estuary due to its location and highly capable facilities. It seems the ideal choice for the London Array project which totals 1 GW over four years. Located on the Thames it has superb transportation links. The port is too far from the Greater Wash to be used as a construction base for the projects here. The port is not actively being pushed for offshore wind.

5.3.3 Advantages of Lowestoft and Great Yarmouth

Great Yarmouth and Lowestoft have key advantages which will position them well for future offshore wind work. Their past experience in the industry and the work being undertaken to market them as offshore wind ports is of great importance, particularly considering the lack of promotional work being undertaken by other ports. Geographically they are very well positioned as they have good access to both the Greater Wash and Thames Estuary, effectively doubling their potential market.

Felixstowe is highly capable and this port represents the greatest threat. It should also be accepted that Immingham is well-placed to win work in the Greater Wash. Tilbury is a potential threat in the Thames Estuary.

5.3.4 How Much Work is Likely?

There are too many variables and unknowns to be able to forecast the amount of work the two ports will win but some generalisations can be made to indicate the relative advantages of them.

Judged geographically, Lowestoft and Great Yarmouth are highly suitable for approximately 75% of future installations, with only the northernmost and southernmost of projects most likely to be awarded to other ports.

There are 23 projects (individual wind farms or phases) forecast for 2008-2015. If current trends continue it is likely that foundations and topsides (turbines, towers, blades) will be installed over two years for each project. There is, therefore, effectively as many as 46 different contracts to be placed with ports for this period. With 7 capable ports (only three of which have offshore wind experience, and three of which are primarily focused on other activities) the potential for Lowestoft & Great Yarmouth is great.

It is our belief, therefore, that the ports could win work each season from 2008 to at least 2014. If the EastPort development goes ahead, Great Yarmouth will be the natural choice for developers for a large number of projects. Lowestoft will win work but its smaller size is limiting.

On a moderate assumption, both ports are sufficiently capable of utilising 10,000m^2 or more of dedicated space for offshore wind activities. This would allow both ports to handle one mid-sized project per year each such as those forecast for 2008-2009.

From 2009-2010 to 2014 when the 250 MW-plus projects are built, 25-50,000m^2 areas of land could realistically be fully utilised each year at the ports if they were available. In 2010 alone, spatial requirements identified earlier indicate that 250,000m^2 of space will be required.

5.4 How Can Lowestoft and Great Yarmouth Secure the Work?

The ports of Lowestoft & Great Yarmouth must take an active role in gaining contracts. It could be argued that because they are established ports in a region with forecast high growth that they would automatically gain some work from the many future projects. Whilst this is true to an extent, taking actions to promote the ports and secure the work is crucial.

Many of the offshore wind farm projects are individual phases of large developments spread over a number of years. Additionally there are multiple projects from the same developers. What this means is that putting the effort into winning one contract could reap tremendous rewards for future projects.

The port operators need to forge links with project developers, key manufacturers and local companies active, or with the intention of becoming active, in offshore wind. Such communications can be facilitated via regional support agencies such as EEEGR, EEDA or Renewables East. Departments of government, most prominently the Department of Trade and Industry have specific teams to help develop UK content in offshore wind and can help foster links with industry leaders both in the UK and abroad.

Market intelligence is of great importance to the port operators and they need to be confident of which projects they should be targeting with the knowledge of what they could offer the project developer.

Additionally, there would be benefit in working to enhance the access from the main port areas to the inner port areas which have great storage potential. Either by road or by water, there must be easy access for manoeuvrability of the main components – eg. 60 metre structures that could weigh in the region of 300-500 tonnes.

Ports need to be thinking ahead in terms of the services they can provide. The offshore wind industry is young and new solutions are constantly sought, one example given earlier was the conceptual 'one-piece' turbine installations. Because of the lengthy process involved in upgrading ports, decisions need to be made far in advance. The outer harbour at Great Yarmouth will be a great asset and will enable the port to offer a greater range of services to the offshore wind industry, but the development process for this major work has taken a considerable amount of time.

The two towns/ports must try to attract offshore wind companies to establish themselves around the port. This will create a cluster of experience that will naturally draw attention to the ports. The Offshore Renewable Energy Centre in Lowestoft has this potential.

It should also be noted that the two ports have a much greater chance of winning work by offering joint services to some large projects. This is true where one developer has a number of projects in the area or if a large project wants to do a one season installation. Individually, neither port would be able to fully undertake such work, but by offering a joint package they can compete with the very largest ports in the region.