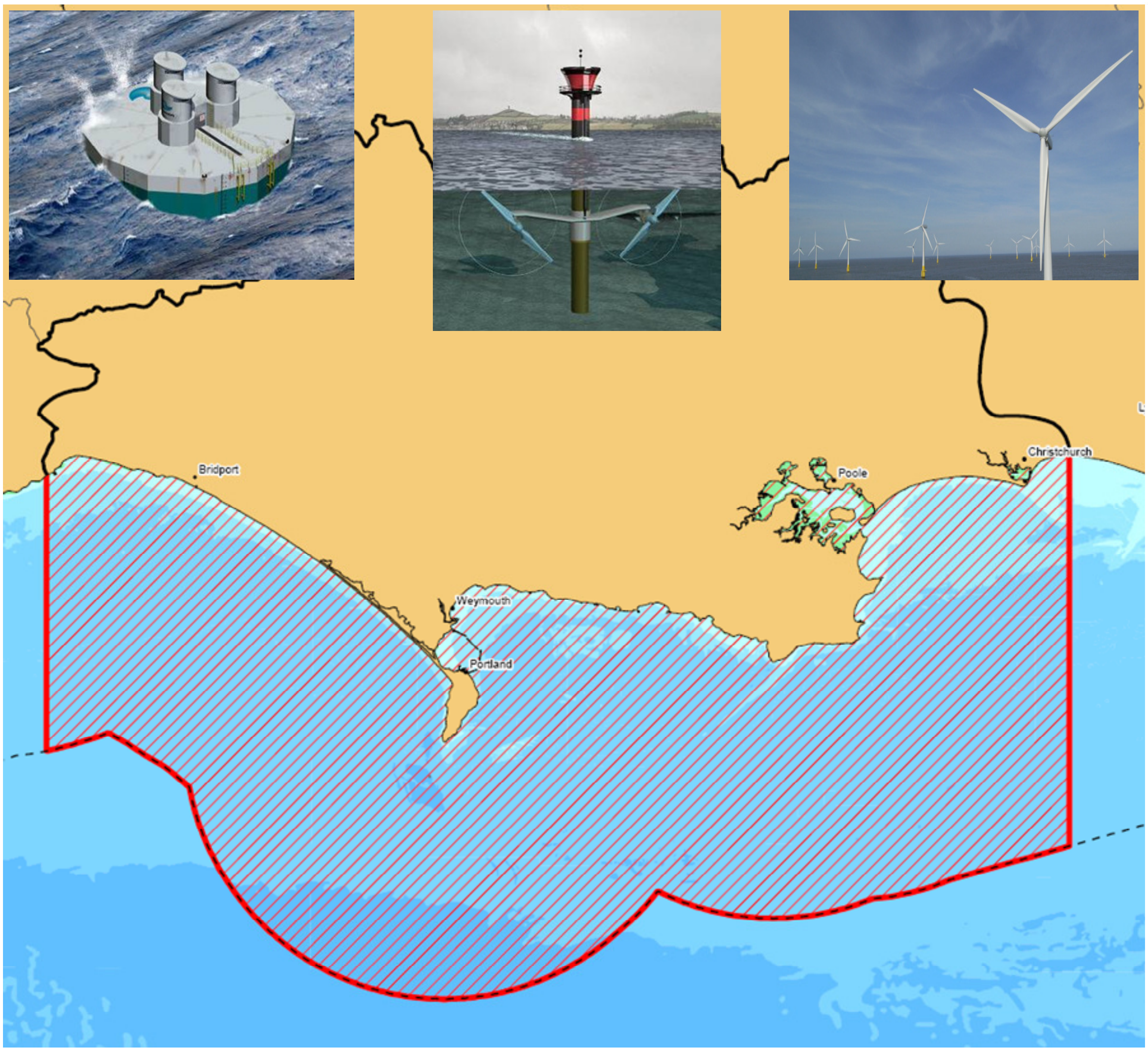
ROYAL HASKONING



An Offshore Renewables Capacity Study for Dorset

Dorset C-SCOPE Project

Dorset Coast Forum

1 April 2010

Final Report

9V5867

c~scope
Combining Sea and Coastal Planning in Europe

Investing in your future
Cross-border Cooperation Programme
2007-2013
Part-financed by the European Union
(European Regional Development Fund)

DORSET COAST FORUM

ROYAL HASKONING

Stratus House
Emperor Way
Exeter, Devon EX1 3QS
United Kingdom
+44 (0)1392 447999 Telephone
Fax
info@exeter.royalhaskoning.com E-mail
www.royalhaskoning.com Internet

Document title	An Offshore Renewables Capacity Study for Dorset Dorset C-SCOPE Project
Document short title	Offshore Renewables Capacity Study
Status	Final Report
Date	1 April 2010
Project name	Offshore Renewables Capacity Study
Project number	9V5867
Client	Dorset Coast Forum
Reference	9V5867/R/303424/Exet

Drafted by	J. Trendall, G. Chapman & P. Gaches	
Checked by	Peter Gaches	
Date/initials check	………………….	………………….
Approved by	Steve Challinor	
Date/initials approval	………………….	………………….

ROYAL HASKONING

CONTENTS

1 INTRODUCTION

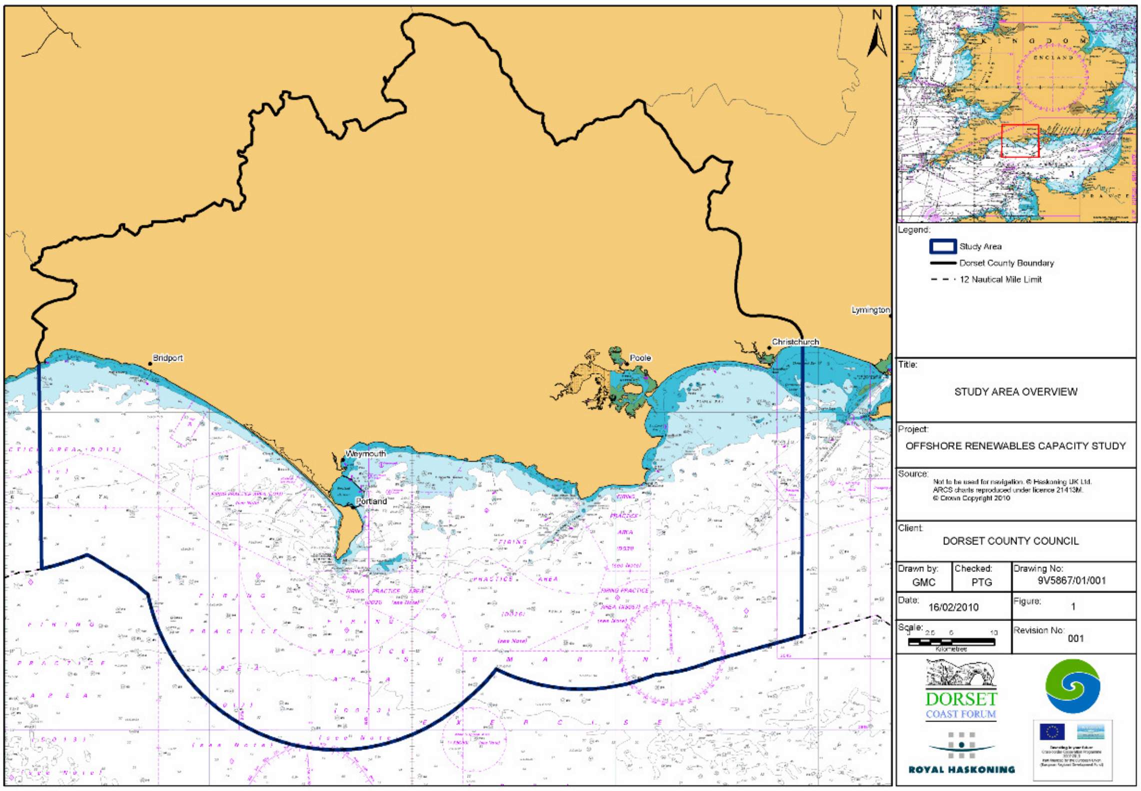
Royal Haskoning have been commissioned by Dorset Coast Forum (DCF) to undertake an Offshore Renewables Capacity Study for the waters off the Dorset coast. **Figure 1** identifies the study location and boundaries. The Offshore Renewables Capacity Study provides DCF with an understanding of those areas within the Dorset marine environment that may be considered suitable for marine renewable energy development from wave, tidal stream and offshore wind technology groups.

The study, part funded by the Interreg IV A 'Two Seas' Programme, forms part of C-SCOPE (Combining Sea and Coastal Planning in Europe), a joint venture established between Dorset Coast Forum and the Belgian Integrated Coastal Zone Management (ICZM) Coordination Centre.

More specifically this study forms one of five studies (the others being Land and Seascape Assessment, Interactions Matrix, Seabed Mapping and Collection of Sectoral Spatial Information and relevant data) that will collectively inform marine policy development to underpin a Marine Spatial Plan (MSP) for the region. It is recognised that the MSP would be non-statutory though could be a potential pilot for subsequent statutory entities which may arise out of the Marine and Coastal Access Act 2009.

The findings from these five studies will help development of the MSP to manage the many current and future pressures facing the Dorset coast, from new development and climate change to competition for space between interests such as shipping, commercial fishing, recreation and renewable energy.

Figure 1 Study Area Overview



1.1 Study Overview

The Offshore Renewables Capacity Study comprises the following aspects:

- **Current Technologies Review (Section 2)** – setting out the current industry status for offshore wind, wave and tidal stream, providing a high level overview of the infrastructure requirements for the development of these devices and discussing the likely future evolution of these technology groups within the UK.
- **Land-based Infrastructure Requirements (Section 3)** – providing a high level overview of the typical infrastructure requirements for small scale and large scale marine renewable energy device / array deployments.
- **Renewable Capacity Study (Section 4)** – establishing the Minimum Feasible Operating Criteria (MFOC) for each technology group, defining the development constraints, mapping of marine energy resources, identification of potential development areas, constraint discussion and discussion of potential landfall locations.
- **Conclusions (Section 5)** – Summary of study findings.

2 CURRENT TECHNOLOGIES REVIEW

The following section sets out Royal Haskoning's desk-based review of the current status of the offshore wind, wave and tidal stream technology groups within the UK. This study has been informed by information that is publically available. It should be recognised that given the nascent status of some of these industries (especially for wave and tidal stream), there is much commercial sensitivity relating to device and site development. Therefore, there may be developments within these industries that has not yet reached the public domain, and cannot therefore, be included within this study.

2.1 Offshore Wind Technology Overview

Current Technology Group Status

The Crown Estate is responsible for the leasing of the seabed for offshore wind development within the UK Renewable Energy Zone (REZ) and the territorial waters of England and Wales. The first phase of seabed leasing (known as Round 1) took place in 2001, and following its success and apparent appetite for growth in the sector The Crown Estate undertook further leasing programme (Round 2) in 2003. Rounds 1 and 2 are anticipated to contribute 8GW of energy generation. A number of these projects are now in operation, many are under construction whilst a few still remain in the consenting phase. In 2007 it was announced that the UK would undertake an Offshore Energy Strategic Environmental Assessment (SEA) to assess the impact of a draft plan/programme for up to 25GW of additional generation capacity by 2020. Following positive findings from the SEA, The Crown Estate (in January 2010) formally announced the developers that would take forward nine Development Zones around the UK that would be capable of delivering 25GW. Furthermore, in July 2009, The Crown Estate announced plans to hold a Round 2.5 leasing programme for extensions to existing Round 1 and 2 projects. No ambition has been set of target capacity from this leasing round and development is unlikely to occur on all existing projects. Announcements on the extensions that will be taken forward are expected to be announced by The Crown Estate in April 2010.

Of particular relevance to the Dorset coastal waters is the West of Wight Round 3 Zone, a significant proportion of which extends into the study area for this project. It should also be noted that early iterations of The Crown Estates Round 3 plans included a much larger area within Lyme Bay. However, following the consultation process this was dropped in favour of the West of Wight Zone.

Technology Summary

A typical offshore wind farm will comprise the following elements:

- Wind turbine generators and supporting tower structures (WTGs);
- Foundations for the WTGs with associated support (transition) structures;
- Subsea interarray and export cables;
- Offshore substation(s) and associated foundations;
- Ancillary infrastructure (such as accommodation platform and meteorological mast(s) (if required)); and
- Onshore elements comprising the cable landfall, onshore transition pit and substation to connect to the National Grid Network.

The components of an offshore wind farm are typically prefabricated separately in specialist manufacturing facilities. The components are then, depending on the fabrication location either shipped to a local port for storage and pre-assembled ready for transportation by jack-up barge to site, or taken direct to site for installation. The construction process occurs in sequence with the foundation structures and export cabling installed first, followed by the transition structures and then the nacelle and finally the rotor including the hub and blades (these latter two phases may be sometimes combined into one). Alongside this construction process the interarray cables and associated offshore support infrastructure (such as substations and meteorological masts) will also be installed. Specialist installation equipment is required for each phase of the process. Analogous to the offshore works will be those occurring onshore (such as onshore cabling, transition pit and substation construction).

The following section provides an overview of the technology associated with the WTGs and foundations. The aspects associated with the inter-array and export cables and ancillary structures are not discussed in further detail in this report. Aspects relating to onshore components are discussed in **Section 3**.

The WTGs consist of three primary components:

- The tower (support structure);
- The nacelle (containing the generator and all electrical equipment); and
- The rotor (including hub & blades).

Within the UK there are currently (as of January 2010) three turbine manufacturers with offshore WTGs in operation:

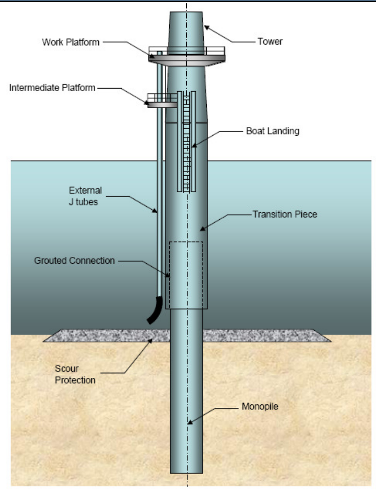
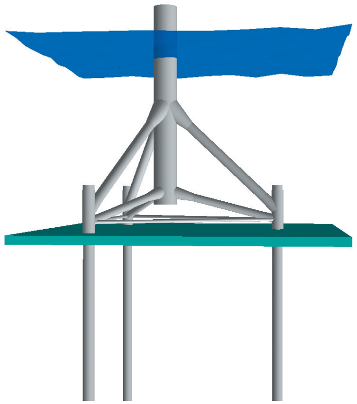
- Siemens (3.6MW WTG);
- Vestas (2MW and 3MW WTGs); and
- Repower (5MW demonstration WTG).

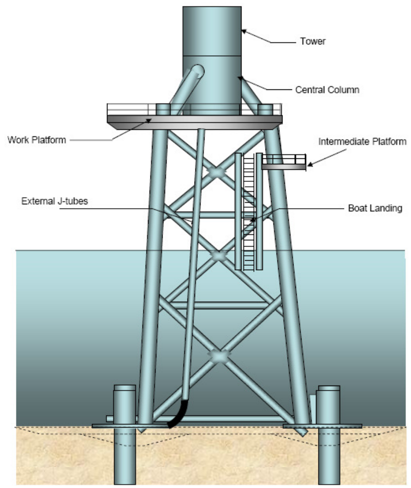
The offshore wind industry is sufficiently advanced that the principal design of the WTG varies relatively little between manufacturer i.e. the system used is based on a three blade, horizontal axis design as indicated in **Figure 2.1** below.

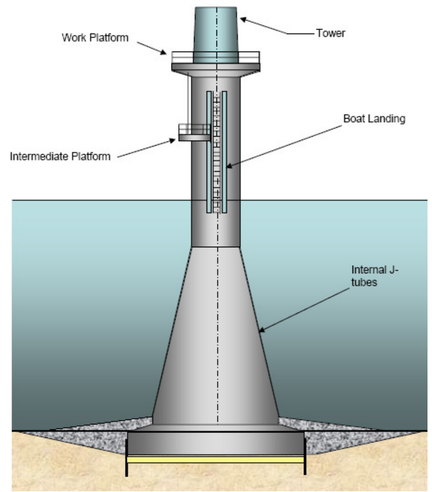
Figure 2.1 Typical offshore WTG design

There is, however, significantly more variation in the market place with regard to the design of the foundation structures that support the WTGs. This is largely driven by the physical and financial constraints posed by operating in the marine environment. **Table 2.1** summarises the types of foundation structures currently available to developers.

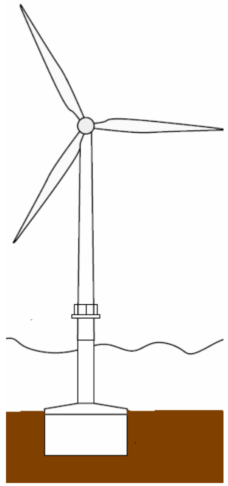
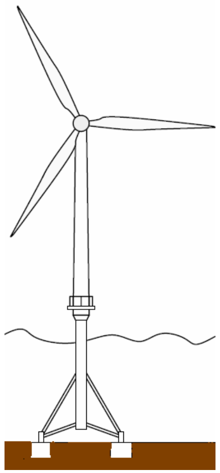
Table 2.1: Offshore Wind Industry – foundation types

Foundation type	Physical Aspects	Status of development	Image
Monopile	Steel monopiles are typically between 3m and 6m in diameter. Suitable in water depth up to around 30-35m. Not suitable where deep soft sediments (such as muds) exist (EWEA, 2004).	Most common within the UK. Monopile diameters are increasing to enable exploitation of deeper water depths to be technically feasible, although there are financial constraints associated with this.	 Source (DOW 2009)
Tripod	Comprises steel tripod legs piled into seabed. Steel lattice structure provides support to connect legs to the WTG support tower. Suitable for water depths above 30m (EWEA, 2004). Not ideal for deep soft sediments.	Not currently in used within any operational UK offshore wind farms, although knowledge from the oil and gas industry means that this system does not represent a technological challenge.	 Source (GGOWF 2006)

<table>
<tr><th>Foundation type</th><th>Physical Aspects</th><th>Status of development</th><th>Image</th></tr>
<tr><td>Jacket</td><td>Comprises steel legs (typically four but three legs are also possible) with cross bracings. The leg members are attached to the seabed most commonly by ‘pin-piles’. Jacket design is conceptually stiffer than a monopile and is more effective at reducing wave loading. Jackets are typically installed without scour protection (mud mats) owing to the difficulty of its placement (DOW, 2009). Suitable for deep water and wave exposed sites.</td><td>Widely in the oil and gas industry in the North Sea. Jacket foundations have been used at the Beatrice offshore wind farm demonstrator project in Scotland and at Ormonde in the Irish Sea where they support 5MW WTGs.</td><td>

Source (DOW 2009)</td></tr>
<tr><td>Gravity base</td><td>Suitable for most sediment types. Typically concrete in design, but can also be steel. Financial constraints are likely to limit deep water deployment. Requires the preparation of seabed prior to installation.</td><td>Commonly used in early Danish offshore wind development. Not currently used at any operational offshore wind farms within the UK to date.</td><td>

Source (DOW 2009)</td></tr>
</table>

Foundation type	Physical Aspects	Status of development	Image
Mono-suction caisson	Suitable for soft sand and clay sediment environments (EWEA, 2004). As with the traditional monopile, this technology is best suited to shallow waters (<30m).	Not currently used at any operational offshore wind farms within the UK to date.	 Source (Bryne & Houlsby 2006)
Multi-suction caisson	Suitable for soft sand and clay sediment environments (EWEA, 2004). Similar to the tripod pile system and therefore is suitable for water depths >30m.	Not currently used at any operational offshore wind farms within the UK to date.	 Source (Bryne & Houlsby 2006)

Foundation type	Physical Aspects	Status of development	Image
Floating base	There are numerous design aspects being considered including: ballast, buoyancy and mooring line options. All of which are aimed at enabling deployment in deep water without the costs of the foundations becoming prohibitive to deployment.	As of 2009, two operational floating wind turbines have been trialled: Blue H deployed the first floating wind turbine 113km off of the coast of Italy in December, 2007. It was then decommissioned at the end of 2008 after completing a planned test year of gathering operational data. This system was based around a ballast rig support structure, will chain anchors to the seabed. StatoilHydro deployed the first large-capacity (2.3MW) floating wind turbine (known as Hywind), in the North Sea off Norway in September, 2009 and is still operational as of October 2009. This system is attached to the top of 'Spar-buoy' and moored to the seabed by three anchor points.	 Source: www.bluehusa.com  Source: www.news.bbc.co.uk

2.2 Offshore Tidal Stream Technology Overview

Current Technology Group Status

Tidal energy resources are concentrated around the south, west and northern coastlines of the UK, including the Portland headland on the Dorset coast (BERR, 2008) However, tidal current energy is very site specific, optimised only where tidal range is amplified by factors such as shelving of the sea bottom, funneling in estuaries and reflections by large peninsulas (www.emec.org.uk).

Tidal power has the distinct advantage of being highly predictable compared with some other forms of renewable energy and, where correctly sited, can have a greater guarantee to produce electricity than wave or wind development, making it an attractive resource option.

Development within the UK to date has been restricted to several single demonstration devices and one full scale commercial device (MCT's SeaGen project).

Technology Summary

Unlike the offshore wind industry, where the turbine design differs little from the combination of current successful onshore turbine technology and existing convergent activities in the marine environment such as the oil and gas industry, many innovative tidal stream devices have been developed over recent years (BWEA, 2009).

The majority of the devices currently in the market place comprise horizontal axis, with typically either a two or three blade rotor system. The funnel like 'Venturi effect' design has also proved a success for OpenHydro. A number of other design types are in the market place within the UK (either through UK based design or overseas interest in UK deployment). These are detailed in **Table 2.2**.

The industry can therefore be described as being nascent in that it is still proving itself, with the majority of deployments to date restricted to either scaled down prototypes or in a few cases full scale demonstration devices. This nascent state is reflected by the variety of different types of devices currently in the market place. Deployment to date has largely been within the Scottish marine sector where clear Government support through financial incentives and firm commitments (such as the Strategic Environmental Assessment (SEA) of the Pentland Firth area) has helped provide the necessary security for developers to secure funding for device deployment. Within England and Wales activity to date has been restricted to a limited number of prototype deployments, with the only known firm plans for array deployment being off Anglesey in Wales. It is considered that to date the lack of firm Governmental plans (or SEA) for the industry sector development combined with current financial incentives has somewhat held the industry back within England and Wales in terms of array deployment.

2.3 Offshore Wave Technology Overview

Current Technology Group Status

Around the UK, suitable wave energy potential is distributed around the western and northern half of the country, generated by the Atlantic fetch (www.emec.org.uk). However, the extent to which this will prove practical to harness will depend upon the successful development of both near shore and deep water technologies.

Although there are only a small number of devices currently installed in the UK and generating to the grid, several other prototype devices are following planning consent routes to allow installation in the near future. A number of devices (such as Pelamis Wave Power's Pelamis device and Ocean Power Technology's PowerBuoy) have been trialled both within and outside of the UK. The industry's relatively unproven status and technical difficulties experienced during device testing means that there has been a reluctance to provide the level of investment that the industry needs to take devices on from prototype to commercial scale. However, the promotion of Pentland Firth wave and tidal strategic area has helped to stimulate interest off Scottish waters, where favourable renewable energy generation incentives exist.

Technology Summary

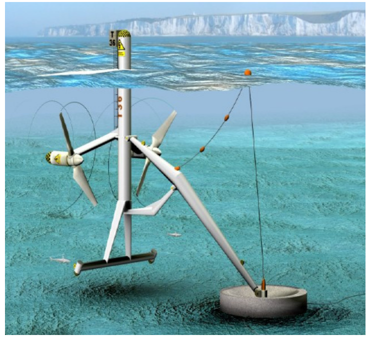
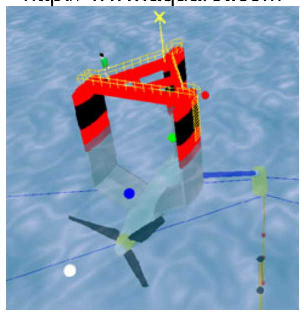
Wave energy development is even more nascent than that of the tidal stream industry and similarly there are a high number of device designs in the market place.

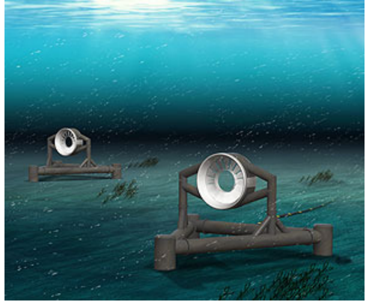
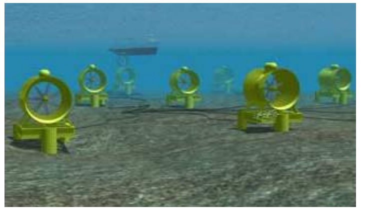
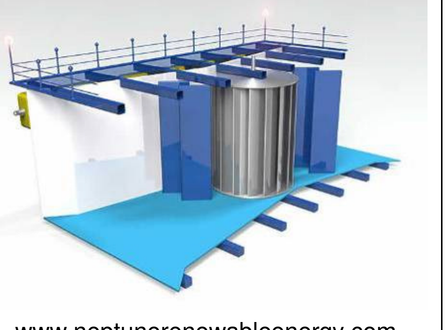
The limited devices tested to date comprise a mix of technological approaches (e.g. the Pelamis attenuator device, OPT's PowerBuoy device and Aquamarine Power's Oyster device). One of the key factors that has restricted the rate of progress in device development and deployment on a significant scale to date, is the ability to construct a device that is capable of not only operating (and therefore, generating power) in, but also surviving the harsh conditions within which the devices will operate. **Table 2.3** provides an overview of the current technologies being investigated within the UK.

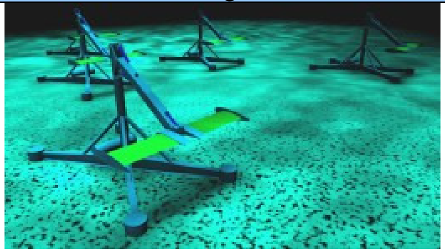
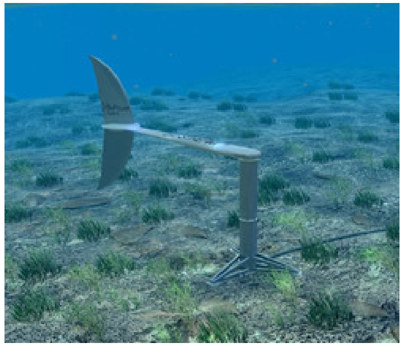
For nearshore devices, such as the Limpet and Sidar, the technological challenges to development and deployment are much reduced and therefore, commercialisation of these type of projects is on a much clearer path. However, the ability of these devices to dominate the market place will be limited due to their highly specific location requirements restricted location and likely increased consenting risks (due to visual and physical impacts of the development on the associated coastline) compared to devices located offshore. Further offshore, greater resource potential exists with fewer consenting constraints and therefore, devices that are aimed at energy extraction in these areas are the ones that are undergoing greatest expansion.

Table 2.2: UK Offshore Tidal Stream Industry

Technology Type	Physical Aspects	Status of development	Images
Horizontal axis turbine These devices extract energy from moving water in much the same way as wind turbines extract energy from moving air. Devices can be housed within ducts to create secondary flow effects by concentrating the flow and producing a pressure difference (www.emec.org.uk)	Typically comprises: - support structure; - blades & rotor/s; - offshore (e.g. Seagen) or onshore (submerged devices) control system; - Marker buoys (if submerged); and - export cabling.	E.g. **Marine Current Turbines Ltd's** 1.2MW **SeaGen** demonstration devise which is the world's first commercial scale grid connected device. Future projects include deployment in the Bay of Fundy, by 2011 and an array in Anglesey. **Tidal Energy Ltd** have submitted an EIA for a 12 month test of their 1MW **Deltastream** devise off the Pembrokeshire coast Wales. **Hammerfest Strom** had a Prototype installed in 2003 near Finnmark, Northern Norway. A 1MW test device is to be deployed at EMEC. EIA for a 20MW array of ten devices in Sound of Islay is underway. **Atlantis** plan to test the **AK-1000** at EMEC in 2010. **TidEL Tidal Turbines** have built a 1/10th sized prototype system which recently underwent seven weeks of testing at NaREC. Next step is full scale testing at EMEC.	 http://www.seageneration.co.uk  http://www.hammerfeststrom.com  www.atlantisresourcescorporation.com

Technology Type	Physical Aspects	Status of development	Images
Horizontal axis turbine (continued)		**Aquamarine** (Neptune & Evopod) have a test birth secured at EMEC. **TidalStream** are currently testing the **Triton** 1/20th scale devise using indoor facilities. They are testing a 2, and a 6 turbine model. **Ocean Flow Energy** are currently developing a 1/5th scale model of their **Evopod** after successful deployment of a 1/10th scale model in Strangford narrows. **Swan Turbines** aim to install and operate a medium scale demonstrator devise (330kw) in 2010. **Tidal Generation Limited** are now working with their project partners to complete the detailed design and install a 500kW 'Deep Gen' device at the EMEC.	 http:// www.aquaret.com  www.oceanflowenergy.com

Technology Type	Physical Aspects	Status of development	Images
Venturi Effect By housing the device in a duct, this has the effect of concentrating the flow past the turbine. The funnel-like collecting device sits submerged in the tidal current. The flow of water can drive a turbine directly or the induced pressure differential in the system can drive an air-turbine (www.emec.org.uk).	Typically comprises: - support structure; - blades & rotor/s; - offshore or onshore (submerged devices) control system; - Marker buoys (if submerged); and - export cabling.	E.g. **Open Hydro** Installed a 250kW test device (**Open-Centre Turbine**) at EMEC in 2006 which commenced electricity generation onto the UK national grid in 2008. A 1MW commercial turbine was deployed in the Bay of Fundy in 2009. Currently progressing investigations for a commercial array in Alderney (English Channel). **Lunar Energies** which have deployed tested & evaluated their **Rotech** 1MW device in Korea. Start of sea trials of the ⅓ scale device at EMEC. The first UK commercial development is planned to be operational in 2011.	 http://www.openhydro.com  www.lunarenergy.co.uk
Vertical axis turbine This device extracts energy from moving in a similar fashion to that above, however the turbine is mounted on a vertical axis (www.emec.org.uk).	Typically comprises: - support structure; - blades & rotor/s; - offshore or onshore (submerged devices) control system; - Marker buoys (if submerged); and - export cabling.	E.g. **Neptune Renewable Energy who** are hoping to deploy their full scale **Proteus** devise in the Humber Estuary 2010.	 www.neptunerenewableenergy.com

Technology Type	Physical Aspects	Status of development	Images
Oscillating Hydrofoil A hydrofoil attached to an oscillating arm and the motion is caused by the tidal current flowing either side of a wing, which results in lift. This motion can then drive fluid in a hydraulic system to be converted into electricity.	Typically comprises: - A devise that mimics the shape and motion of a fast swimming fish - an arm holding the devise - a single point connection - a central support structure - swivel mechanism for changes in flow. Marker buoys (if submerged); and - export cabling.	E.g. **Engineering Business Ltd** have recently completed its programme to design, build, install offshore, test and decommission a full scale demonstrator of its **Stingray** tidal stream generator. **Biopower** are currently developing their **bioSTREAM** devise in Australia. The 250kW pilot project should be up and running in 2010. They are looking to break into UK markets (Biopower systems). **Tidal Pulse** have deployed their 100kW **Humber** prototype system which has proved successful and Pulse is now engineering a much larger device that should be operational by 2012.	 http://www.engb.com/  www.biopowersystems.com  www.pulsetidal.com

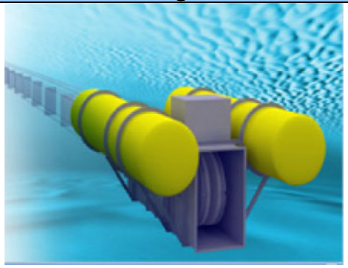
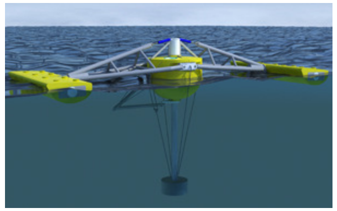
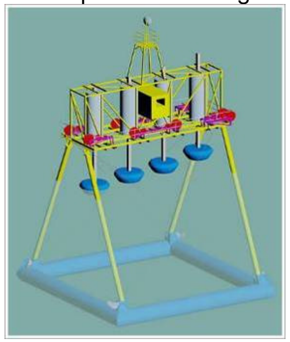
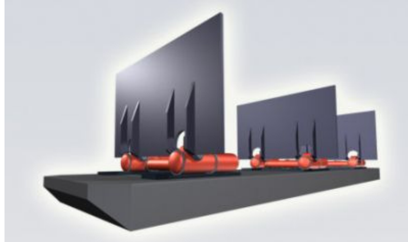
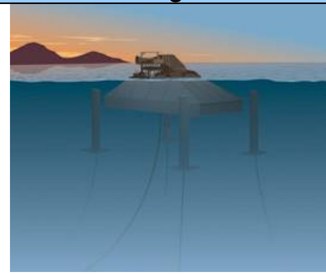
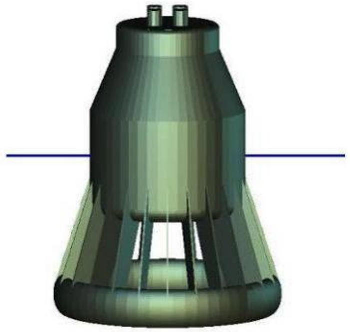
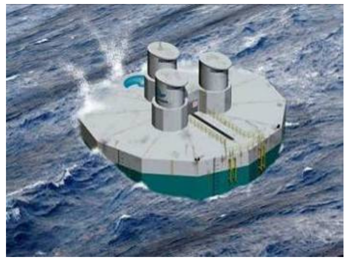
Technology Type	Physical Aspects	Status of development	Images
Other Designs This covers those devices with a unique and very different design to the more well-established types of technology or if information on the device's characteristics could not be determined (www.emec.org.uk).	Typically comprises: - support structure; - blades & rotor/s or sails; - offshore or onshore (submerged devices) control system; - Marker buoys (if submerged); and - export cabling.	E.g. **Woodshed Technologies Pty Ltd.** Who own a largely untested technology with large impacts that has yet to see any real development in the UK. **Tidal Sails** is an embryonic technology, with limited locations for deployment in the UK, more suited to Norway.	

Table 2.3: UK Offshore Wave Industry

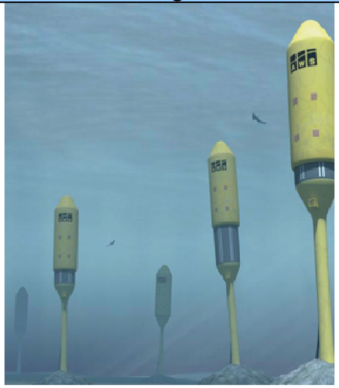
Technology Type	Physical Aspects	Status of development	Images
Attenuator An attenuator is a floating device which works parallel to the wave direction and effectively rides the waves. Movements along its length can be selectively constrained to produce energy. It has a lower area parallel to the waves in comparison to a terminator, so the device experiences lower forces (www.emec.org.uk)	Typically comprises: - articulated floating housing units - internal hydraulic energy generation system - mooring lines	E.g. **Pelamis Wave Power** installed a 2.25MW **P1** device off Portugal in 2008. Pelamis are currently developing a **P2** device for installation at EMEC in 2010 and are looking to commercial scale deployment in Pentland Firth. Another attenuator prototype that has been tested and is looking to move forward to commercial deployment by 2012 is **Green Energies' WaveTreader**.	 www.pelamiswave.com  www.greenoceanenergy.com
Point Absorber This device is a floating structure which absorbs energy in all directions through its movements at/near the water surface. The power take-off system may take a number of forms, depending on the configuration of displacers/reactors. (www.emec.org.uk).	Typically comprises: - An Asymmetric Buoy (occasionally they are symmetrical) that is moored to the seabed. -A hollow chamber. -pumping system. Electromechanical or hydraulic energy converter -	E.g. **OPT's** 1.39MW **Wavebob** is now producing power in the Atlantic off the coast of Co Galway (Irish independent).	 www.marine.ire

Technology Type	Physical Aspects	Status of development	Images
Point Absorber (continued)		**OPT** has undertaken long-term prototype trials off Hawaii and New Jersey. They are currently in the process of installation of a number of its **PowerBuoy** devices to produce 1.39 MW wave farm in Spain. In 2008, OPT signed a Berth Agreement with EMEC. A full size demonstration array of up to 5MW capacity is planned for installation at Wave Hub in 2011. **Trident Energy** have consent to deploy a demonstration devise called **DECM** 5 miles off East coast of the UK. They aim to deploy a fully functional demonstration WEC in 2010. **SEEWEC** have developed the **FO3 device** the design of which was revised in 2008/2009 further trials are anticipated. **Ocean Navitas** are currently investigating sites around the UK. For deployment of their **Aegir devise.** They Plan to install three small demonstration devices in Taiwan during 2010-11.	 www.oceanpowertechnologies.com  www.tridentenergy.co.uk  www.seewec.org

Technology Type	Physical Aspects	Status of development	Images
Oscillating Wave Surge Converter This device extracts the energy caused by wave surges and the movement of water particles within them. The arm oscillates as a pendulum mounted on a pivoted joint in response to the movement of water in the waves (www.emec.org.uk).	Typically comprises: - A plate anchored to the seabed by its lower part - A hinge allowing the plate to move back and forth. - A piston pump - A closed hydraulic system in combination with a hydraulic motor/generator system	E.g. **Waveroller** marine tests undertaken at EMEC, as well as in Peniche, Portugal. **Aquamarine Power's** 350kW **Oyster** device is currently undertaking full scale testing a EMEC. Also there are plans to build and test Oyster 2 by 2011, with investigations for an array off Orkney. **Neptune Renewable Energy Ltd** have developed the 400kw **Neptune Triton** which is still in the design and testing stage. **Biopower** are developing their Biowave ocean power systems for 250kW, 500kW, 1000kW capacities to match conditions in various location. They are based in Australia but are looking to break into UK markets.	 www.aw-energy.com  www.aquamarinepower.com  www.neptunerenewableenergy.com

Technology Type	Physical Aspects	Status of development	Images
Oscillating Water Column An oscillating water column is a partially submerged, hollow structure. It is open to the sea below the water line, enclosing a column of air on top of a column of water. Waves cause the water column to rise and fall, which in turn compresses and decompresses the air column. This trapped air is allowed to flow to and from the atmosphere via a turbine, which usually has the ability to rotate regardless of the direction of the airflow. The rotation of the turbine is used to generate electricity (www.emec.org.uk). There are many designs for this concept, some are floating, some are incorporated into the shore line and some are integrated into coastal defences.	Typically comprises: - Hollow chamber open at the bottom to the sea - A turbine that can rotate either way -	E.g. **Oceanlinx** have been operating since 2006 producing power to 500 homes in Australia. Oceanlinx are interested in deploying in the UK (Oceanlinx, undated). **Orecon** whose future status of **MRC** device is uncertain. A full scale 1.5MW device was planned to be deployed off the coast of the UK in 2011. **Siadar Wave Energy** have **r**ecently granted consent for a 4MW devise, due to be constructed in 2010-11 off coast of Lewis, Western Isles. Using **WaveGen** technology. **Voith Hydro's WaveGen** 0.5MW device **Limpet 500** which was installed in Scotland in 2000 and produces power for the national grid. Many other devises of this type which are at various stages of development including: **Sperboy;** **OE Buoy** duct devise; **Pico OWC**; and **Mutriko OWC.**	 Illustration: Arthur Mount  www.sperboy.com  www.orecon.com

Technology Type	Physical Aspects	Status of development	Images
Overtopping Device This type of device relies on physical capture of water from waves which is held in a reservoir above sea level, before being returned to the sea through conventional low-head turbines which generates power (www.emec.org.uk).	Typically comprises: -Wall built at level where waves will overtop it. -collectors to concentrate the wave energy (www.emec.org.uk). - They can be floating or fixed. -Turbine	E.g. **Wave Dragon**, a floating devise that has had successful 1:4.5 scale tests. A 7MW device is planned for deployment in Wales. Construction and grid connection should begin during 2011/2012. The financial crisis has meant that Wave Dragon is now seeking venture capital. Fixed devises which include: **SSG** (Sea Wave Slot Cone Generator, integrated into a breakwater) which is at early stages of development and the **Tapchan** devise in Norway which has been operating on a commercial scale for a number of years	 www.wavedragon.net  www.wavessg.com

Technology Type	Physical Aspects	Status of development	Images
Submerged Pressure Differential These devices are typically located nearshore and attached to the seabed. The motion of the waves causes the sea level to rise and fall above the device, inducing a pressure differential in the device. The alternating pressure can then pump fluid through a system to generate electricity (www.emec.org.uk).	Typically comprises: - self-contained float & generating unit -mooring system.	E.g. **AWS** are focused on delivery of the **AWS-III**, a multi-MW, floating system. Evolved from testing of the AWS-I offshore Portugal in 2004 and detailed design of the AWS-II. Prototype to be deployed at EMEC. First mini wave farm of 500kW Archimedes units to be constructed by the third quarter of 2010, increasing to 20 units within 12 months. **CETO** have developed a prototype device which was tested in Australia. Deep water testing of full scale device is planned from 2010 onwards.	 www.awsocean.com 

Technology Type	Physical Aspects	Status of development	Images
Other This covers those devices with a unique and very different design to the more well-established types of technology or if information on the device's characteristics could not be determined. For example the Wave Rotor, is a form of turbine turned directly by the waves. Flexible structures have also been suggested, whereby a structure that changes shape/volume is part of the power take-off system (www.emec.org.uk).	N/A (as the technology types are undefined there are no 'typical' components).	E.g. **Checkmate Seaenergy UK Ltd** are currently at stage two of the testing of their **Anaconda Devise** will use a number of 50m models. They are creating a series of scale prototypes.	 www.soton.ac.uk

2.4 Wave and Tidal Stream Foundation Systems

Further to the categories of devices identified above for wave and tidal stream technologies, there is also a range of methods that are likely to be utilised to secure the energy converters to the seabed. **Sections 2.4.1** to **2.4.5** provide an overview of the typical options under consideration.

2.4.1 Seabed Mounted / Gravity Base

Under this system the energy converter is physically attached to the seabed or is fixed by virtue of its massive weight. In some cases there may be additional fixing to the seabed. Several devices are adapted to this method of attachment, including Hammerfest Strom, OpenHydro and Tidal Energy Ltd devices and Wavegen's LIMPET.

2.4.2 Pile Mounted

This foundation principle is analogous to that used to mount most large wind turbines, whereby the device is attached to a monopile penetrating the ocean floor. Horizontal axis devices will often be able to yaw about this structure. This may also allow the turbine to be raised above the water level for maintenance. This method is currently used on MCT's Seagen device, and Aquamarine's Oyster device.

2.4.3 Floating (with three sub-divisions)

- **Flexible mooring**: The device is tethered via a cable/chain to the seabed, allowing considerable freedom of movement. This allows a device to swing as the tidal current direction changes with the tide, or wave devices to move with the waves. Pelamis Wave Power's Pelamis device and the Archimedes wave swing are designed to work in this method;
- **Rigid mooring**: The device is secured into position using a fixed mooring system, allowing minimal leeway. Ocean Power Technology's PowerBuoy is moored to the seabed using this method; and
- **Floating structure**: This allows several turbines to be mounted to a single platform, which can move in relation to changes in sea level.

2.4.4 Hydrofoil Inducing Downforce

This device uses a number of hydrofoils mounted on a frame to induce a downforce from the tidal current flow. Provided that the ratio of surface areas is such that the downforce generated exceeds the overturning moment, then the device will remain in position. The Energy Business's Stingray was designed using this method of seabed attachment.

2.4.5 Causeway

A causeway can be constructed, and breakwater with several concrete caissons containing wells turbines. This method has the largest footprint on the seabed. The Siadar project in Lewis, Scotland, is based on this method, and is designed to use WaveGen technology, incorporating a breakwater structure with an array of 20 Oscillating Water Column devices installed.

2.5 Wave & Tidal Stream Support Facilities

A number of research and test centres have been established within the UK to help support and promote the development of the wave and tidal stream technology groups and to ensure that the UK remains at the global forefront of marine energy development. The following paragraphs provide an overview of these centres.

2.5.1 The New and Renewable Energy Centre (NaREC)

NaREC, located in Blyth, Northumberland was established in 2002 as an independent Research and Development Centre providing support to the renewable energy industry. The consultants at NaREC provide developers with concept evaluation and technical expertise to support the progression of devices to commercial viability. NaREC has dry dock facilities and a large-scale wave flume and a tidal testing facility to allow small scale models of prototype devices to be tested in a controlled and monitored environment (BWEA, 2009).

2.5.2 The European Marine Energy Centre (EMEC)

EMEC, located in Orkney, was established in 2003 and it offers developers the opportunity to test full-scale grid connected prototype wave and tidal streams devices. The centre operates two sites, providing a wave test facility and a tidal test facility which both have multiple berths, allowing devices to be tested in the open sea. The berths have an existing connection to the onshore electricity network and facilities for technology and environmental monitoring (BWEA, 2009). The centre has been instrumental in supporting the progression of several developments including Open Hydro's Open Centre Turbine, Pelamis Wave Power's Pelamis device and Aquamarine's Oyster.

2.5.3 WaveHub

The South West of England Regional Development Agency (South West RDA) secured planning consent in September 2007 for an offshore substation, export cable and associated land based grid connections to export the generated energy. Construction started in 2009 with a view to completion in 2010. The result will be the UK's first offshore facility for demonstrating the operation of arrays of wave devices. Wave Hub will have four separate berths; each will be capable of exporting 5MW. The system will operate initially at 11kV but can be upgraded to 33kV operation once suitable connectors and other components have been developed by the industry (www.southwestrda.org.uk).

2.5.4 Peninsula Research Institute for Marine Renewable Energy (PRIMaRE)

PRIMaRE is a partnership of the Universities of Exeter and Plymouth, which receives funding from the South West RDA. The partnership forms a team of world-class researchers to provide expertise and research capacity to address the wider considerations of all environmental and ecological aspects of marine renewable energy. PRIMaRE has recently secured funding to develop a unique (in the UK) facility that will allow model testing in both multi-directional waves and variable direction currents, and will also be able to model shallow and deep water conditions. It will enable the testing of scale models of wave and tidal energy devices individually and in arrays (www.primare.org).

2.5.5 QinetiQ

In 2008 QinetiQ incorporated the testing of marine energy devices within its remit and their facility at Gosport, in Hampshire, provides one of the largest testing tanks in UK. The QinetiQ consultants also provide impartial services to marine energy device developers and energy suppliers, for example research, design and hydrodynamics advice and technology readiness assessment, amongst other services (BWEA, 2009).

2.5.6 SuperGen

SuperGen Marine research programme is a consortium of the Universities of Edinburgh, Heriot-Watt, Lancaster, Robert Gordon and Strathclyde, and is funded by the Engineering and Physical Sciences Research Council. Established in 2003, the programme aims to complete generic research on the potential for future exploitation of the marine energy resource. The current phase of the programme aims to increase knowledge and understanding of device-sea interactions of energy converters from model scale in the laboratory to full size in the open sea. The results from the research are disseminated to stakeholders through workshops and publication of papers (BWEA, 2009).

2.6 Additional Development Requirements (Wind, Wave and Tidal Stream)

Whilst it is common place for much of the components to be manufactured overseas, where the market place is most competitive, opportunities do exist within the UK, particularly with regard to the foundation systems for wind, wave and tidal stream devices.

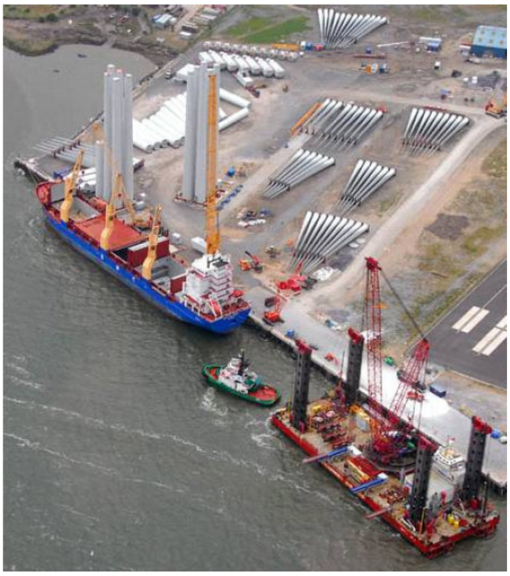
Wind, wave and tidal industries will all share similar service characteristics in terms of the requirements for constructing and operating a project. Developers will require port based facilities close to the deployment site in order to service the construction and operation needs of a project throughout its life span.

For large scale arrays (be it wind, wave or tidal) it is likely that significant storage and assembly facilities will be required for the various components of the devices within close proximity to the deployment site so that they can be efficiently shipped to site ready for deployment.

Taking offshore wind as an example, the requirements for a construction and maintenance port comprise:

- At least 80,000m^2 (8 hectares) suitable for lay down and pre assembly of product (based on 100 turbines per annum);
- 200–300m length of quayside with high load bearing capacity and adjacent access;
- Water access to accommodate vessels up to 140m length, 45m beam and 6m draft (or up to 2.5m for a maintenance port) with no tidal or other access restrictions;
- 24hr access;
- Overhead clearance to sea of 100m minimum (to allow vertical shipment of towers); and
- Sites with greater weather restrictions on construction may require an additional lay-down area, up to 300,000m^2 (30 hectares) to accommodate any back log of WTG units (DECC, 2009).

Figure 2.2 - View of the Port of Mostyn (DECC, 2009)



Portland is one of three named south coast ports (along with Southampton and Newhaven) as having suitable facilities to service construction needs (DECC, 2009).

2.7 Wind, Wave and Tidal Stream: Future Speculation

In October 2008 the UK agreed to a legally binding UK target of 15% of our energy consumption to come from renewable energy by 2020 and in November of the same year, the UK adopted a target for 80% reduction in carbon emissions (from 1990 levels) by 2050 and (DECC, 2009a). These targets provide the incentive for the continued development of the marine renewable energy sector.

2.7.1 Offshore Wind Industry

Much of this planned development from Rounds 2, 2.5 and 3 will be at least under construction if not operation by 2020, and therefore, will contribute to the UK's 2020 renewable energy targets. Given the proven status of the offshore wind industry, the fact that the UK has the best offshore wind resource in Europe and the 2050 targets, it is likely that industry growth will continue beyond 2020 (albeit at a potentially slower rate).

Current (Rounds 1 and 2) offshore wind farm development has been focused on areas of shallower water (typically less than 35m) where the economic conditions (driven by the water depth and proximity to shore) have enabled the relatively rapid development of the industry. As confidence in the industry has grown (in terms of the device components, as well as installation and operation capabilities) focus for future development has begun to switch to deeper waters (Round 3 extends out to 60m water depth) further offshore and larger wind turbine generators (WTGs). .

WTG Evolution
All current operational wind farms, including those under construction utilise between 2 and 3.6MW WTGs. A number of planned Round 2 developments are proposing to use 5MW WTGs, although whether these are available in time remains to be seen. It is likely that many of the Round 3 projects will utilise these larger WTGs, with The Crown Estate's latest predictions being that 5-6MW WTGs are likely to be in the market place

by 2015 (The Crown Estate, 2010). WTG capacity is expected to increase further, with Clipper Windpower Marine Ltd currently designing a 10MW prototype WTG (known as the Britannia Project) through the support of DECC funding. If design and subsequent prototype testing proves successful these larger WTGs may be available for use within some of the Round 3 project timescales. Inherent with the increase in energy generation capacity of these traditional designs, is the increase in the size of the WTG (a typical 3.6MW WTG having a tip height of around 130m and a 10MW potentially closer to 200m in height).

Further to the evolution of the standard 3-blade approach to WTG design, offshore-specific turbines are also being considered, which may see the shift to a novel WTG design (such as two blade or vertical axis) (The Carbon Trust, 2008 and 2010).

Deeper Water Exploration

The offshore wind industry has to date been somewhat restricted in its ability to develop into deeper water by the cost of foundation manufacture. A number of the Round 3 Zones have significant extents that are beyond the depths of traditional monopile foundations and therefore, will require alternative foundation structures to that utilised by the majority of the UK offshore wind farm industry to date. Looking beyond Round 3 it is likely that wind farm exploration will extend out into even deeper waters.

A number of European organisations are already experimenting with floating foundation concepts (such as Hywind in Norway and BlueH in the Mediterranean) that will enable access to deeper water areas without the financial constraints posed by seabed based foundations. Within the UK The Carbon Trust has set up an Offshore Wind Accelerator initiative that will focus on reducing the cost and risk associated with wind farm design, construction and operation, including research on (amongst other aspects) new types of wind turbine foundation with lower capital and installation costs, designed for deployment water depths of 30m to 60m. Towards the end of 2009 seven designs were selected to the next phase of the project which will see large scale demonstration projects from 2010 onwards.

Test centres around the UK for new WTG designs and deep water technologies will be announced in April 2010.

Cabling

Traditionally export cables have been based around the High Voltage Alternating Current (HVAC) design. The advantages of this system for short cable routes is the lower costs associated with the infrastructure required to covert the electricity to a grid compatible format. However, over larger distances (greater than 60km) and with bigger project capacity (i.e. many Round 3 projects) it is considered likely that there will be a switch to the use of a High Voltage Direction Current (HVDC) cable design as result of lower electrical losses and therefore overall preferential economics.

The cabling manufacturing market will need to expand within the UK to meet the demand that the offshore wind farm market will require over the coming decade. It is anticipated that new facilities will be linked to portside facilities and from where existing lay vessels and associated fleet will operate (The Crown Estate, 2010).

ROYAL HASKONING

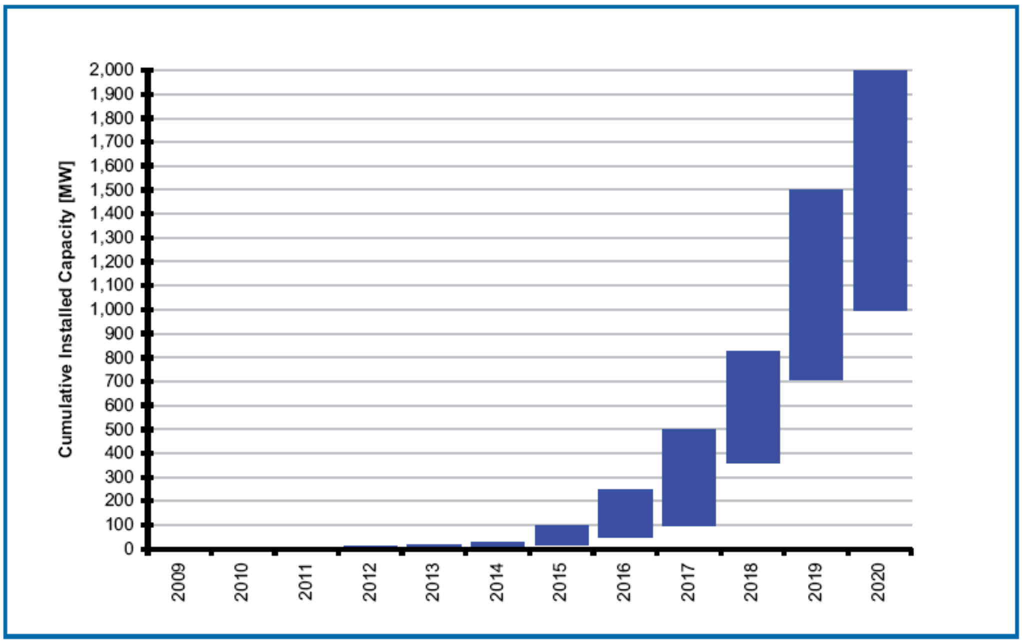
2.7.2 Tidal Stream and Wave Industry

Progression of Wave and Tidal Developments

As has been discussed the development of the wave and tidal energy industries are less advanced than that of the wind industry. A diverse and complex range of technologies are currently being developed. Prototypes are being tested, with many recently installed in waters around the UK, particularly Scotland, and the immediate future shows the major challenges will be proving the technology is effective to secure the further investment of funding and ensure the future development of this growing industry in the UK. Whilst many developers have successfully tank tested scaled model devices and conducted initial prototype device testing during the demonstration phase, the critical next phase is to successfully deploy full scale devices at sea to ensure the technologies are effective at consistently generating the predicted amounts of electricity.

It is believed by the industry that potentially 1 to 2 GW of marine wet renewables (wave and tidal stream) projects could be installed in the UK by 2020 (BWEA 2009, **Figure 2.3**); however this progression is extremely dependant on support of the industry and availability of finance. If the industry proceeds in its current manner it may be difficult to achieve an installed capacity of 1GW.

Figure 2.3 Potential UK Cumulative Installed Capacity of Marine Energy Projects (Wave and Tidal) to 2020 (Source BWEA, 2009)



NB this graph is for illustrative purposes only demonstrating the potential industry growth to reach estimated targets of 1GW 2020 and 2 GW installed capacity by 2020. Actual levels of capacity will be highly dependant on actions and policies to support the industry.

Marine renewable energy (wave and tidal stream energy generation) has the potential to become competitive with other generation forms in future, providing between 15 and 20% of the current UK electricity demands (The Carbon Trust, 2006). However, in present market conditions, it is likely to be more expensive than other renewables and conventional generation until at least hundreds of megawatts capacity are installed, lowering the cost curves (The Carbon Trust, 2006). With a large number of devices competing for limited funding resources to further develop and prove their technology, the industry believes there is a funding gap between the capital grants available for small scale prototype development and the revenue support for long term operation (BWEA 2009). Whilst this funding gap exists development is likely to continue at its current state.

There are a number of factors that are likely to play a critical role in determining whether the UK is able to maximise the potential from wave and tidal stream energy generation potential, including:

- Finance and funding;
- Technology;
- Test sites and development facilities;
- Government support;
- Legislation;
- Renewable Obligation Certificate banding; and
- Grid Access and electricity networks.

Finance and Funding

Many of the marine energy device developers are small to medium sized companies formed to solely develop a specific device. Developers must therefore secure their own funding to support the day to day operation of the company, development of the device and design engineering, public relations, prototype testing and deployment projects. Potential funding sources include Government grants, private investors or the sale of shares. However, with a large number of developers in competition for funding, some devices may struggle to receive financial support to progress into the future commercial arena. Devices which prove themselves early on in a competitive market will potentially encourage investment and will therefore grow at the fastest rate.

Technology

A high percentage of demonstration devices tested in the marine environment to date have experienced technical challenges (especially within the wave industry). Ability for a device developer to prove the survivability, whilst maintaining cost effectiveness and energy generation efficiency of the technology is a major challenge. Judging by the experiences of other technologies, fast continuous development is likely to be necessary to maximise learning and bring about cost reductions in the shortest possible time (Carbon Trust, 2006). It is likely therefore, that a number of devices currently in the market place will drop out as others that prove more efficient and cost effective get taken forward to commercial scale development.

Test Sites and Development Facilities

The UK's test centres, such as the EMEC and Wave Hub are providing critical infrastructure and assistance for monitoring the operation of the devices in the marine environment to aid future development. These sites help the device developer keep the cost of installation and grid connection down during the early testing stages of development. Other centres of excellence such as NaREC, PRIMaRE, and SuperGen Marine Research programme and QuintiQ, are essential to ensure device developers are able to take their prototype designs through the testing stages and help to secure funding for further scaled development.

It should be noted that deployment of prototype devices can also be successfully established outwith the test sites and development facilities. MCT, one of the first developers to progress their technology to getting a device in the water, conducted their own research and development, with Governmental support, to install SeaGen in the tidal narrows of Strangford Lough in Northern Ireland. MCT's independence from UK test centres was largely driven by the lack of facilities at the time when MCT were looking at potential sites of deployment. In addition, Wavegen's Limpet was successfully deployed on Islay in 2000.

Despite these occasional independent success stories, it is likely that on the whole the progression of the industry will remain heavily reliant on the continued support provided by such facilities.

Government Support

Strong Government support is necessary to show confidence in the future growth of the market and encourage private investment.

The Crown Estate owns the UK seabed out to the 12 nautical miles territorial sea limit and has rights under the Energy Act 2008 to licence the generation of renewable energy in the Renewable Energy Zone (REZ) on the UK's continental shelf to 200 nautical miles. In September 2008, the Crown Estate announced an application process for commercial sea bed lease options in the Pentland Firth strategic area (north Scotland) for marine energy devices (www.thecrownestate.co.uk). It is the first marine power 'licensing and geographic area' location to be made available for commercial development in the UK. The Crown Estate target for the Pentland Firth strategic area is 700MW of offshore wave and tidal stream generation by 2020, so a significant proportion of the capacity may be installed in this area, supporting UK and devolved Governments goals to develop a low-carbon economy.

The announcement by the Crown Estate followed completion of a Strategic Environmental Assessment (SEA) assessing the potential for wave and tidal energy in Scotland by the Scottish Government in 2007, which concluded a generating capacity of between 1 GW and 2.6 GW could be developed in Scotland with generally minor effects on the environment (Scottish Executive, 2007), with potential to bring significant economic benefits to Scotland (BWEA, 2009). SEAs are required under the European Union SEA Directive to incorporate environmental considerations into policies, plans and programmes, and are necessary to be completed prior to the strategic development of marine energy. SEAs are completed for UK waters for oil and gas and for offshore wind energy. An SEA is also underway for offshore wind and marine energy in Northern Ireland waters. Within England and Wales a screening study was announced at the BWEA Wave and Tidal Conference in April 2009 (BWEA, 2009) to identify the potential for commercial scale wave and tidal farms, to establish realistic timescales for installation and commission and to ascertain whether a full SEA is required for England and Wales. Should it be deemed required for a full SEA to be conducted, this will need to be completed (and if so is estimated for publication late 2011, BWEA, 2009) before The Crown Estate can announce leasing application processes for English and Welsh strategic areas for future marine renewable developments. Should an SEA be taken forward for England and Wales it is likely to substantially increase the future development of these technology groups within the UK.

The drivers behind future Governmental support will be the continued commitment to the UK's 2050 carbon reduction targets and the likely sustained high fossil fuel prices leading to a high base cost of electricity (which will help the ability of wave and tidal stream energy development to become cost-competitive) (Carbon Trust, 2006).

Legislation
Legislation will play a significant role in influencing the progression of the wave and tidal stream industries.

The Planning Act received Royal Assent in November 2008 and mainly applies to England and has some implications for Wales. The Act allows a streamlining of consenting process for nationally significant infrastructure projects, which includes marine energy projects greater than 100MW installed in the territorial seas in England and Wales or in a Renewable Zone (not Scotland). Under this Act, the need and context for specific energy development is set out in National Policy Statements (NPS) for the various energy sectors. Whilst briefly discussed in the overarching Energy NPS, there is currently no dedicated NPS for wave and tidal energy sector and there is unlikely to be one until the completion of any SEA. The provision of such a dedicated NPS would further solidify in legislation the Governments commitment to these industries.

The Department of Energy and Climate Change (DECC) and the Office of Gas and Electricity Markets (Ofgem) have recently developed a new regulatory regime for offshore electricity transmission (operating at 132kV or above). The requirement for the regime is largely driven by the development of offshore wind energy, but it will benefit wave and tidal stream development in the future, by providing the connection of offshore renewable energy generation to the onshore grid. Prototype wave and tidal developments and small arrays are likely to connect to the onshore network at 33kV in the near future, however the regime is likely to be first applicable to the Pentland Firth if a strategic approach is adopted between developers (BWEA 2009).

Renewable Obligation Certificate (ROC) banding
The Renewables Obligation Order came into effect in April 2002. The RO is the main support scheme for renewable electricity projects in the UK. It places an obligation on UK suppliers of electricity to source an increasing proportion of their electricity from renewable sources (www.ofgem.gov.uk).

In April 2009, the UK Governments introduced additional revenue support for marine energy devices through the Renewables Obligation (RO), Renewables Obligation (Scotland) (ROS) and Renewables Obligation (Northern Ireland) (NIRO). The introduction of banding to these obligations allocates two Renewable Obligation Certificates (ROCs) to every megawatt hour (MWh) of electricity generated from a marine energy device (BWEA 2009) with Government subsidies paid to energy companies for every unit of renewable energy produced.

Following approval from the European Commission, the Scottish Government plans to increase the support available to be three ROCs per MWh of tidal stream device generated electricity, and five ROCs for wave device generated energy. The industry believes this will encourage development in Scotland at the expense of others areas of the UK as two ROCs is considered to provide insufficient support to developing projects (BWEA, 2009). A less competitive ROC banding in England and Wales (as currently stands) is likely to inhibit the level of development within these waters compared to Scotland.

Grid Access and Electricity Networks
Proximity to grid connections and available grid capacity will heavily influence the ability of wave and tidal stream industries to maximise their potential.

The UK has varying levels of available grid capacity. In some areas future development is grid constrained and therefore, the National Grid will need to upgrade the current infrastructure to accommodate new energy generation. Within the UK the locations that are most attractive to wave and tidal stream development include northern and western Scotland, west Wales and south west and southern England (grid specific aspects relating to the Dorset region are discussed in **Section 3**).

Summary

The future of wave and tidal stream devices is likely to become streamlined in the coming years, with the focus on technologies that:

- Prove to be able to withstand the harsh conditions within which they are deployed;
- Can successfully generate the predicted levels of electricity (including without changing the natural energy reserve to the detriment of the device, and allowing for cost effective operation and maintenance to enable competitiveness in the market);
- Comply with the legislation and planning processes required to show they do not significantly adversely impact the environment; and
- Can secure and maintain the necessary financial support for development.

These devices would have the highest chance for receiving further funding and therefore with financial support would progress the soonest to become commercially viable arrays.

The challenge for offshore wave device developers remains gaining sufficient funding to enable the testing and development of devices to a sufficient level so that modifications (that are required) can be made to ensure the devices are able to overcome the operational challenges experienced within the harsh environments that they are deployed. Only once this rigorous level of testing has been undertaken is it likely that there will be significant advancement in the scale of wave device deployment. Until that juncture it is likely that test facilities and prototype deployment sites will play a critical role in maintaining the future of the industry. Whether the industry is able to maximise this resource potential will depend on its ability to overcome the technological and financial challenges posed by operating in these environments.

3 LAND-BASED INFRASTRUCTURE REQUIREMENTS

3.1 Grid Overview

National Grid Transco (NGT) owns and operates the high voltage transmission system in England and Wales, transferring electricity generated at power stations in 'bulk' to substations where it is reduced in voltage for local distribution by regional electricity distributors. NGT predominantly operates at 400kV with some 275kV circuits. Regional distributors (or distribution network operators, DNOs) operate at 132kV and 66kV for distribution within their regions of operation and at 33kV, 11kV and lower voltages for local distribution, (South West RDA, 2004).

Within the south and south west there is currently grid capacity for major projects although the majority of this is likely to be taken up by the Round 3 offshore wind farm projects and nuclear development. However, it has been identified that small marine energy schemes in the south west of the UK could connect into the local distribution system, with capacity for up to 100MW without significant reinforcements required in the network (SDC, 2007). Sufficient capacity within the local 33kV network around Portland has been identified to take up to a 16MW development without requiring any grid reinforcements (SDC, 2007). Connections larger than 16MW however, are likely to require reinforcements back to Chickerell (near Weymouth), where a 400kV transmission network is present (see **Figure 3.2**).

The broad location at which an offshore renewable energy project connects its offshore cabling infrastructure to that onshore will largely depend upon the capacity (MW) of the project and the locality of the most suitable grid connection point.

Several factors require consideration for the specific location of landfall sites to minimise adverse interaction with the built and natural environment. These include the ease of access for construction, operation and maintenance, along with hard constraints including subsea obstacles such as existing oil or gas pipelines, excessive depth change or mineral extraction areas and other existing developments. Developments will require approval from planning authorities and statutory agencies to assess the extent to which adverse effects to the natural or built environment may arise. Therefore, further considerations for the site of landfall and onshore cable routing will be required and include, but are not limited to, nature conservation interests, cultural heritage, hydrology, landscape and visual assessment, commercial fisheries, Ministry of Defence (MoD) activities and local communities including the impacts on noise, air quality, recreation, port, harbour, traffic and access receptors.

3.2 Infrastructure Requirements

The following text describes the key components are required for connection to the grid and are shown schematically in **Figure 3.2**. The grid connection requirements will vary greatly depending upon the scale of development, and where this is likely effort has been made to distinguish between the differing requirements.

Offshore aspects

Subsea cables are used to connect the device to shore with these commonly being buried between 1 and 2 metres into the seabed to prevent damage from fishing or shipping activities. To date that industry has used High Voltage Alternating Current (HVAC) cables to transmit the power to shore, and for nearshore projects (within 60km from landfall) that is likely to remain the case. These cables can be laid by a vessel, directionally drilled or pulled from a site onshore. Where significant multiple device developments are present **inter-array cabling** is commonly used to connect to an **offshore substation or transformer platform** (multiple substations are common place for large offshore wind farms), where the voltage is stepped up and the multiple inter-array cables marshalled to a single or reduced numbers of cables to shore (South West RDA, 2004). Commonly, cables between wind turbines in large offshore arrays are 33kV, and are stepped up to 132kV for transmission to shore.

The size and detail of offshore substation platforms will vary depending on specific project requirements. The Round 1 Sheringham Shoal Offshore Wind Farm project's offshore substations will be 30.5m in length, 17.7m in width and 16m in height (www.scira.co.uk). **Figure 3.1** below shows the offshore substation at the Barrow Offshore Wind Farm.

Figure 3.1: Typical offshore substation platform

Source: www.bowind.co.uk

Onshore aspects

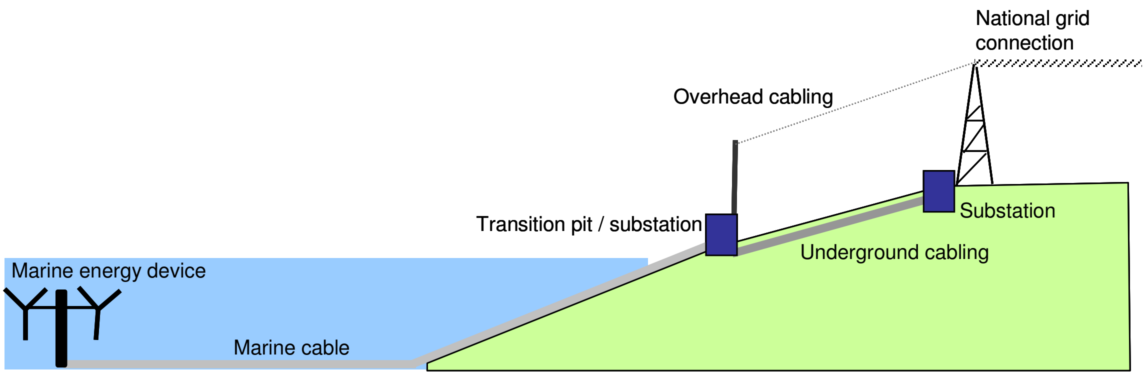
Once ashore the infrastructure required is dependent upon the capacity of the device / array.

For a single device, where no offshore substation is necessary, an **onshore substation** (comprising at a minimum voltage switches, transformers and associated cabling and wiring) will be required to convert the current generated from marine to a grid compatible form. The only other infrastructure likely to be required will be either **buried** or **overhead cabling** to connect the power to the nearest suitable local network connection. The type of supporting structure for overhead cabling may be location specific, but generally 11kV and 33kV lines are supported on wooden poles (usually

Trident of Portal design), 132kV lines may be supported on wooden poles or metal towers, and 275 and 400kV lines are supported by metal (usually steel) towers.

For larger array projects, where offshore substations are deployed, the cabling will typically be brought ashore and tied into a buried **transition pit**, located close to shore. A transition pit serves to land cables on shore and transfer the electricity to terrestrial cables. From here either **buried** or **overhead cabling** will be required to take the power to a **substation** from where the electricity will be fed into the main National Grid network. Where no suitable existing substation is present within close proximity to the site, it is likely that the developer will need to provide for one. The substation(s) would require access tracks or roads to enable construction and maintenance.

Figure 3.2: Schematic of grid connection requirement options



3.3 Technologies

The following study investigates the potential for offshore wind, wave and tidal stream energy generation in waters off the Dorset coast. The study will focus on potential for commercial scale development of these technologies. It is anticipated that given the relatively wave sheltered nature of the study area, there may be limited potential for commercial scale wave deployment, and therefore, this study will also consider the potential for ¼ scale demonstration wave devices.

3.4 Minimum Feasible Operating Conditions

3.4.1 Background

Dorset Coast Forum have requested that 'Minimum Feasible Operating Conditions (MFOC)' be established for each technology group (wind, wave and tide) to serve as the basis of the capacity study.

Marine energy devices will have a range of resource operating capacity, and at a certain point when the resource (be it wind, wave or tidal) conditions are strong enough the device will produce sufficient energy output to be considered commercially viable.

A number of studies have been undertaken (especially for tidal and also wave technologies) that have considered this MFOC at specific device and or technology group level (such as ABPMer 2007 and ABPMer 2008). Royal Haskoning have supplemented this existing data with consultation with three of the UK's leading wind, wave and tidal developers to establish what they consider what the MFOC would be for them to consider an area of potential commercial interest.

It is recognised that there may be a small number of devices that are capable of operating at lower MFOC than specified in this report, given the range of devices in the market place and different strategies taken by developers. However, given that this study forms a high-level overview of the three technology groups the most appropriate approach is deemed to be the application of a standard MFOC for each group to reflect what may be considered indicative conditions at which marine renewable energy development may be considered viable.

Furthermore, it is recognised that the point at which a specific device passes this threshold will be further influenced (beyond device design) by a number of factors, which may include (but not be limited to):

- Cost of onshore grid connection;
- Distance (and therefore, cost) of bringing the power to shore;
- Physical constraints requiring engineering mitigation to enable deployment / operation; and
- Operational and maintenance costs; and
- ROC Banding.

However, for the purposes of this high-level study these have not been taken into account.

3.4.2 MFOC

Offshore wind

With the increase in turbine capacity, offshore wind farm developers are confident of being able to exploit lower resource areas than when the UK industry was in its infancy (i.e. Round 1 of The Crown Estate's seabed leasing programme). Scottish & Southern Energy Renewables (who are currently installing the 500MW Greater Gabbard Offshore Wind Farm in the Outer Thames Estuary), consider anything above 7m/s to represent a commercially viable wind speed. It is therefore, proposed that this figure is taken forward for this project.

Tidal stream

Recent studies (ABPMer, 2007) have suggested that tidal current flows around 1.5m/s represent the cut in threshold at which devices will start to produce commercially viable electricity. This is supported by discussions undertaken for this study with the leading tidal stream developer Marine Current Turbines (MCT). Consideration needs to be given to the fact that Mean Spring Peak Currents (MSPC) approach twice that of Mean Neap Peak Currents (MNPC) and therefore, for a device to be commercially viable throughout a Spring – Neap tidal cycle the resource will need to be above 1.5m/s for a substantial proportion of the time. A recent UK wide resource study (ABPMer, 2009) mapped areas above 2m/s MSPC as representing suitable resource for commercial development and for the purposes of consistency and continuity between the studies the same approach is adopted here.

Wave

Discussions (in 2009) with a leading UK wave energy developer (Orecon), who are currently in talks with the South West of England Regional Development Agency (South West RDA) over potential deployment at Wave Hub, consider any resource over 20kW/m could be of interest to offshore wave industry. The technical feasibility study for Wave Hub (Halcrow, 2005) similarly determined from 13 wave energy converter device developers that 20kW/m represented the minimum operating criteria. A recent study (ABPMer, 2009) also took on board developer views and considered that anything above 2m annual average significant wave height (which roughly equates to 20kW/m) was considered commercially viable. Given these previous findings it is considered reasonable to assume that an MFOC of an annual average of 20kW/m or over is applied to the wave resource mapping.

Discussions with Orecon (2009) regarding suitable wave resource for a ¼ scale demonstration device indicate that when scaling down a device the same approach is taken to wave resource (along the lines of the Froude scale) and therefore the MFOC would be ¼ of full scale device requirements (i.e. 5kW/m).

Table 4.1 summarises the MFOC that has been adopted for the purposes of the Dorset offshore renewables resource capacity mapping.

Table 4.1 MFOC for wind, wave & tidal stream technology groups

Technology Group	MFOC
Offshore wind	≥7m/s Average annual wind speed
Tidal Stream	≥2m/s Mean spring peak current
Wave	≥20kW/m Average annual wave height
¼ Scale wave	≥5kW/m Average annual wave height

3.5 Methodology

3.5.1 Background

This part of the Dorset Offshore Renewable Energy Capacity Study comprised the mapping in GIS of MFOC data (see **Section 4.3.2**) and overlaying this with 'hard' constraint information (see **Section 4.3.3**). From this areas where suitable resource coincided with no 'hard' constraints Potential Development Areas were identified. These Potential Development Areas have then been discussed in terms of the development considerations (i.e. parameters that may influence the complexity of development these areas but do not restrict it out right). This aspect is further discussed in **Section 4.3.4**.

3.5.2 Resource Data

Royal Haskoning have identified the Department of Business Enterprise and Regulatory Reform (BERR) renewable resource atlas dataset (BERR, 2008) to be most suitable of data for the purposes of this study. This atlas represents the most detailed broad-scale description of potential marine energy resources in UK waters and was developed (by ABPmer, the Met Office and the Proudman Oceanographic Laboratory) to help guide policy and planning decisions of future site licensing rounds. The data provides detailed annual, seasonal and monthly mean data for data cells ranging from 1.8*1.8km for tidal information to 12*12km for wave and wind resource information.

These resource datasets were downloaded from the BERR website (www.renewables-atlas.info) and incorporated into Royal Haskoning's GIS system.

3.5.3 'Hard' Constraint Consideration

The term 'hard constraint' has been used in this study to define those environmental parameters that will preclude development within their footprint. For some hard constraints, development will need to avoid them by a certain distance (or 'buffer'). Hard constraints may vary between technology groups, and therefore, what may be considered a hard constraint for offshore wind energy development, may not have the same influence for a tidal stream device.

The hard constraints that have influenced this study are detailed in **Tables 4.2** to **4.6**.

Table 4.2: Generic hard constraints – all industries

Hard Constraint	Detail	Justification
Live cables	500m buffer. South of study area	As specified in cable licence
Proposed pipeline (Portland)	Avoid	As specified in pipeline licence
Out of service/decommissioned cables	100m buffer	Outlined in DECC Strategic Environmental Assessment
Oil/Gas subsurface wells (disused)	100m buffer	Outlined in DECC Strategic Environmental Assessment
Aggregate extraction areas	Avoid	As specified in aggregate licence
Aggregate application areas	Avoid	As specified in aggregate

Hard Constraint	Detail	Justification
		application
Aggregate option areas	Avoid	As specified in aggregate option agreement
International Maritime Organisation (IMO) designated shipping lane	Avoid with 2nm buffer	As specified by MCA
Charted wrecks	100m buffer	Outlined in DECC Strategic Environmental Assessment
Historic protected wrecks	Buffer defined by statutory instrument	As determined by Statutory Instrument
Hydrocarbon fields	Avoid	As used in Offshore Wind Farm planning
Offshore installations	Outfalls and marine farms	As used in Offshore Wind Farm planning
Obstructions (inc. foul grounds)	100m buffer	As used in Offshore Wind Farm planning
Anchorage areas	Avoid	As specified by MCA
Navigation aids – Lighthouses	500m buffer	Outlined in DECC Strategic Environmental Assessment
Navigation aids – Cardinal Buoys	100m buffer	Outlined in DECC Strategic Environmental Assessment
Active disposal sites	Avoid	As specified by MCA

Table 4.3: Additional hard constraints – wind energy

Hard Constraint	Detail	Justification
Round 3 wind farm zone	5km buffer	As currently proposed by The Crown Estate
Bathymetry ≥60m	Avoid	As currently proposed by The Crown Estate
Sandbanks	Avoid	Industry standard
Bedrock	Avoid	Industry standard

Table 4.4: Additional hard constraints – tidal energy

Hard Constraint	Detail	Justification
Round 3 wind farm zone	Avoid	No buffer requirement specified
Bathymetry ≤4m	Avoid	As utilised in tidal resource studies, such as ABPmer (2007)

Table 4.5: Additional hard constraints – wave energy

Hard Constraint	Detail	Justification
Round 3 wind farm zone	Avoid	No buffer requirement specified
Bathymetry ≥50m	Avoid	As advised by Orecon Ltd and utilised in previous wave resource studies such as Garrad Hassan (2008)

Table 4.6: Additional hard constraints – ¼ scale demonstration device wave energy

Hard Constraint	Detail	Justification
Round 3 wind farm zone	Avoid	No buffer requirement specified
Bathymetry ≥25m	Avoid	As advised by Orecon Ltd

The resource mapping work has been undertaken with these hard constraints applied (see **Figures 4.5** to **4.8**). The symbology for all of the hard constraints has been unified to enable easy interpretation of areas unsuitable for development.

3.5.4 Development Considerations

There a numerous additional environmental parameters that will have to be taken into consideration during the planning stages of renewable energy deployment. These parameters have the potential to influence the project where they overlap but are unlikely to prevent deployment (as per hard constraints). For such parameters, or 'development considerations' as they have been termed in this study, mitigation is likely to be required to reduce the level of impact on the parameter. This may be in the form of site layout and device locations, cable routing, seasonal installation, navigational aids, device design (such as choice of foundation or mooring system) and installation techniques etc.

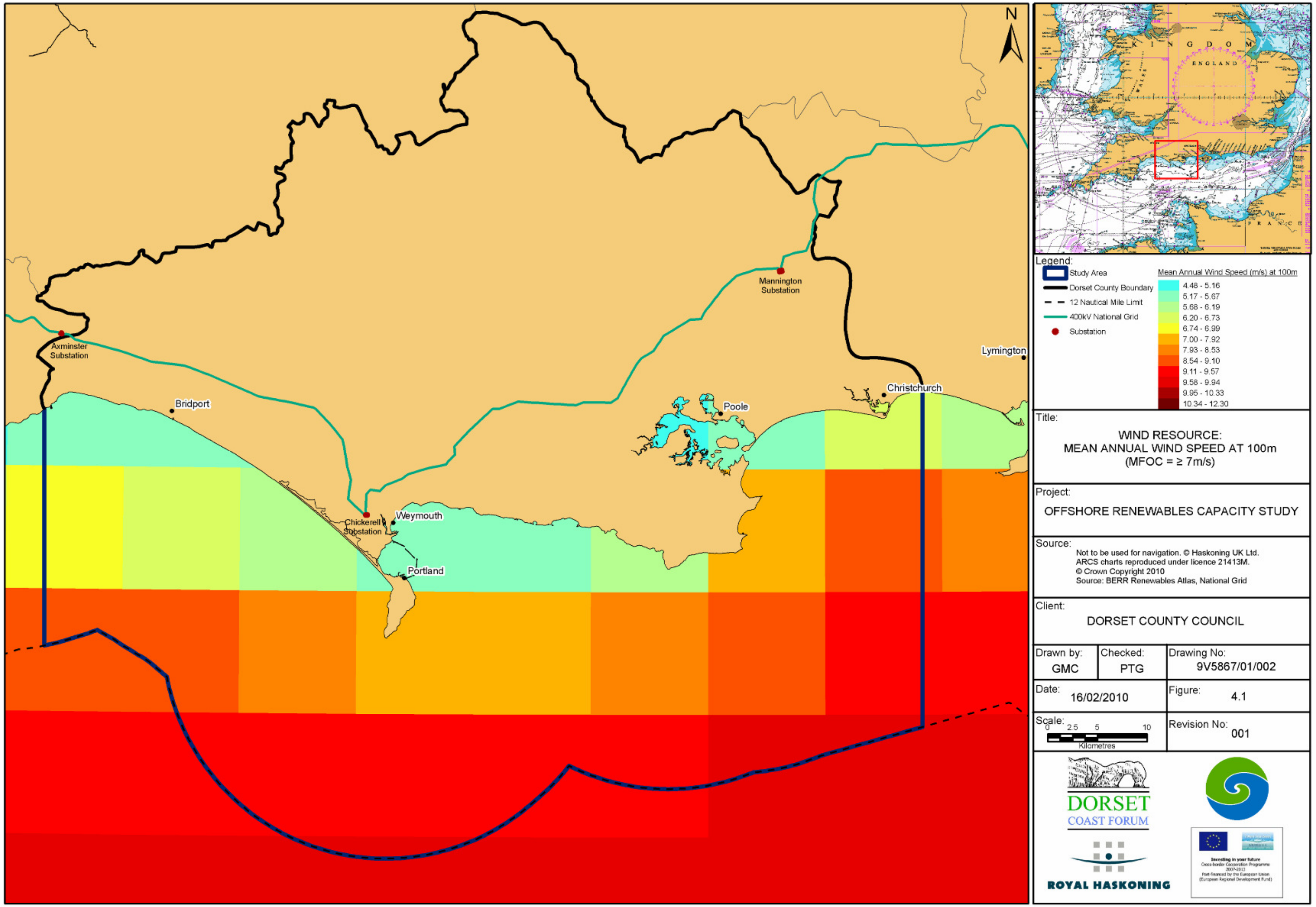
Development considerations are typically considered to comprise the following:

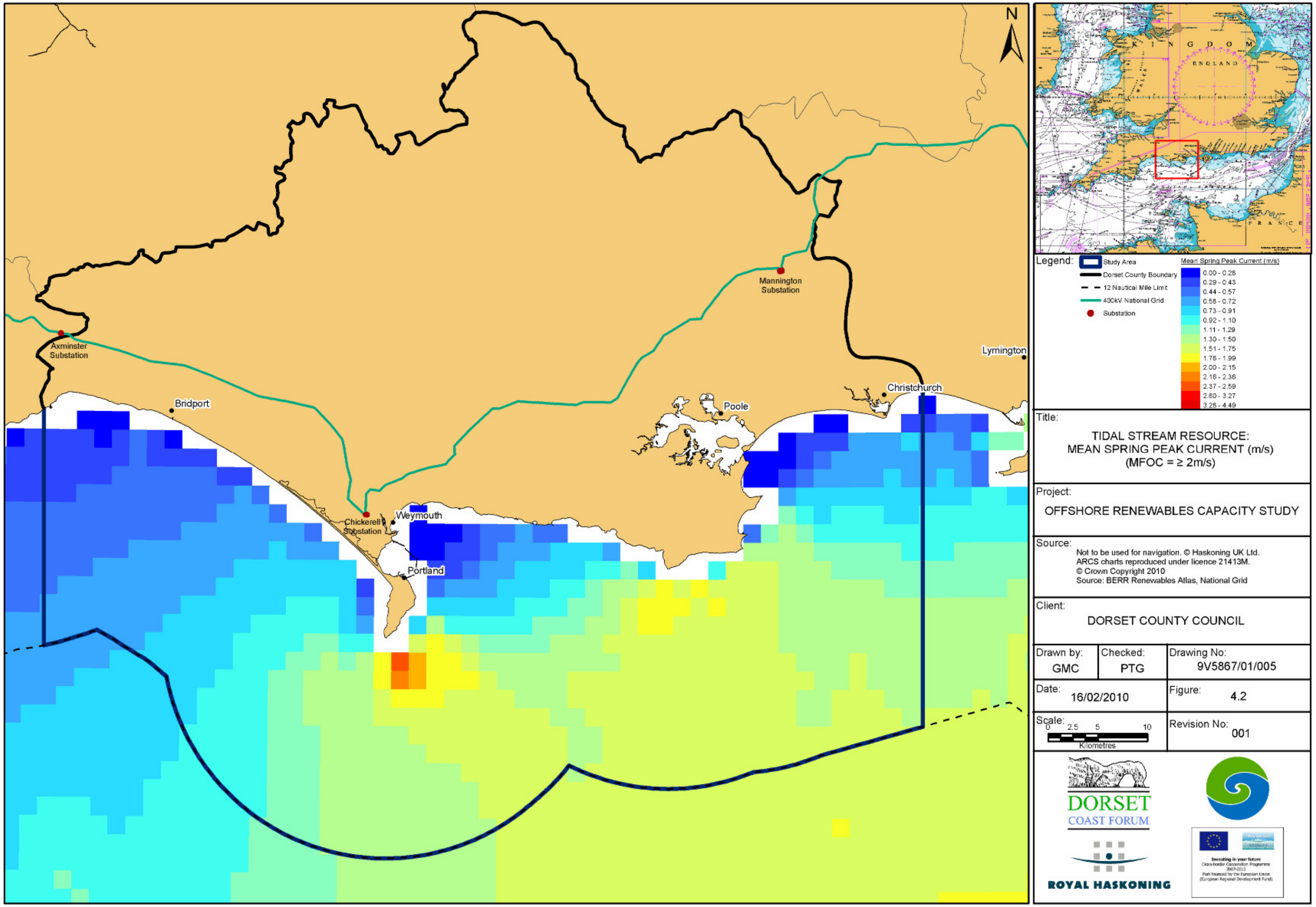
- Bathymetry (potential hard constraint too);
- BGS seabed sediments (potential hard constraint too);
- Nature designations - existing and planned;
- Sensitive benthic communities & habitats;
- Fish spawning grounds;
- Shellfish areas;
- Important bird areas;
- Sensitive terrestrial ecological features;
- Important archaeology / heritage features;
- High usage shipping areas;
- Landscape designations;
- High use recreation areas;
- Historic marine activity areas;
- Key fishing areas;
- MoD usage areas;
- Aviation / radar coverage; and
- National Grid network.

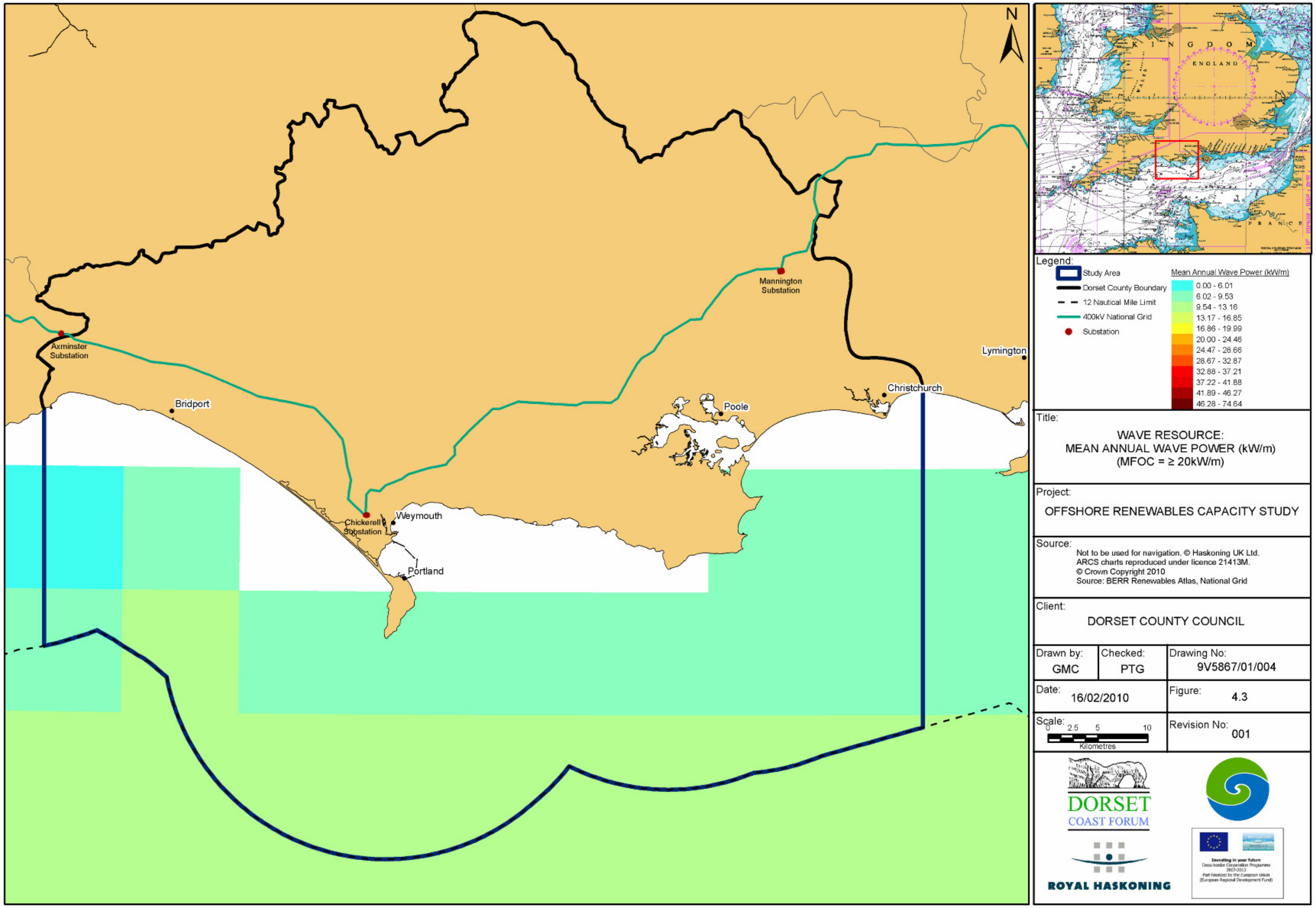
Development considerations have been identified (although not shown in the main figures) and considered for each of the potential development areas and are discussed in **Section 5**.

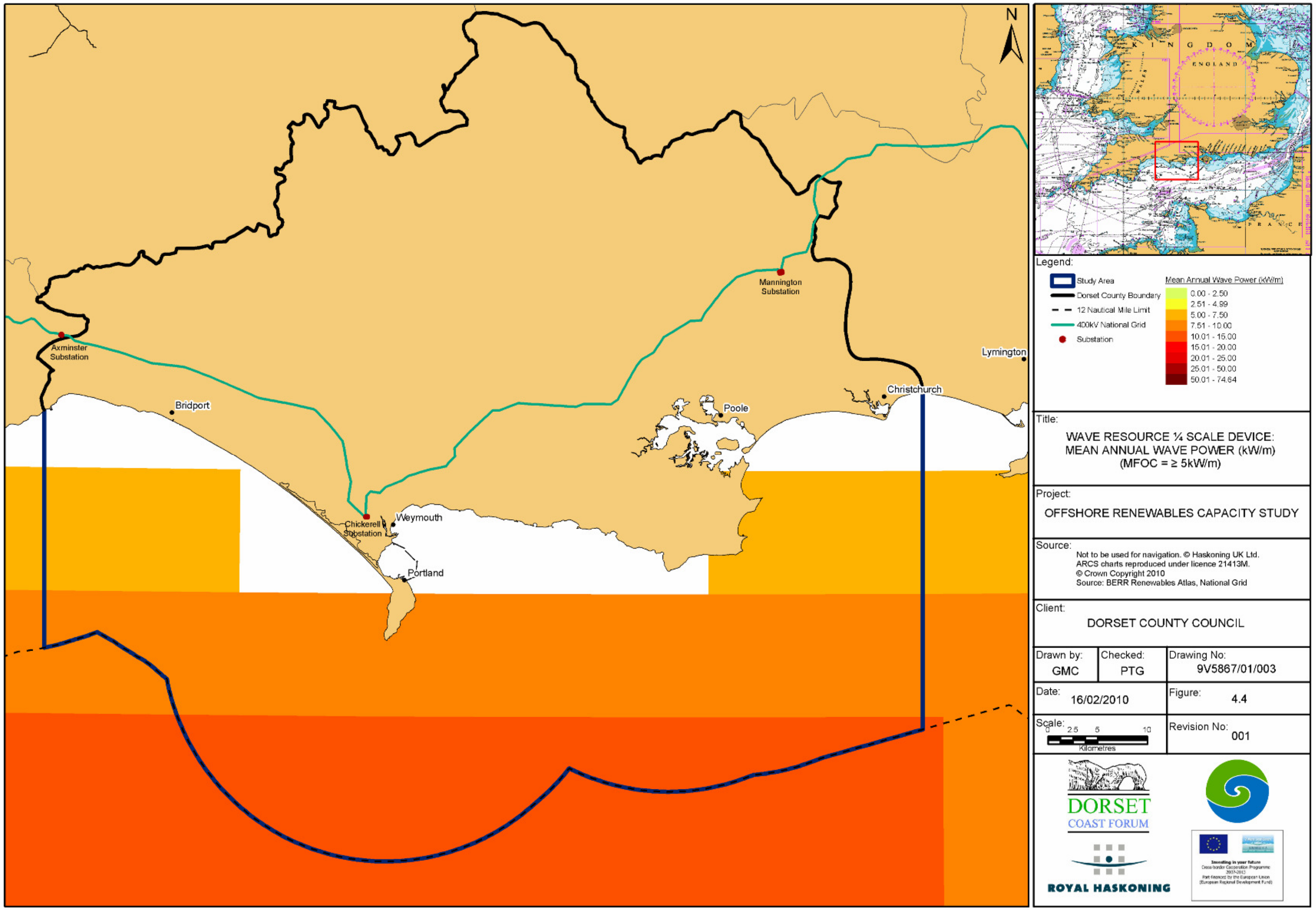
3.6 Resource Mapping

The following figures (**Figures 4.2 to 4.4**) show the offshore wind, tidal stream and wave resource for the waters off Dorset.


N
Axminster Substation
Bridport
Chickerell Substation
Weymouth
Portland
Mannington Substation
Poole
Christchurch
Lymington
Legend:
Study Area
Dorset County Boundary
12 Nautical Mile Limit
400kV National Grid
Substation
Mean Annual Wind Speed (m/s) at 100m
4.48 - 5.16
5.17 - 5.67
5.68 - 6.19
6.20 - 6.73
6.74 - 6.99
7.00 - 7.92
7.93 - 8.53
8.54 - 9.10
9.11 - 9.57
9.58 - 9.94
9.95 - 10.33
10.34 - 12.30
Title:
WIND RESOURCE:
MEAN ANNUAL WIND SPEED AT 100m
(MFOC = ≥ 7m/s)
Project:
OFFSHORE RENEWABLES CAPACITY STUDY
Source:
Not to be used for navigation. © Haskoning UK Ltd.
ARCS charts reproduced under licence 21413M.
© Crown Copyright 2010
Source: BERR Renewables Atlas, National Grid
Client:
DORSET COUNTY COUNCIL
Drawn by: GMC
Checked: PTG
Drawing No: 9V5867/01/002
Date: 16/02/2010
Figure: 4.1
Scale: 0 2.5 5 10 Kilometres
Revision No: 001
DORSET COAST FORUM
ROYAL HASKONING

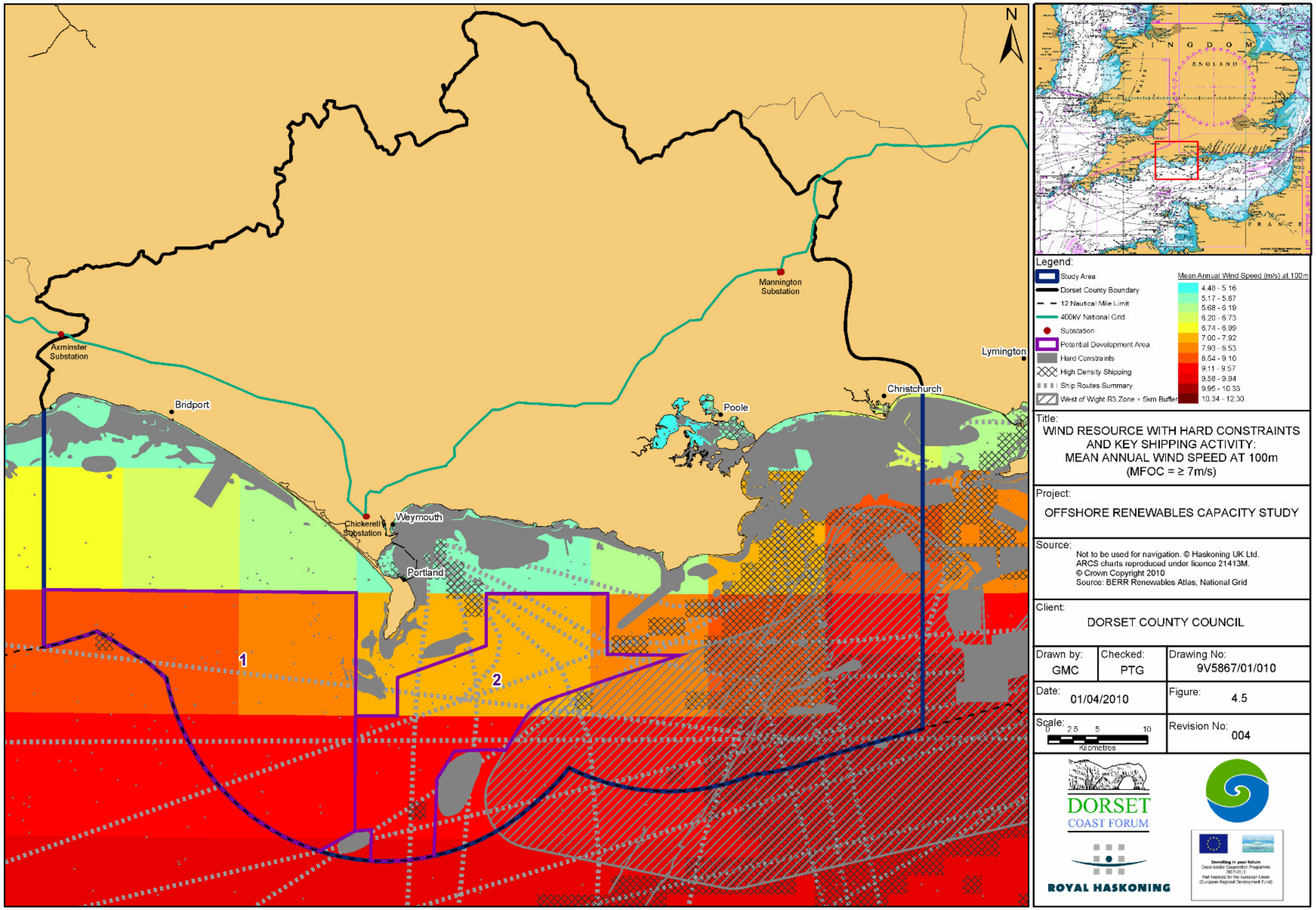

N
Axminster Substation
Bridport
Chickerell Substation
Weymouth
Portland
Mannington Substation
Poole
Christchurch
Lymington
K I N G D O M
E N G L A N D
F R A N C E
Legend:
Study Area
Dorset County Boundary
12 Nautical Mile Limit
400kV National Grid
Substation
Mean Spring Peak Current (m/s)
0.00 - 0.28
0.29 - 0.43
0.44 - 0.57
0.58 - 0.72
0.73 - 0.91
0.92 - 1.10
1.11 - 1.29
1.30 - 1.50
1.51 - 1.75
1.76 - 1.99
2.00 - 2.15
2.16 - 2.36
2.37 - 2.59
2.60 - 3.27
3.28 - 4.49
Title:
TIDAL STREAM RESOURCE:
MEAN SPRING PEAK CURRENT (m/s)
(MFOC = ≥ 2m/s)
Project:
OFFSHORE RENEWABLES CAPACITY STUDY
Source:
Not to be used for navigation. © Haskoning UK Ltd.
ARCS charts reproduced under licence 21413M.
© Crown Copyright 2010
Source: BERR Renewables Atlas, National Grid
Client:
DORSET COUNTY COUNCIL
Drawn by: GMC
Checked: PTG
Drawing No: 9V5867/01/005
Date: 16/02/2010
Figure: 4.2
Scale: 0 2.5 5 10 Kilometres
Revision No: 001
DORSET
COAST FORUM
ROYAL HASKONING

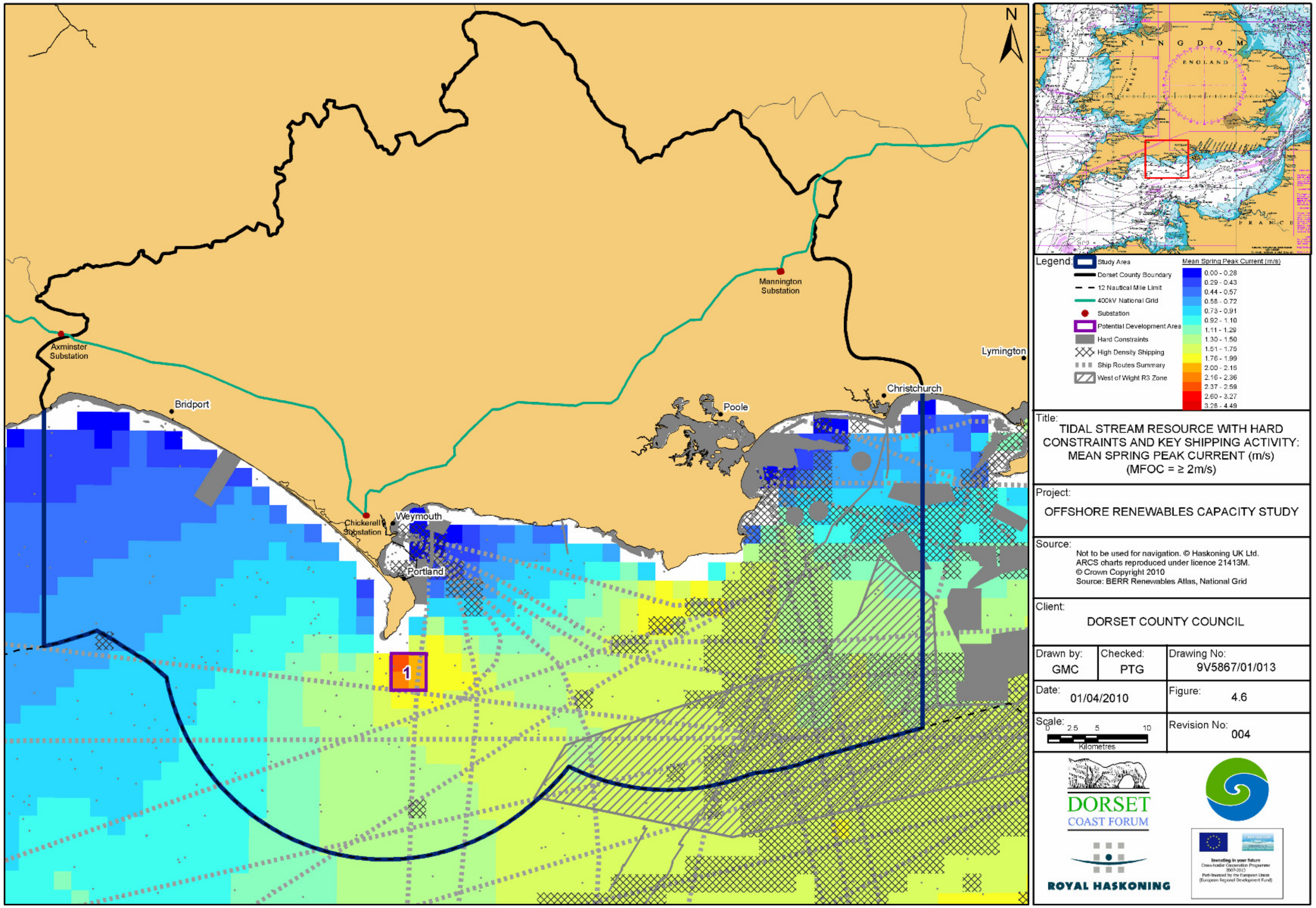

N
Axminster Substation
Bridport
Chickerell Substation
Weymouth
Portland
Mannington Substation
Poole
Christchurch
Lymington
Legend:
Study Area
Dorset County Boundary
12 Nautical Mile Limit
400kV National Grid
Substation
Mean Annual Wave Power (kW/m)
0.00 - 6.01
6.02 - 9.53
9.54 - 13.16
13.17 - 16.85
16.86 - 19.99
20.00 - 24.46
24.47 - 28.66
28.67 - 32.87
32.88 - 37.21
37.22 - 41.88
41.89 - 46.27
46.28 - 74.64
Title:
WAVE RESOURCE:
MEAN ANNUAL WAVE POWER (kW/m)
(MFOC = ≥ 20kW/m)
Project:
OFFSHORE RENEWABLES CAPACITY STUDY
Source:
Not to be used for navigation. © Haskoning UK Ltd.
ARCS charts reproduced under licence 21413M.
© Crown Copyright 2010
Source: BERR Renewables Atlas, National Grid
Client:
DORSET COUNTY COUNCIL
Drawn by: GMC
Checked: PTG
Drawing No: 9V5867/01/004
Date: 16/02/2010
Figure: 4.3
Scale: 0 2.5 5 10 Kilometres
Revision No: 001
DORSET COAST FORUM
ROYAL HASKONING

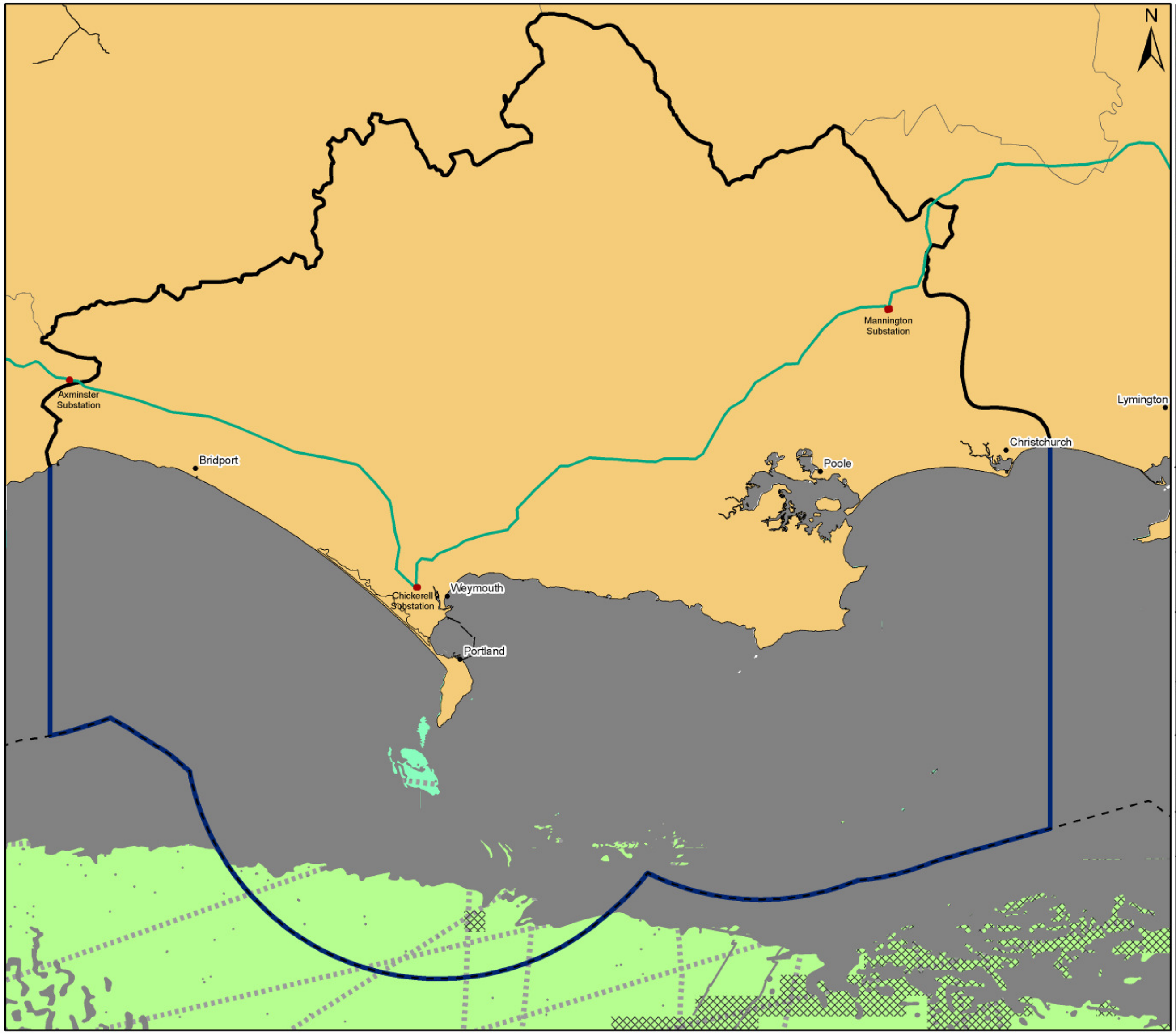

N
Axminster Substation
Bridport
Mannington Substation
Lymington
Christchurch
Poole
Chickerell Substation
Weymouth
Portland
Legend:
Study Area
Dorset County Boundary
12 Nautical Mile Limit
400kV National Grid
Substation
Mean Annual Wave Power (kW/m)
0.00 - 2.50
2.51 - 4.99
5.00 - 7.50
7.51 - 10.00
10.01 - 15.00
15.01 - 20.00
20.01 - 25.00
25.01 - 50.00
50.01 - 74.64
Title:
WAVE RESOURCE ¼ SCALE DEVICE:
MEAN ANNUAL WAVE POWER (kW/m)
(MFOC = ≥ 5kW/m)
Project:
OFFSHORE RENEWABLES CAPACITY STUDY
Source:
Not to be used for navigation. © Haskoning UK Ltd.
ARCS charts reproduced under licence 21413M.
© Crown Copyright 2010
Source: BERR Renewables Atlas, National Grid
Client:
DORSET COUNTY COUNCIL
Drawn by: GMC
Checked: PTG
Drawing No: 9V5867/01/003
Date: 16/02/2010
Figure: 4.4
Scale: 0 2.5 5 10 Kilometres
Revision No: 001
DORSET COAST FORUM
ROYAL HASKONING

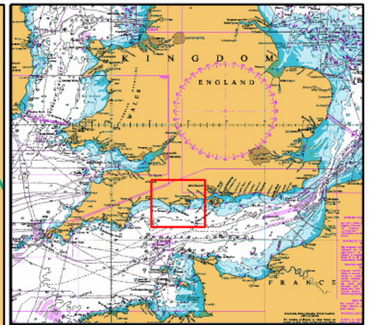
3.7 Constraints Mapping

The following figures (**Figures 4.5 to 4.8**) show the offshore wind, tidal stream and wave resource for the waters off Dorset.


N
Axminster Substation
Bridport
Chickerell Substation
Weymouth
Portland
Mannington Substation
Poole
Christchurch
Lymington
1
2
Legend:
Study Area
Dorset County Boundary
12 Nautical Mile Limit
400kV National Grid
Substation
Potential Development Area
Hard Constraints
High Density Shipping
Ship Routes Summary
West of Wight R3 Zone + 5km Buffer
Mean Annual Wind Speed (m/s) at 100m
4.48 - 5.16
5.17 - 5.67
5.68 - 6.19
6.20 - 6.73
6.74 - 6.99
7.00 - 7.92
7.93 - 8.53
8.54 - 9.10
9.11 - 9.57
9.58 - 9.94
9.95 - 10.33
10.34 - 12.30
Title:
WIND RESOURCE WITH HARD CONSTRAINTS AND KEY SHIPPING ACTIVITY:
MEAN ANNUAL WIND SPEED AT 100m
(MFOC = ≥ 7m/s)
Project:
OFFSHORE RENEWABLES CAPACITY STUDY
Source:
Not to be used for navigation. © Haskoning UK Ltd.
ARCS charts reproduced under licence 21413M.
© Crown Copyright 2010
Source: BERR Renewables Atlas, National Grid
Client:
DORSET COUNTY COUNCIL
Drawn by: GMC
Checked: PTG
Drawing No: 9V5867/01/010
Date: 01/04/2010
Figure: 4.5
Scale: 0 2.5 5 10 Kilometres
Revision No: 004
DORSET COAST FORUM
ROYAL HASKONING


N
Axminster Substation
Bridport
Chickerell Substation
Weymouth
Portland
Mannington Substation
Poole
Christchurch
Lymington
1
Legend:
Study Area
Dorset County Boundary
12 Nautical Mile Limit
400kV National Grid
Substation
Potential Development Area
Hard Constraints
High Density Shipping
Ship Routes Summary
West of Wight R3 Zone
Mean Spring Peak Current (m/s)
Title:
TIDAL STREAM RESOURCE WITH HARD CONSTRAINTS AND KEY SHIPPING ACTIVITY: MEAN SPRING PEAK CURRENT (m/s) (MFOC = ≥ 2m/s)
Project:
OFFSHORE RENEWABLES CAPACITY STUDY
Source:
Not to be used for navigation. © Haskoning UK Ltd.
ARCS charts reproduced under licence 21413M.
© Crown Copyright 2010
Source: BERR Renewables Atlas, National Grid
Client:
DORSET COUNTY COUNCIL
Drawn by: GMC
Checked: PTG
Drawing No: 9V5867/01/013
Date: 01/04/2010
Figure: 4.6
Scale:
Kilometres
Revision No: 004
DORSET COAST FORUM
ROYAL HASKONING





Legend:

- Study Area
- Dorset County Boundary
- 12 Nautical Mile Limit
- 400kV National Grid
- Substation
- Hard Constraints
- High Density Shipping
- Ship Routes Summary
- West of Wight R3 Zone

Mean Annual Wave Power (kW/m)

- 0.00 - 6.01
- 6.02 - 9.53
- 9.54 - 13.16
- 13.17 - 16.85
- 16.86 - 19.99
- 20.00 - 24.46
- 24.47 - 28.66
- 28.67 - 32.87
- 32.88 - 37.21
- 37.22 - 41.88
- 41.89 - 46.27
- 46.28 - 74.64

Title:
WAVE RESOURCE WITH HARD CONSTRAINTS AND KEY SHIPPING ACTIVITY:
MEAN ANNUAL WAVE POWER (kW/m)
(MFOC = ≥ 20kW/m)

Project:
OFFSHORE RENEWABLES CAPACITY STUDY

Source:
Not to be used for navigation. © Haskoning UK Ltd.
ARCS charts reproduced under licence 21413M.
© Crown Copyright 2010
Source: BERR Renewables Atlas, National Grid

Client:
DORSET COUNTY COUNCIL

Drawn by:	Checked:	Drawing No:
GMC	PTG	9V5867/01/008

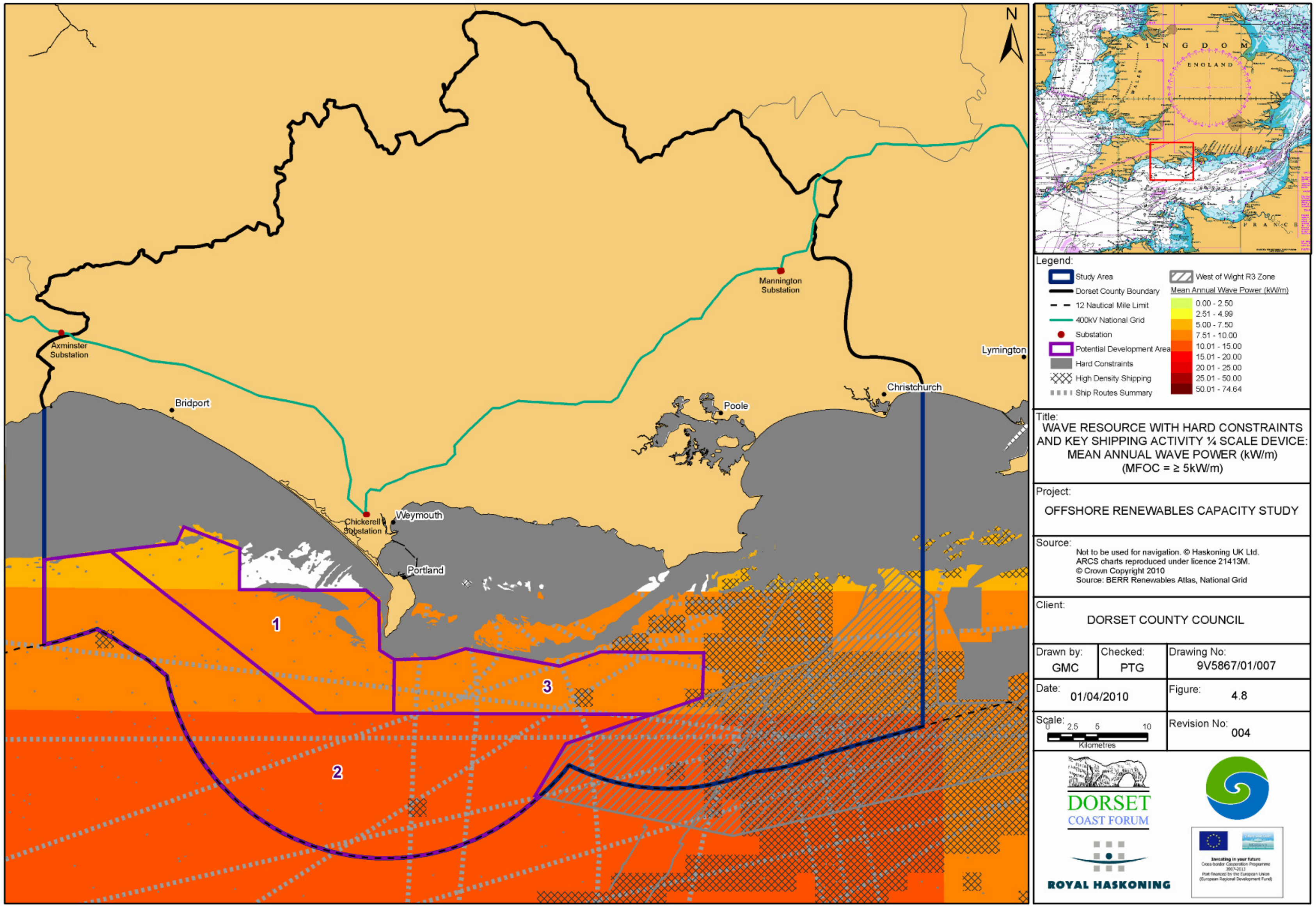
Date:	Figure:
01/04/2010	4.7

Scale: 0 2.5 5 10 Kilometres

Revision No: 004

DORSET COAST FORUM

ROYAL HASKONING


N
Axminster Substation
Bridport
Chickerell Substation
Weymouth
Portland
Poole
Mannington Substation
Christchurch
Lymington
1
2
3
ENGLAND
FRANCE
Legend:
Study Area
Dorset County Boundary
12 Nautical Mile Limit
400kV National Grid
Substation
Potential Development Area
Hard Constraints
High Density Shipping
Ship Routes Summary
West of Wight R3 Zone
Mean Annual Wave Power (kW/m)
0.00 - 2.50
2.51 - 4.99
5.00 - 7.50
7.51 - 10.00
10.01 - 15.00
15.01 - 20.00
20.01 - 25.00
25.01 - 50.00
50.01 - 74.64
Title:
WAVE RESOURCE WITH HARD CONSTRAINTS AND KEY SHIPPING ACTIVITY ¼ SCALE DEVICE: MEAN ANNUAL WAVE POWER (kW/m) (MFOC = ≥ 5kW/m)
Project:
OFFSHORE RENEWABLES CAPACITY STUDY
Source:
Not to be used for navigation. © Haskoning UK Ltd.
ARCS charts reproduced under licence 21413M.
© Crown Copyright 2010
Source: BERR Renewables Atlas, National Grid
Client:
DORSET COUNTY COUNCIL
Drawn by: GMC
Checked: PTG
Drawing No: 9V5867/01/007
Date: 01/04/2010
Figure: 4.8
Scale: 0 2.5 5 10 Kilometres
Revision No: 004
DORSET COAST FORUM
ROYAL HASKONING

4 DISCUSSION

The following sections provide an overview of the Potential Development Areas identified for wind, tidal stream and wave technology groups within Dorset coastal waters. Details on the hard constraints are discussed as are the development considerations (although these are limited to only those that are of key importance to the Potential Development Area in question).

4.1 Offshore Wind Resource Capacity

The waters off the Dorset coast have been identified as being suitable for offshore wind farm development, as it indicated through the inclusion of the West of Wight Zone within The Crown Estate's Round 3 seabed leasing programme. The resource mapping exercise undertaken as part of this study has indicated that there is further suitable resource within Dorset's waters (see **Figure 4.5**). For ease of reporting this suitable resource has been divided into two Potential Development Areas:

- Potential Development Area 1 - West Dorset; and
- Potential Development Area 2 - East Dorset.

4.1.1 Potential Development Area 1 – West Dorset considerations

Key development considerations for this Potential Development Area comprise:

- Nature designations;
- Marine ecology;
- Fishing activity;
- MoD activity;
- Shipping & Navigation;
- Radar & civil aviation; and
- Designated landscapes.

Nature Designations

Whilst there is no overlap with any current or proposed designated sites, the waters off Lyme Regis and Portland Bill have been identified as a possible Special Area of Conservation (pSAC) by Natural England. Consultation is currently ongoing with regard to these sites, following which the final boundary configuration and management policy will be established. There are a number of further onshore sites of European status that would be of particular importance to any export cable connections from this site to Chickerell. Studies during any consenting process would need to establish whether the integrity of these sites would be compromised by development.

Fish Spawning Grounds

Sensitive benthic communities associated with the Annex I reef habitat occurring in the inshore areas of Lyme Bay and around Portland Bill would need to be considered, but are unlikely to prevent development. The export cable route will also need to take this into consideration if connecting at Chickerell or an alternative location to the west (such as Axminster).

Sole and sprat have spawning grounds within the Potential Development Area. Experience from existing offshore wind farm development within the UK would suggest that construction timing restrictions may be required to reduce impact levels on spawning activity of these species.

Fishing Activity

Commercial and recreational fishing activity (e.g. trawling) within Lyme Bay is high. Any offshore wind farm development will require a restriction on human activity within a set area around the devices particularly for mobile gear. Fisheries interests would be an important consideration as part of any consents process. Export cable route options would also need to take these interests into account especially with regard to potential temporary disruption to static gear fisheries, which is extensive in the inshore waters of Lyme Bay.

Ministry of Defence (MoD) Exercise Areas

Much of the Potential Development Area lies within a number of adjoining MoD practice and exercise areas (PEXAs). Within these areas the MoD undertakes a wide range of activities including, air, naval and submarine exercises including live firing.

The precise location of these activities and their frequency and duration is not specified, but any development would need to consult early on with MoD to establish their concerns over potential conflict between development and their activities. Based on past offshore wind farm development experience, it is likely that the MoD may object to any development with their activity areas, given the scale of such projects.

Shipping & Navigation

The main high shipping density areas have been avoided when deciding on this Potential Development Area. However, a number of shipping routes pass through the area and would potentially influence development.

Civil Aviation & Radar

The presence of a helicopter base on Portland would require investigation to establish potential radar interference and flight path conflicts.

Designated Landscapes

The close proximity of the World Heritage Site would have the potential to significantly impinge on the ability to develop this Potential Development Area (especially the inshore sections). Whilst offshore wind farms do exist within close proximity to the coast, the latest offshore energy SEA suggests that for high sensitivity coasts development within 12nm may lead to significant landscape effects for development over 100MW (DECC, 2009b). The SEA identified that any development within 13-24km from the coast between Weymouth and Bournemouth would impact on the landscape (DECC, 2009b), and it is considered the same for Lyme Bay area to the west. However, the SEA does state that this should not be seen as a barrier to development, but more that these areas should be avoided if possible, and if not then will face greater consenting challenges.

4.1.2 Potential Development Area 2 – East Dorset Considerations

Key development considerations for this Potential Development Area comprise:

- Nature designations;
- Marine ecology;
- Fishing activity;
- MoD activity;
- Human infrastructure & activity;
- Shipping & Navigation;
- Radar & civil aviation; and
- Designated landscapes.

Nature Designations

The waters off Swanage to Weymouth and off Portland Bill have been identified as a possible Special Area of Conservation (pSAC) by Natural England. There is overlap between the Potential Development Area and the pSAC. Should the pSAC be formally designated then it would not necessarily prohibit development (it is widely recognised that offshore wind farm deployment in designated sites is likely to occur around the UK within a number of the Round 3 Zones). However, developers would need to ascertain whether adverse impacts to the sites were likely, and if so then there would be potential for this to influence the development.

Fish Spawning Grounds

Sensitive benthic communities associated with the Annex I reef habitat occurring off the Swanage coastline would need to be considered, but are unlikely to prevent development. The export cable route would also need to take this into consideration if connecting at Chickerell or an alternative location to the east (such as Mannington).

Sole and sprat have spawning grounds within the Potential Development Area. Experience from existing offshore wind farm development within the UK would suggest that construction timing restrictions may be required to reduce impact levels on spawning activity of these species.

Fishing Activity

Commercial and recreational fishing activity is relatively high off of the Swanage and Portland coastlines within the region of the Potential Development Area identified. It is likely that impacts on the fishing industry may occur and therefore, their interests would need to be considered as part of any consents process. Export cable route options would also need to take these interests into account especially with regard to potential temporary disruption to static gear fisheries which are extensive in this area.

A number of licensed shellfish harvesting area (for mussels and scallops) exists to the southeast of Portland Bill, west of St Albans Head, within Portland Harbour and at the mouth of the Wey estuary. Consideration of the potential effects on these areas during construction and operation activities would need detailed consideration to ensure any potential impacts are limited.

Ministry of Defence (MoD) Exercise Areas

Much of the Potential Development Area lies within a number of adjoining MoD PEXAs. Within these areas the MoD undertakes a wide range of activities including, air, naval and submarine exercises including live firing.

The precise location of these activities and their frequency and duration is not specified, but any development would need to consult early on with MoD to establish their concerns over potential conflict between development and their activities. It is possible that the MoD may object to any development with their activity areas, given the scale of such projects.

Infrastructure & Human Activity

There are numerous small hard constraints within this Potential Development Area which comprise wrecks, seabed obstructions and navigational aids. These do not pose major concern and could be avoided through micrositing of WTGs. Export cable routing (assuming landfall at either Portland or Chickerell) would need to consider the implications for the Portland gas storage pipeline (crossing Portland to Weymouth).

Furthermore, there are a number of anchoring prohibited areas and RYA recreational sailing routes in the vicinity that would need to be taken into consideration for cable route planning.

Consideration will also need to be given to the planned or existing (depending on timescale of any future development) Round 3 West of Wight Zone and its export cable. The Round 3 Zone has been avoided for the purposes of this study as it is not clear what areas within this Zone will be developed. Once this has been clarified (as will become evident through the consenting process for the site) areas within the Zone may become available for future development. However, it should be noted that any areas within the Zone not developed by Eneco (the developer) are likely to have been avoided for a substantive reason and therefore may not necessarily represent future potential developable area.

Shipping & Navigation
The main high shipping density areas have been avoided when deciding on this Potential Development Area. Considerable shipping activity in the Potential Development Area is still likely as can be seen from the route summary information in **Figure 4.5**. Furthermore the presence of the future West of Wight offshore wind farm may influence current shipping activity within this region, which could increase the level of shipping activity in the surrounding areas as they avoid the wind farm.

Civil Aviation & Radar
The presence of Bournemouth airport within relatively close proximity to this Potential Development Area is likely to mean that it would be of concern for the National Air Traffic Services (NATS) with regard to radar interference. Furthermore there is a helicopter base on Portland which would require investigation to establish potential radar interference and flight path conflicts.

Designated Landscapes
As with Potential Development Area 1 all of the area lies within 12nm of the coast. The presence of the world heritage coastline would have the potential to significantly impinge on the ability to develop the area, especially given the presence of existing development immediately offshore of this area.

4.2 Tidal Stream Resource Capacity

Within the Dorset coastal waters it can be seen from **Figure 4.6** that there is only one Potential Development Area identified, that being off Portland Bill. This is consistent with the previous studies that have assessed tidal stream resource within the area (e.g. South West RDA 2004, SDC 2007 and ABPMer 2009). Further areas around St Albans ledge may also be suitable in the future should technology progress to enable commercialisation in slightly lower resource areas. However, at this juncture it is considered that only the waters off Portland represent a viable resource based on the current technology status.

The only hard constraint within this Potential Development Area is the presence of the West of Shambles cardinal buoy, which could be easily avoided through micrositing of devices.

4.2.1 Potential Development Area 1 – Portland Bill Considerations

Within this area there are a number of key development constraints that any tidal stream prospector would need to consider, comprising:

- Bathymetry & hydrodynamics;
- Seabed conditions;
- Nature designations;
- Marine ecology;
- Fishing activity;
- MoD activity;
- Human infrastructure & activity; and
- Shipping & Navigation.

Bathymetric and Hydrodynamic Conditions

It has been highlighted previously that this area has not been considered one of the UK's best tidal resource locations on the grounds of the relatively shallow water depths (which may be insufficient to allow the installation of high capacity devices, (ABPmer, 2007)) and eccentricity of tidal flows, where flow reversals of up to 35% have been recorded (ABPmer, 2007).

Seabed Conditions

Exposed bedrock off Portland Bill may constrain some types of devices that require a softer sediment to install foundation structures. However, this is unlikely to greatly restrict the potential of the site, as the majority of tidal stream devices will be designed to allow for solid seabed conditions given the nature of the environments within which they are installed (i.e. one where strong tidal conditions will winnow out any mobile seabed sediment).

Nature Designations

The waters off Portland Bill have been identified as a possible Special Area of Conservation (pSAC) by Natural England. Should the pSAC around Portland Bill progress then it would not necessarily prohibit development. However, it will require any development plans to identify whether they would have an adverse impact to the site. Tidal stream deployment in designated sites is likely to occur around the UK given the fact that by nature of the high tidal currents suitable sites often occur in areas where Annex I reef habitat is present. Examples to date where there is overlap between potential development and designated sites include Strangford Lough and Ramsey Sound. Therefore, small scale development is unlikely to be of major concern however, development at array scale may require consideration of foundation types and installation methods (for both the device and cable) to reduce potential impacts on the protected site.

Marine Ecology

Sensitive benthic communities associated with the Annex I reef habitat occurring off Portland Bill would need to be considered, but are unlikely to prevent development. Export cable route would also need to take this into consideration if connecting at Portland and also the deepwater mud communities within Portland Harbour if connecting at Chickerell.

Fishing Activity

Commercial and recreational fishing activity is relatively high off of Portland Bill within the region of the Potential Development Area identified. A licensed shellfish harvesting area for mussels and scallops lies to the southeast of Portland Bill. Any tidal stream development would be likely to require a restriction on human activity within a set area around the devices. Potential impacts on the fishing industry would need to be thoroughly considered as part of any consents process. Export cable route options would also need to take these interests into account especially with regard to potential temporary disruption to static gear fisheries.

Ministry of Defence (MoD) Exercise Areas

The Potential Development Area overlaps with an MoD PEXA. Within these areas the MoD undertakes a wide range of activities including, air, naval and submarine exercises including live firing.

The precise location of these activities and their frequency and duration is not specified, but any development would need to consult early on with MoD to establish their concerns over potential conflict between development and their activities.

Infrastructure & Human Activity

Considerable ongoing human activity occurs off Portland and Weymouth. Export cable routing (assuming landfall at either Portland or Chickerell) will need to consider the implications for the Portland gas storage pipeline (crossing Portland to Weymouth). Furthermore, there are a number of anchoring prohibited areas and RYA recreational sailing routes in the vicinity that would need to be taken into consideration.

Consideration will also need to be given to the planned or existing (depending on timescale of any future development) Round 3 West of Wight Zone export cable.

Shipping & Navigation

Shipping (including tankers and hi-speed craft) from / to Portland and Weymouth transits across this Potential Development Area. Whilst many of the tidal array devices are fully submerged in their design access would be necessary for installation, operation and maintenance purposes. The level of impact this shipping activity is likely to have on development would depend on device type and consultation outcomes with the shipping industry. It is considered that shipping activity would have the potential to influence future development.

4.3 Wave Resource Capacity

The waters off the Dorset coast are not suitable for commercial scale wave energy development, as a result of insufficient resource potential. However, for prototype device testing (at ¼ scale) there would appear to be suitable resource. For the purposes of descriptive reporting, these areas have been divided into three Potential Development Areas (**Figure 4.8**):

- Potential Development Area 1 - West Dorset Inshore;
- Potential Development Area 2 - Dorset Offshore; and
- Potential Development Area 3 - East Dorset.

The development considerations for a small scale prototype will be greatly reduced given the fact that it would likely be a single device installed for a temporary period (typically around 12 – 24 months) to test its energy production capabilities and survivability. Cabling for such devices may be required with connection to the local network (33kV), which is likely to be in the form of a coastal settlement where a suitable t-junction may be available, such as at a holiday park. Grid connection is however, not always required as developers may opt for load-banks that will take-off the energy produced on site, negating the requirement for power export. Development considerations for the areas identified for potential ¼ scale wave device deployment are similar to those discussed above for offshore wind given their shared spatial extents (although development issues would be on a much smaller and temporary scale). They are therefore, not discussed in detail here to avoid repetition.

4.3.1 Potential Development Area 1 – West Dorset Inshore Considerations

Key development considerations for this Potential Development Area comprise:

- Bathymetry;
- Nature designations;
- Fishing activity;
- MoD activity; and
- Shipping & Navigation.

Summary

There are limited development considerations within this Potential Development Area. Shallow areas, nature designations (both offshore and onshore) key fishing grounds, MoD activity and shipping are likely to be of concern, although could easily be avoided through careful siting of a device.

4.3.2 Potential Development Area 2 – Dorset Considerations

Key development considerations for this Potential Development Area comprise:

- Nature designations;
- Fishing activity;
- MoD activity;
- Shipping & Navigation;
- Human infrastructure;
- Distance from shore; and
- Proximity to grid.

Summary

Development considerations are similar to the West Dorset Inshore Potential Development Area, with the exception of shipping activity which is far more intense in this area. The major development consideration would be the distance from a suitable grid connection and from shore meaning that costs for exporting power and servicing the device would be much greater than in inshore waters.

4.3.3 Potential Development Area 3 – East Dorset considerations

Key development considerations for this Potential Development Area comprise:

- Fishing activity;
- MoD activity;
- Shipping & Navigation;
- Human infrastructure; and
- Proximity to grid.

Summary

There are numerous development considerations within this Potential Development Area. Key fishing grounds particularly in the east, MoD activity and intense shipping activity are likely to be of concern. However, above and beyond these considerations the key influencing factor for this area is likely to be the distance from shore (and therefore, cost of connecting a device to the grid as well as undertaking construction, operation and maintenance activity).

5 CONCLUSIONS AND MSP CONSIDERATIONS

5.1 Wind

The offshore wind industry will expand rapidly over the coming decade, with the bulk of this growth seen through Round 3. The presence of a Round 3 development zone within Dorset's waters means that there is likely to be considerable activity and opportunity within the region in terms of the manufacturing, construction and operation & maintenance aspects. Two Potential Development Areas based around current industry interpretation of hard constraints have been identified within Dorset's waters. The least constrained area being in Lyme Bay off West Dorset, although landscape, MoD, and shipping considerations are likely to be significant in determining how realistic development is in this area. The Potential Development Area off East Dorset has more development considerations associated, and it is likely that any development within this area may be restricted to future extension to the West of Wight Round 3 Zone.

Any major new offshore wind farm development will require connection with the main 400kV network, which has a number of potential connection points in relative close proximity to the coast, with Chickerell being the most attractive (given its proximity to the coast and therefore likely reduced planning and economic constraints). It is likely that any future connection will require upgrading of the network to handle the extra energy generation (assuming the West of Wight Zone is already connected at that juncture).

MSP Considerations
Whilst substantial potential resource may exist (as identified by Potential Development Areas 1 and 2), it is highly unlikely that either of these areas would be developed to their full extent. Therefore, for MSP consideration purposes the offshore wind development (in addition to the development of the West of Wight Zone) is likely to be, at best, restricted to:

- Potential extension to the West of Wight Zone in the deeper water areas; and
- Possible development in the deeper water areas, further offshore within Lyme Bay (as part of a larger project including the adjacent waters off Devon) should future Crown Estate leasing re-consider this area.

5.2 Tidal

Tidal industry in the UK is currently small but, over the coming decade, is likely to see considerable growth providing the prototype devices continue to successfully prove their operational capacity. Arrays are being planned around the UK (in Scotland, Wales and the English Channel) and further expansion is likely, especially if Government formally back the industry through an SEA for English and Welsh waters and a subsequent Crown Estate leasing plan.

Suitable resource within Dorset's waters (based on current technology) is limited to an area off Portland Bill. This area has few hard constraints associated with it and as such has been considered as a Potential Development Area. However, the Potential Development Area does have a number of key development considerations, notably relatively shallow water depths and eccentric current flows (ABPMer, 2007). Furthermore, the Potential Development Area has significant shipping activity across some of this area in addition to a number of other development considerations that would increase the challenge of development within this area.

The area has suitable and attractive grid connection opportunities (in terms of proximity and current capacity) for both small and larger scale development. Any project 16MW or less in capacity can connect to local network in Portland whilst any project of greater capacity than this can connect to the main network at Chickerell. Taking this into consideration when combined with its suitable resource (which are relatively restricted around the UK) means that future development here has creditable potential, especially if technologies advance to counter the bathymetric and current flow considerations. It should be noted however, that the cumulative effects on energy removal from multiple arrays in this relatively constrained resource area has been identified (ABPmer 2007). The theory behind this being that if multiple arrays are densely packed together (as would be the case in confined resource areas) then cumulative affects on the tidal current energy may start to affect the capacity of the devices and therefore, the project economics.

Therefore, despite having suitable MSPC, the Dorset coast is not identified as a major UK tidal resource.

MSP Considerations

Given its key development considerations, it is likely that other more attractive areas around the UK would get developed before Portland. However if it is included in a future SEA for England and Wales, then development of this area should be considered a realistic possibility and factored into MSP considerations.

5.3 Wave

Like the tidal stream industry, wave energy is currently in its infancy, although its development is somewhat less clear than that of tidal, given the current difficulties experienced to date in securing sufficient funding to take devices through a rigorous testing and proving cycle.

The resource assessment has identified that there are no suitable areas for commercial scale wave energy converter deployment in the waters off Dorset. However, suitable resource for small scale prototype wave deployment has been identified. Potential deployment sites would be as close to the coast as possible, where suitable local grid connections exist in conjunction with adequate port servicing facilities. Within the study area, the waters within the eastern half of Lyme Bay would be most appropriate, where water depths and resource are suitable. However, despite the presence of suitable resource and grid connection points in close proximity to the coast, the distance from shore where water depth is greater than 25m may restrict the attractiveness of this area to device developers. Keeping costs from cabling and vessel mobilisations to a minimum is of high importance for test devices, especially if deployment took place outwith of a subsidised test facility.

MSP Considerations

Development of wave energy within Dorset's waters is considered highly unlikely. With no suitable resource for commercial scale devices, development potential is restricted to small scale prototype device deployment. Given the available test facilities elsewhere around the UK and the fact that many devices in the market place have already been through this stage of development, it is considered that no specific areas should be set aside with regard to MSP considerations.

6 REFERENCES

ABPMer (2007). Quantification of Exploitable Tidal Energy Resources in UK Waters: Volume 1. Npower Juice report.

ABPMer (2009). Wet Renewable Energy and Marine Nature Conservation: Developing Strategies for Management.

Byrne, B.W. & Houlsby, G.T. (2006). Assessing Novel Foundation Options for Offshore Wind Turbines Oxford University, UK.

BWEA (2009b). Wind energy in Wales - State of the Industry Report by BWEA Cymru

BWEA – Npower Juice (2006). Path to Power: Stage 3 Discussion Document – GB Electricity Network Access. Econnect Project No: 1548.

BWEA (2009). Marine Renewable Energy: State of the Industry Report.

Carbon Trust (2006). Future Marine Energy Results of the Marine Energy Challenge: Cost competitiveness and growth of wave and tidal stream energy

Department of Business Enterprise and Regulatory Reform (2008). Atlas of UK Marine Renewable Energy Resources. A report by ABPmer Ltd.

Department of Energy and Climate Change (2009). UK Ports for the Offshore Wind Industry: Time to Act. A report by BVG Associates.

Department of Energy and Climate Change (2009a). A Prevailing Wind: Advancing UK Offshore Wind Deployment.

Department of Energy and Climate Change (2009b). Offshore Energy Strategic Environmental Assessment.

Dudgeon Offshore Wind Limited (2009). Dudgeon Offshore Wind Farm Environmental Statement.

European Wind Energy Association (2004). Wind energy – the facts. An analysis of the wind energy in the EU-25.

Greater Gabbard Offshore Winds Limited (2006). Greater Gabbard Offshore Wind Farm Environmental Statement.

Sustainable Development Commission (2007). Research Report 1 - UK tidal resource assessment. A report by Metoc Plc.

Scottish Executive (2007). Scottish Marine Renewables Strategic Environmental Assessment.

South West of England Regional Development Agency (2004). Resources, Constraints and Development Scenarios for Wave and Tidal Stream Power in the South West of England. A report by Metoc Plc.

The Carbon Trust (2008). Offshore wind power: big challenge, big opportunity Maximising the environmental, economic and security benefits.

The Crown Estate (2009/2010). Round three offshore wind farm connection study.

The Crown Estate (2010). UK Offshore Wind Report 2010.

6.1 Websites

www.alternative-energy-news.info/technology/hydro/wave-power/
http://nnmrec.oregonstate.edu/book/export/html/84
www.aquamarinepower.com
hwww.aquaret.com
www.aquamarinepower.com/about-us/
www.atlantisresourcescorporation.com
www.aw-energy.com/index.php/performance.html
www.biopowersystems.com/market.php
www.bluehusa.com
www.defra.gov.uk
www.emec.org.uk
www.engb.com/
www.greenoceanenergy.com
www.hammerfeststrom.com
www.independent.ie/business/irish/irish-company-joins-the-elite-few-generating-electricity-from-the-sea-1198405.html
www.marineturbines.com
www.news.bbc.co.uk
www.oceanflowenergy.com/
www.oceanlinx.com/index.php/current-projects/areas-of-interest
www.ofgem.gov.uk
www.openhydro.com
www.pelamiswave.com
www.portlandmonthlymag.com/
www.pulsegeneration.co.uk/?q=node/53
www.seageneration.co.uk
www.sperboy.com/
www.wavessg.com/SSGConcept.htm

=O=O=O=