Roadmap to the deployment of offshore wind energy

in the Central and Southern North Sea (2020 – 2030)

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Roadmap to the deployment of offshore wind energy in the Central and Southern North Sea (2020 - 2030)

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Printing:	RICOH	
Photos:	www.flickr.com	(Cover page. Users:dingbat2005, adstream, extrajection, crawfish_head, royaldutchshell, 8929612@N04, oneeighteen. Used under non-commercial non-derivative Creative Commons attribution licences www.creativecommons.org/licenses/by-nc-nd/3.0/)
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Executive summary

This Roadmap represents the final deliverable of the WINDSPEED project. It has a dual objective. Firstly, it aims to present an ambitious but realistic target for offshore wind with minimum negative impacts on other sea functions present in the Central and Southern North Sea basin in the time frame to 2030. Secondly, it aims to identify actions and milestones required to achieve this target.

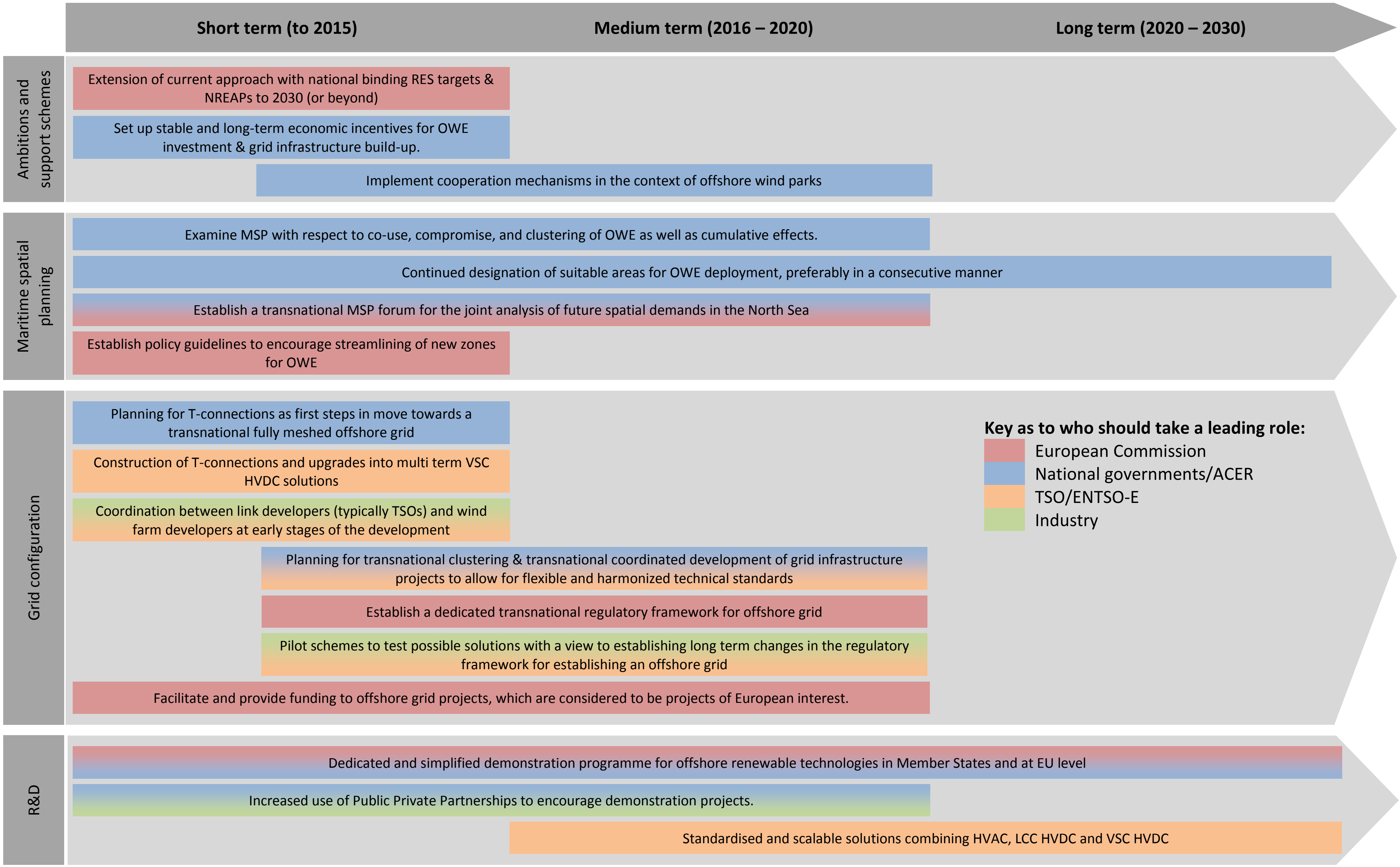
The North Sea countries – Belgium, Denmark, Germany, the Netherlands, Norway and the UK – are facing a number of challenges and opportunities in their quest for rapid expansion of offshore wind energy in the Central and Southern North Sea basin. The WINDSPEED project has carried out an assessment of (ambitious but realistic) deployment potentials under different scenarios to gain better insight into how key uncertainties can impact on OWE developments. An early understanding of how different development perspectives influence challenges and opportunities, as well as uncertainties, will allow for better adaptation of policies and approaches to promote large scale offshore wind energy (OWE). This is particularly important at a time when OWE is strongly driven by EU and national policy needs in attempting to reach overall policy goals of a competitive, secure and sustainable energy system.

There is ample space in the Central and Southern North Sea. But many attractive areas for developing OWE within reasonable cost ranges are already occupied by other sea users. Moving OWE further from shore and into deeper waters not only drives costs up, but also raises the issue of the availability of deep sea technology components and the need for an offshore grid. To date, the North Sea countries will have developed a capacity of around 2 GW in the North Sea. It has taken a decade to get this far. Important lessons are being learnt and these must be taken into account in the development of OWE towards 2030.

The WINDSPEED project concludes that a capacity of 135 GW of OWE in the Central and Southern North Sea is feasible by 2030. Assuming that the NREAP projections of around 32 GW for the six North Sea countries involved are achieved in 2020 (this also includes developments in additional sea basins), a capacity of 135 GW in the Central and Southern North Sea basin implies a growth of more than 100 GW in the time frame 2020 - 2030. Due to long lead times in developing offshore wind projects, changing the current pathway in the period up to 2020 may be difficult. This is, however, not the case for the period 2020 - 2030. A development of this magnitude will clearly require a different approach and policy framework regarding OWE deployment than what we see today.

To achieve 135 GW OWE in the Central and Southern North Sea by 2030, countries must be willing to both increase spatial prioritisation to OWE (closer to shore) and establish an offshore grid. In order to do so, greater coordination between countries is necessary.

The final WINDSPEED recommendations – consisting of key actions, milestones and which stakeholders should take the lead in following up the necessary actions to achieve 135 GW of OWE by 2030 – are summarised as follows:


Short term (to 2015)
Medium term (2016 – 2020)
Long term (2020 – 2030)
Ambitions and support schemes
Extension of current approach with national binding RES targets & NREAPs to 2030 (or beyond)
Set up stable and long-term economic incentives for OWE investment & grid infrastructure build-up.
Implement cooperation mechanisms in the context of offshore wind parks
Maritime spatial planning
Examine MSP with respect to co-use, compromise, and clustering of OWE as well as cumulative effects.
Continued designation of suitable areas for OWE deployment, preferably in a consecutive manner
Establish a transnational MSP forum for the joint analysis of future spatial demands in the North Sea
Establish policy guidelines to encourage streamlining of new zones for OWE
Grid configuration
Planning for T-connections as first steps in move towards a transnational fully meshed offshore grid
Construction of T-connections and upgrades into multi term VSC HVDC solutions
Coordination between link developers (typically TSOs) and wind farm developers at early stages of the development
Planning for transnational clustering & transnational coordinated development of grid infrastructure projects to allow for flexible and harmonized technical standards
Establish a dedicated transnational regulatory framework for offshore grid
Pilot schemes to test possible solutions with a view to establishing long term changes in the regulatory framework for establishing an offshore grid
Facilitate and provide funding to offshore grid projects, which are considered to be projects of European interest.
Key as to who should take a leading role:
European Commission
National governments/ACER
TSO/ENTSO-E
Industry
R&D
Dedicated and simplified demonstration programme for offshore renewable technologies in Member States and at EU level
Increased use of Public Private Partnerships to encourage demonstration projects.
Standardised and scalable solutions combining HVAC, LCC HVDC and VSC HVDC

1 Introduction

A Roadmap is a dynamic and responsive plan, consisting of three key elements – a starting point, a destination and a route description – often triggered by the need and the will to follow a better pathway than the current one. This chapter gives a brief introduction to the rationale behind and structure of this WINDSPEED Roadmap, the approach taken to develop it and the involvement of stakeholders in doing so.

Rationale – why a Roadmap to offshore wind deployment?

Offshore wind energy (OWE) is a newcomer to the sea, and many argue that it will play a key role in moving towards a sustainable energy system in Europe in 2020 and beyond. The EU energy system is challenged by global climate change threats, increasing dependency on energy imports as well as threats of supply disruptions from countries outside the EU. Faced with these challenges, the EU recently established a policy framework which includes a target of 20% share of renewable energy source (RES) by 2020.

OWE deployment is foreseen to expand dramatically in the years to come. This expansion is strongly driven by EU and national policies that aim to provide a low-carbon and reliable energy system. The European Commission anticipated, in its 2008 Communication on offshore wind energy (EC, 2008), that *"Offshore wind can and must make a substantial contribution to meeting the EU's energy policy objectives through a very significant increase — in the order of 30-40 times by 2020 and 100 times by 2030 — in installed capacity compared to today"*. The installed offshore wind capacity in Europe by end of 2008 was 1.5 GW. A hundredfold increase implies 150 GW by 2030. This target has also been presented by the European Wind Energy Association (EWEA, 2009).

OWE is more complex and costly than onshore wind. However, due to a combination of better wind resources and larger turbines, it provides higher energy yields. In addition, the sea offers more space and less public resistance. The latter is an increasing problem for wind energy onshore. Successful deployment of large scale OWE in the coming years requires additional preparation and adaptation of the current policy framework. In order to do this it is necessary to understand the constraints (spatial, policy, growth, grid and market integration) on the realistic potential for OWE in a given sea basin, in this case the Central and Southern North Sea. This is a precondition for designing transparent, stable and favourable framework conditions in order for OWE to fully develop its realisable potential. These are key focus areas of the WINDSPEED project.

The Central and Southern North Sea is an attractive sea basin for large scale deployment of OWE, and a hotspot for past and ongoing developments in offshore activities in general. At a first glance, the North Sea wind resources seem abundant. The available wind resources could potentially fulfil a large share of the ambitious EU 20% renewable energy target to be achieved by the European Member States by 2020. At the same time, there are increasing pressures on this marine environment as more uses are being introduced and current uses are being expanded. Large OWE projects are in the pipeline and countries surrounding this sea basin are, to some extent, speeding up planning activities in an attempt to find viable locations for development. However, the overall management of this sea basin is still somewhat fragmented, nationally focussed and rarely steam-lined in terms of timing.

The Central and Southern North Sea basin is one of the busiest seas in the world. It is surrounded by densely populated and highly industrialised countries such as Belgium, Denmark, Germany, the

Netherlands, Norway and the United Kingdom. Major activities in the North Sea include shipping, fishing, sand and gravel extraction, military activities and offshore energy related activities such as the exploitation of oil and gas reserves including the laying of cables and pipelines. The North Sea has numerous ports and harbours situated on its coasts, including two of the world's largest ports - Rotterdam and Hamburg. The North Sea is frequently traversed with many dense shipping lanes, particularly in the Southern part of the North Sea. Generally, there is an increase on pressures on marine space and many parts the sea basin are strongly congested, especially near shore[1].

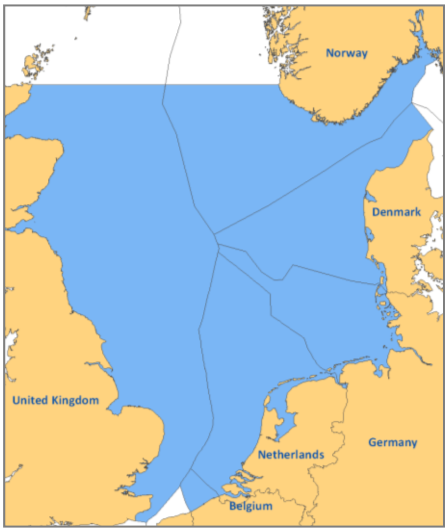


Figure 1: WINDSPEED study area and countries

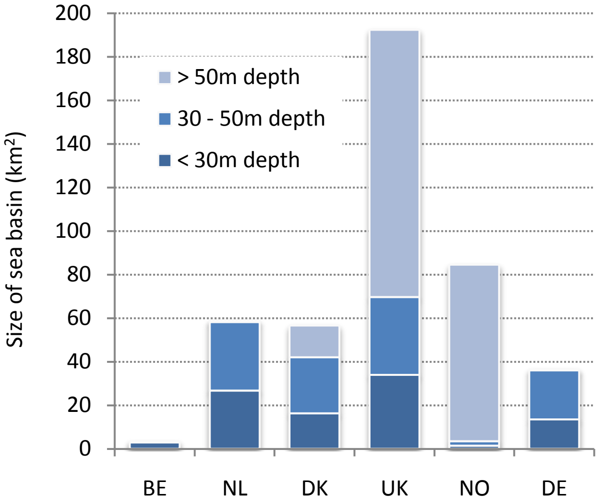


Figure 2: Size of sea basin by country and depth

Country	Sea basin size (km^2)	Key characteristics
Belgium	3 400	Small and densely used area. Very little room for further development of OWE.
Denmark	56 600	One of two sea basins belonging to Denmark, but holds the majority of OWE opportunity. Fairly large coastline and areas of shallow waters.
Germany	38 400	One of two sea basins belonging to Germany but much larger than the German Baltic Sea basin. Compared to North Sea neighbours, it is relatively small and fairly congested, including IMO shipping lanes and major nature reserves.
Netherlands	58 900	Quite congested areas, in particular closer to shore, including important IMO shipping lanes. Fairly shallow waters
Norway	84 500	For a large part deep waters, average water depth of over 100m
UK	192 400	Largest area of the six countries, water depth increases with distance from shore

Table 1: Key characteristics of each country's EEZ (in Central and Southern North Sea)

At a time when OWE is strongly driven by EU and national policies, and pressures on marine space are increasing, an early understanding of how driving forces can impact on opportunities, challenges and future trends will allow for a better adaptation of policies to promote a greater deployment of OWE. This merits a more in-depth and detailed analysis of the different parameters that relate to competition for sea space and the cost of OWE. This is a key motivation behind the WINDSPEED project. The WINDSPEED project, funded under the Intelligent Energy for Europe programme, has taken a closer look at the potentials for OWE in the Central and Southern North Sea. To do this, it has developed a methodology for an integrated assessment of how various constraints – spatial, policy, growth, grid and market integration – impact on deployment potentials.

[1] There is no clear cut definition of what is meant by near shore. In the WINDSPEED project, use of the term near shore includes the areas which are currently planned for OWE deployment.

Approach

This Roadmap has been developed in four phases:

Phase I: Information on different sea uses and their geographical presence in the North Sea was collected and harmonised. Sea uses comprise fisheries, oil and gas extraction, sand extraction, shipping, cables and pipelines, existing and planned OWE, military activities, nature conservation, and marine wildlife preservation. Taking stock of the current and future presence of sea uses is a prerequisite for an assessment of the potential for further development of OWE. Datasets on, amongst others, average wind speeds, wave regimes, bathymetry, staging port locations, were used to determine the levelised production cost (LPC) of OWE. Finally, this phase also included the definition of calculation rules to allocate space between OWE and other sea use functions.

Phase II: Datasets and calculation rules from phase I were incorporated into a so-called Decision Support System (DSS). Such a tool, developed for maritime spatial planning purposes, uses geographical information system (GIS) software which allows for the spatial representation of offshore wind energy in relation to costs and presence of non-wind sea use functions.

Phase III: Four different scenarios were then developed (illustrated in Figure 3) to study how OWE might develop in the time frame to 2030 under different constraints and priorities. The resulting feasible growth of OWE was modelled for each of the scenarios in order to account for the fact that not all of the North Sea's vast potential for OWE will be realised, the lowest cost areas are most likely to be developed first and growth will be dependent on support policies in each country.

Phase IV: The last phase incorporated all results into a final Roadmap, which identifies an ambitious but realistic target for OWE deployment in the Central and Southern North Sea, and a set of policy recommendations on how to achieve this target.

In assessing the potential for offshore wind deployment, an important distinction was made between the time period up to 2020 and the time period 2020 - 2030. The scenario analysis has assumed an implementation of the NREAP projections for OWE in the Central and Southern North Sea countries involved by 2020, and focused on an assessment of additional space for OWE deployment for the time period 2020 - 2030.

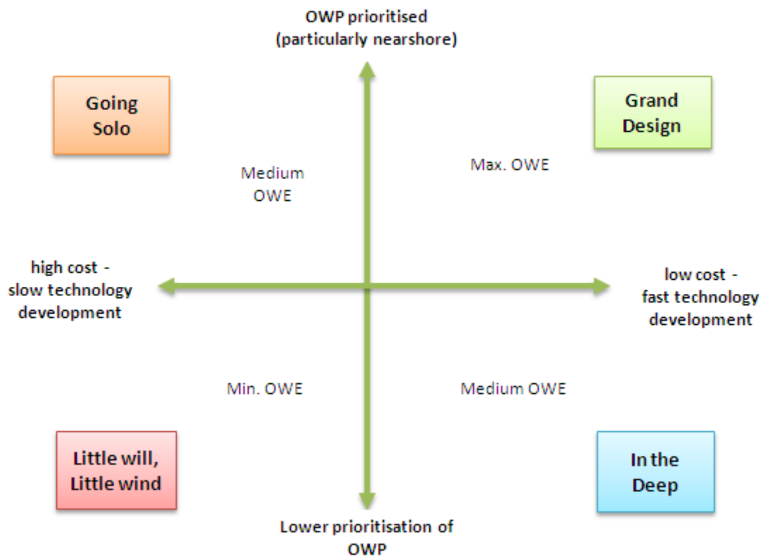


Figure 3: WINDSPEED scenarios

Scenarios have been chosen to reflect different aspects influencing OWE deployment, such as OWE ambitions in 2030, priority given to OWE over other sea use functions, constraints on costs, and attention to international, cross-border synergies. These are described in more detail in Chapter 4. The different development perspectives and their corresponding pathways can help to identify what policy framework is needed to match the chosen OWE deployment ambition

Stakeholder involvement

'Stakeholders' generally refers to different parties who have a vested interest (or 'stake') in decisions being taken. In the context of the WINDSPEED project, there are numerous stakeholder; the offshore wind industry – including manufacturers, developers and various companies involved in the processing chain; policy makers; regulators; TSOs; as well as all those representing other sea uses. Their interests relate to decisions on where, when and how much OWE can be developed.

Stakeholders have been involved in each step of the WINDSPEED process, primarily through stakeholder workshops organised as part of the project as well as through numerous dissemination events. Feedback from stakeholders has focused on two aspects. Firstly, in establishing the DSS, and, secondly, the approach taken that includes the application of the DSS to address opportunities for new deployment areas for OWE. The stakeholders have assisted in bringing to the surface key issues with respect to further developments in OWE and other sea uses, such as the potential synergies between OWE and oil & gas. An aspect that is, however, difficult to take into account in the planning of new areas for OWE since details of decommissioning plans are often not fully disclosed. Another important issue raised was the important of health and safety as well as collision risks in determining safety and buffer zones. With large scale deployment of OWE on the horizon, many stakeholders are concerned about the impact of OWE in a sea basin which already accommodates numerous economic related activities and at the same time is home to a rich biodiversity. Care was taken by the WINDSPEED team when designing the DSS and scenario analysis to allow for such concerns to be addressed.

Roadmap structure

This Roadmap is structured as follows:

Chapter 2 presents the "starting point" for further analysis of OWE potentials in the Central and Southern North Sea. It gives an overview of where we are in terms of current and planned deployment. It briefly describes the policy framework, including targets and ambitions, planning and permitting procedures, support mechanisms and grid integration issues.

Chapter 3 addresses some of the challenges and opportunities regarding two key uncertainties; namely competition for space at sea (in particular near shore), and technology development and cost evolution.

Chapter 4 summarises how OWE could potentially develop in the future, depending on different priorities and how key uncertainties impacting on the development of OWE will unfold. This chapter presents highlights and results from the WINDSPEED scenario analysis.

Chapter 5 presents the overall target for OWE in 2030, which the WINDSPEED project concludes is realisable. It also presents recommendations on policy actions and milestones needed to achieve such a target.

2 Point of departure

This chapter highlights the current status of OWE developments and associated policy frameworks, and as such focuses on the first of the three key Roadmap elements; namely the point of departure. In addition to an overview of current developments, this chapter also provides a brief overview of targets/ambitions, support schemes, Maritime Spatial Planning (MSP) as well as incentives and regulations to facilitate the necessary grid infrastructure.

Current developments

The current capacity of operational OWE in the Central and Southern North Sea totals around 1.8 GW. The North Sea currently has the highest installed capacity compared to other sea basins around the world. In comparison, the Baltic Sea and Irish Sea have a total installed capacity of around 650 MW and 450 MW respectively. The operational parks are listed in Table 2.

Wind farm	Country	Capacity (MW)	Turbine size (MW)	Foundation	Water Depth (m)	Dist. to shore (km)	Year of completion
BARD Offshore I	DE	400*	5	Tripile	39-41	101	2012
Thanet	UK	300	3	Monopile	20-25	11	2010
Horns Rev II	DK	209	2.3	Monopile	9-17	32	2009
Lynns & Inner Dowsing	UK	194	3.6	Monopile	6-11	5	2009
Gunfleet Sands	UK	172	3.6	Monopile	2-15	7	2010
Horns Rev I	DK	160	2	Monopile	10-20	18	2002
Belwind	BE	160	3	Monopile	15-37	46	2010
Princess Amalia	NL	120	2	Monopile	19-24	26	2008
OWEZ	NL	108	3	Monopile	15-18	13	2008
Kentish Flats	UK	90	3	Monopile	3-5	10	2005
Scroby Sands	UK	60	2	Monopile	0-8	2.5	2004
Alpha Ventus	DE	60	5	Tripod, jacket	28-30	56	2010
Thorntonbank	BE	30	5	Gravity	13-19	27	2009
Beatrice	UK	10	5	Jacket	45	23	2007
Hywind	NO	2.3	2.3	Floating	220	10	2009

Table 2: Existing parks in the North Sea basin (*partially operational; 15 out of 80 turbines grid connected at July 2011)

The UK is currently the leading country in terms of installed OWE capacity. The largest park to date, Thanet Offshore Wind Park, has an installed capacity of 300 MW, but the BARD Offshore I wind park in Germany will surpass this once complete in 2012. The majority of projects have been installed using monopile foundations, which currently is feasible for water depths of up to 35 m. However, other foundations have been tested and used. Alpha Ventus in the German sea basin is a demonstration project for 5 MW turbine technology using different foundation technologies that are suitable for deeper waters, such as tripod and jacket foundations. The existing parks consist of turbines ranging between 2 and 5 MW. The BARD Offshore I project is using the tripile foundation technology. Table 2 also includes the Hywind project. Although this project is located just outside the WINDSPEED study area, it is the first floating turbine concept in the world. The success of this project could have important implications for developments in the deeper sections of the Central and Southern North Sea basin.

Table 3 gives an overview of the projects that are currently under construction in the WINDSPEED study area. This overview shows that offshore wind in the North Sea is clearly moving from a pioneering phase to large scale deployment. These new parks are typically significantly larger than existing parks. However, with the exception of the BARD I Offshore project, currently under construction and located 90 km from shore, projects remain fairly close to shore.

Wind Farm	Country	Cap. (MW)	Water Depth (m)	Distance to shore (km)	Year of completion
London Array	UK	630	23	20	2012
Greater Gabbard	UK	504	4-37	23	2012
Sheringham Shoal	UK	317	14-23	17	2012
Lincs	UK	270	7-12	8	2012

Table 3: Offshore wind parks currently under construction in the North Sea

In addition to these operational and under-construction parks, there are a large number of projects that can be broadly classed as 'planned'. These projects are to be found at many different stages of the planning process. Some have received the necessary consents but are awaiting commencement (for example 24 projects in German North Sea basin with a total capacity of approximately 6.5 GW), others have been consented but are awaiting support scheme funding (for example in the Netherlands), some have been provided with seabed leases but await further permitting procedures (for example the Round 3 zones in the UK), many have submitted applications for consents and are waiting on responses, and yet a further group are based on the proposed/revealed plans of developers, but have not been taken substantially further at this time. All in all the 'planned' capacity is very large, with European Commission (EC, 2010) estimates putting this figure in the realm of 140 GW across all member states.

Targets and ambitions

EU's climate and energy policy – driven by a three overall objectives: clean, secure and affordable energy – is a key driver behind the growth of RES in Europe, including OWE. The EU's current policy framework includes the Renewable Energy (RES) Directive (2009/29/EC) that sets an EU target of a 20% share of renewable energy in total energy consumption by 2020. This overall target has been broken down into a national binding RES target per Member State. Member States are also obligated to publish a National Renewable Energy Actions Plan (NREAP), indicating the mix of RES technologies which they expect (and intend to promote) to reach their national 2020 targets, along with the policy framework to support this. The NREAPs for Belgium, Denmark, Germany, the Netherlands and the United Kingdom announce an installed OWE capacity of approximately 32 GW by 2020 in their respective sea basins. The majority of this capacity is expected to be deployed in the North Sea. Norway[2] has not currently set any targets for the development of OWE in its sea basin.

However, with the exception of Germany, Denmark and the UK, there is little information regarding ambitions beyond 2020. These three countries have previously indicated targets of 4.6 GW and 33 GW by 2025 (Denmark and UK respectively) and 25 GW by 2030 (Germany).

[2] Norway, a non-EU country, is currently negotiating with the European Commission on a binding RES target for 2020, under the framework of the EEA agreement. Following a successful negotiation, it is expected that Norway will implement the RES Directive and submit a NREAP to the European Commission.

Figure 4: Thorntonbank Offshore Wind Park

Maritime Spatial Planning and conflict management

The expansion of sea use functions, including OWE, and the increasing need to coordinate these use functions has led to an enhanced interest in maritime spatial planning (MSP). MSP is an important tool that brings together multiple users of the sea – including energy, industry, government, fishing, conservation and recreation – to make informed and coordinated decisions on the use of marine resources. MSP can provide OWE developers with more certainty in where offshore wind parks may or may not be built in the future. Finding adequate locations is a prerequisite to large scale deployment. Adequate planning tools, such as geographical Information System (GIS)-based tools, are being used to address and better understand competing uses and spatial opportunities/limitations of different sea uses. These tools are also used to understand potential trade-offs in moving current non-wind sea use functions from favourable offshore wind energy locations to other locations.

Different MSP approaches are used in the WINDSPEED countries to identify and allocate locations for offshore wind parks. In some countries, the permission to build and operate a wind farms is linked to the allocation of support through a tendering scheme. Strategic environmental assessments (SEA) have been applied, such as in the UK, to best identify zones in accordance with important environmental constraints. The UK has also applied the concept of consecutive deployment rounds. This has the advantage of providing flexibility to adapt the zoning of areas as information - for example in relation to environmental impacts - becomes available and technology choices expand throughout the development process and maturity of the industry. Several countries have facilitated demonstration projects in their planning procedures. Examples of such projects include Horns Rev (Denmark) and Egmond an Zee (Netherlands), which allowed for assessment of environmental impacts from design and layout of parks in absence of such knowledge.

Key characteristics of national MSP processes are summarised in Table 4.

Country	Allocation of sea bed rights	Characteristics of MSP regime
Belgium	Tendered	• First North Sea country to introduce an operational, multi-use MSP. • Introduces delimitation for OWE (270 km^2, equivalent space for 2 GW OWE) all of which has been allocated
Denmark	Tendered	• Government led site investigation for OWE development (23 specific locations for 200 MW parks, of which 14 locations are found in the North Sea basin) • Single site tendering process, concessions awarded to projects with best price per kWh
Germany	Open	• National MSP adopted in 2009, which sets guidelines for spatial development, targets and principles for functions and uses in the German sea basins • Priority areas for shipping, sea cables and pipelines and OWE, but developers can propose projects in additional non-excluded areas
Netherlands	Open, moving to tender	• Under outgoing framework, suitable areas for OWE were based on areas not excluded by other sea uses. Demand outstripped support, concessions awarded to developers with lowest tariff • New National Water Plan, awaiting full implementation, defines suitable areas for OWE (4 areas of which 2 are search areas) and is poised to use tenders for specific sites • Development of Round 3 projects put on hold as financial support is not currently available
Norway	-	• 15 areas (of which 2 are in the WINDSPEED area) identified for strategic environmental assessments (SEA) • SEA will be carried out before areas will be made available for OWE deployment
UK	Tendered	• Multi-site tendering of zones • Sea-bed leases awarded from the Crown Estate in consecutive rounds of tendering • Most recent Round 3 specifies zones within which discrete parks are proposed by developers for permitting.

Table 4: Characteristics of MSP regimes in the WINDSPEED countries

The North Sea countries have notably taken steps to improve their own planning framework, with a clear trend towards a more pro-active spatial planning. Well aware of the benefits of more coordinated planning across borders, planning regimes remain nationally focused. The Dogger Bank area, which is interesting from the perspective of large scale OWE deployment, is an area where integrated planning is needed. It has at least two management challenges. Firstly, the area is spread over the EEZs of Denmark, Germany, the Netherland and the UK. Secondly, it is an area with where multiple claims are increasing. Being an important area from the perspective of natural value preservation, the Netherlands and Germany have designated the area as a Natura 2000 site, whereas Denmark and the UK have not (in the UK section of the Dogger Bank, a round 3 zone with a capacity of up to 13 GW is identified). There is a clear need to understand the increasing pressures and impacts of activities from a joint perspective in order to establish common objectives and compatible measures.

It can also be observed that MSP efforts to date have generally been nationally oriented. While some cross-border consultation takes place, it is often ad-hoc or sector based. There is currently no official transnational forum for MSP in the North Sea. Furthermore, different member states have undertaken MSP activities at different times. Without streamlining of the development of MSP and trying to coordinate activities, it is difficult to effectively cooperate on planning decisions.

Support mechanisms

Alongside other RES technologies, commercial deployment of offshore wind currently requires economic incentives or financial support to bridge the gap between the wholesale electricity price and the levelised cost of production of projects. Support mechanisms need to be well-designed to make deployment economically attractive, which in turn can open up for economies of scale and reduce

costs in the medium to long term. The two main types of support mechanisms used today are quota obligations coupled with tradable green certificates, and feed-in tariffs or premiums.
Table 5 shows the variety of support mechanisms used by the six WINDSPEED countries. In addition to differences in design and size of support, countries also apply different rules on who should bear the grid connection costs. Denmark and the Netherlands typically offer feed-in premiums through tendering schemes, allowing for competition to spark the development of parks at lowest cost. In Denmark, the TSO is responsible for the grid connection, whereas in the Netherlands, this burden is put on the developer. Germany, on the other hand, has an open-ended feed-in tariff scheme, which implies that all applicants receiving necessary concessions are granted a feed-in tariff. Frequent changes have been made to the design and size of the German feed-in tariff in attempts to tailor the scheme to real costs. The UK provides OWE developers with tradable green certificates, known as renewable obligation certificates (ROCs), which allow for market-based earnings on top of the wholesale electricity price. Technology banding has been introduced in the UK ROC system to provide for additional support to more expensive technologies, such as OWE.

Country	Main support mechanism	Support level (€/MWh)	Additional incentives	Responsibility for grid connection
Belgium	Quota obligation	Minimum payment of 107 €/MWh (over 20 years) for first 216 MW installed, thereafter 90 €/MWh	Lower balancing cost if real production stays within 30% of nominated production	Developer, support provided by TSO for 25% of cable connection cable cost, max 25M€
Denmark	Tender + feed-in premium	1.05 DKK/kWh (approx. 13 4€/MWh) for first 50,000 full load hours (result of the last tendering process)		TSO
Germany	Feed-in tariff	150 €/MWh for a minimum of 12 years (of which 20€/MWh is bonus for projects initiated before 2015), 35 €/MWh for next 10 years. Alternatively a so-called squeezed FIT of 190 €/MWh which is granted for 8 years can be chosen.	To accelerate investment in OWE, the public German KfW bank is providing a total of €5 bil. loans for the first 10 parks (at market based interest rates)	TSO
Netherlands	Tender + feed-in premium	Average expected premium of 110 €/MWh (over 15 years) above the average yearly electricity price on the day ahead market	Tax incentives	Developer
Norway	Capital grants	Currently no support incentives for development of offshore wind parks. Joint Norwegian-Swedish certificate scheme will be introduced on 1 January 2012, however, it is expected that the certificate price will be too low to be attractive for OWE developers. Additional support for OWE not yet identified.	Capital grants for demonstration projects	Developer
UK	Quota obligation[3]	1.5 ROCs, temporary increase to 2/1.75 ROCs for projects with financial closure by March 2010/2011, average ROC price £50 (approx. €56) (April 2011), certificates to 2037.	Climate change levy Capital grants	Developer

Table 5: Support mechanisms and grid connection regimes in the Central and Southern North Sea countries

[3] The UK has recently announced a move to feed-in tariffs with contracts for difference, compulsory from 2017; however, tariffs are not yet known.

In several of the WINDSPEED countries, there is clearly a lack of coherence between OWE ambitions identified through MSP processes and the level of support generated through the national support schemes. In the Netherlands, the round 3 developments of OWE, foreseen in the period 2012 – 2020, have been put on hold due to a lack of funding mechanisms. In the UK, the significant leases in round 3 are likely to face hurdles with the current forecast RES requirements within their obligation system.

Differences in planning procedures and economic incentives for OWE projects may pose a challenge for future coordination and cooperation of OWE deployment. Whilst the design and size of support in €/MWh differs quite significantly between countries, this may change over time. Should cross-border flows of OWE become significant, this may push support levels closer towards equivalency.

Grid and market integration aspects

Grid integration, comprising onshore connection and offshore interconnections, is a key barrier to large scale deployment of OWE. In anticipation of large scale deployment of offshore wind, an offshore electricity infrastructure in the North and Baltic Seas is at present a key topic on the EU energy agenda. In the European Commission's energy infrastructure blueprint communication (EC, 2010a), one of the priority corridors identified to allow for electricity grids suitable for 2020 is the offshore grid in the Northern Seas and connection to Northern and Central Europe. First steps towards increased cooperation and coordination between countries with respect to connection of large scale OWE in the North and Baltic Seas were initiated through the establishment of the North Sea Country Offshore Grid Initiative (NSCOGI) in December 2010. This important and timely collaboration, between several EU Member States and Norway, aims to create an integrated offshore energy grid linking offshore wind farms and other renewable energy sources across the northern seas of Europe. A first step in this initiative is to address the regulatory, planning and economic challenges involved in linking the offshore wind capacities to a European offshore grid by end of 2012.

The EU is currently also playing a key role in facilitating the establishment of appropriate grid infrastructure through the EU-funded European Energy Plan for Recovery (EEPR), which came into force in 2009. A number of interconnections are currently in the planning stage in the North Sea. Three examples are the interconnector between Norway and Germany (Nor-Ger link), the interconnector between Norway and UK (Brit-Nor link) and the COBRA project between Denmark and The Netherlands. The Nor-Ger and the Brit-Nor links will connect the Norwegian system with the German and British electricity systems respectively, to improve security of supply and provide the German and UK markets with flexible Norwegian hydropower. Hydropower can be used as balancing power to account for the generation variability that increased levels of installed wind power will introduce in the German and British systems. The COBRA project is an undersea electricity cable to be installed between the Netherlands and Denmark. The objective of the COBRA project is to advance the integration of more sustainable energy (particularly wind energy) into the Dutch and Danish electricity supply. For these projects, possibilities of connecting offshore wind farms to the cable in a T-connection configuration will also be investigated. These projects can be regarded as important first steps towards an eventual development of an offshore electricity grid, especially if T-connection solutions connecting the links with one or several wind farms and/or with a nearby offshore hub are chosen. T-connections will likely involve the use of VSC technology, instead of classical LCC technology. VSC is the technological choice needed for multi-terminal meshed offshore grid configuration. The COBRA project has received funding under the EC Recovery plan[4].

Regarding timing for construction of the offshore grid electrical infrastructure, we take as examples the existing Nor-Ned and Brit-Ned links, the future Nor-Ger HVDC link, the existing offshore wind farm

[4] For details on existing projects see (ENTSO-E, 2011).

BARD Offshore 1 and the future offshore wind farm Dogger Bank (see Huertas Hernando *et al.* 2011 for details). The total period of time for the completion of these projects seems to be approximately between 8-10 years, of which the application process, approval and investment decision typically takes 5-7 years and construction phase 3-5 years. For 2030 as target year, it seems reasonable to assume that new pro-OWE regulatory and commercial frameworks should be established in the period 2015-2020 such that large scale investment decisions are being made latest before the beginning of 2020. Under these assumptions, large scale construction of an offshore grid can slowly emerge from national development to international coordination between 2020 and 2030, with a minimum total construction time of 10 years.

The current electricity market rules act as a barrier against using the full 'technical' potential of offshore wind development as well as the added flexibility potential of hydropower as a balancing resource. An important barrier to present and future increase of cross border energy exchange and trade of power between the North Sea, the Nordic area, UK and continental Europe is that there are differences in the markets mechanisms in the European countries. As per today, these are very different between different countries. It is *e.g.* not clear how offshore wind farms could be connected to several different countries to allow for trans-national power exchanges. There are differences in the timing of the different market actions also. Regarding large scale integration of wind power, mechanisms improving the interaction between balancing markets and the intra-day spot markets have been suggested (Grande *et al.*, 2008).

In summary

- The Central and Southern North Sea basin has currently a leading role in the deployment of OWE, with a capacity of 2GW (expected by end of 2011). This sea basin is in a position to continue its leadership in OWE deployment.
- Although foresight and timing are crucial elements for providing investor confidence, there are currently no clear ambitions or targets for further OWE developments beyond 2020.
- There is a clear lack of coherence in the current ambitions and support provided for OWE deployment.
- North Sea countries are notably taking steps to improve their own MSP framework, however, few efforts are being made to look beyond national borders.
- All parks are currently radially connected to shore; however, a few interconnector projects in the planning phase will likely address the possibility of T-connection solutions.
- Current electricity market rules and differences in national support schemes act as a barrier against using the full 'technical' potential of offshore wind development as well as the added flexibility potential of hydropower as a balancing resource.
- National orientation of support mechanisms persists; however, should cross-border flows of OWE become significant, this may push support levels closer towards equivalency.

3 Challenges and Opportunities

The point of departure described in the preceding chapter – at this stage somewhat modest in its level of OWE deployment – holds tremendous promise based on the efforts of member states to date and their ambitions for the future. But, like any roadmap, it can be instructive to understand the obstacles that may lay over the horizon and, equally, the opportunities for smooth travel.

This chapter takes a look at some of the key challenges and opportunities with regards to competition for space at sea and to technology development. These two aspects are used to distinguish the four different scenarios from one another, due to their importance as determinants of future deployment of OWE in the North Seas.

It is vital to understand, firstly, the characteristics and compatibilities of different sea use functions with OWE. Secondly, the key uncertainties with respect to technology availability and costs must be considered, focusing in particular on what the main cost drivers are, on the implications for choice of locations to develop OWE, on how are costs likely to change, on what cost uncertainties OWE faces and on how cost changes are likely to impact on spatial opportunities and constraints.

The North Sea and its dynamic users

The Central and Southern North Sea – approaching half a million square kilometres in size – supports a large volume of varying commercial activities and also provides important value in terms of marine habitats and populations. From a spatial perspective, the challenge is to find space for new OWE that balances the need for low cost renewable energy against the needs of these other, so called, non-wind sea use functions. The non-wind sea functions studied within the WINDSPEED project comprise shipping, fisheries, military areas, cables and pipelines, oil and gas extraction, nature conservation areas, marine wildlife preservation, and sand extraction. These functions have quite different characteristics, with respect to their current and future expected presence, their compatibility and overlap with other sea uses, flexibility in use patterns and general importance to society. Some sea use functions change from year to year as their underlying resource changes (for example fisheries), others align themselves to their optimum areas of the North Sea (for example shipping) while yet others involve immovable infrastructure based on fixed resources (for example oil and gas extraction). Table 6 gives an overview of the most important characteristics for each non-wind sea use function included in the WINDSPEED analysis.

Not only do the characteristics of each sea use function differ, but many of these uses overlap with each other. For example, it is possible to find areas of the North Sea zoned for both nature conservation and military use, with cables or pipelines running underneath, with the same area also allowing shipping passage and fishing activities. This greatly complicates any search for new locations for OWE. Not only must the compatibility and flexibility of each sea use function with respect to OWE be considered, but also their interactions with other non-wind use functions. Figure 5 illustrates the high level compatibility of the different sea use functions considered in the WINDSPEED project.

Sea use function	Current Extent	Future development	Characteristics
Shipping	approx. 10 – 25% (depending on shipping density)	moderate growth	The movement of vessels for a wide variety of purposes. The focus in WINDSPEED is on route-bound traffic which, in travelling from place to place, needs a route of safe passage. The project considers both internationally regulated routes (IMO routes) and national/informal traffic requirements; hence the large variation in extent reported at left, depending on the definition of shipping considered to be 'in use'.
Fisheries	extensive, but not clearly demarcated	Stable, with possible changes to techniques	Fishing activities cover almost all of the North Sea in some form or another depending on targeted fish species, fishing techniques and boat sizes. Moreover the resulting use patterns can be highly variable from season to season and year to year depending on fish stocks. WINDSPEED focuses on heavy fishing using beam trawl or similar methods that have the potential to come into conflict with OWE or the associated cables.
Military areas	approx. 14%	stable	Covering a wide range of activities – including submarine manoeuvres, firing ranges, munitions dumping, aerial exercise and others – military zones are defined by governments in the interest to training and security. WINDSPEED incorporates maps of these zones along with information on usage type where available.
Cables and pipelines	approx. 8%	moderate growth	Cables (for example for electricity or telecommunications) and pipelines (for example for gas or oil transport) run across large stretches of the North Sea. WINDSPEED includes maps of the known cable/pipeline infrastructure and defines exclusion zones on either side of the cable/pipe in order to provide protection and maintenance access.
Oil and gas extraction	approx. 11%	decline through decommission ing	There is a significant amount of infrastructure in the North Sea that relates to the extraction of oil and gas reserves and these platforms and installations require, depending on their nature, varying sizes of exclusion buffer around them to ensure safe and reliable operation. WINDSPEED includes information on both surface and sub-surface infrastructure/platforms. CO_2 storage is also a possibility in the North Sea and could impact on the amount of offshore infrastructure. However a lack of firm knowledge on extent and location meant that it could not be considered in the WINDSPEED project.
Sand extraction	approx. 2%	stable	The extraction of sand and gravel is necessary for a number of onshore activities including land reclamation, beach nourishment and construction. Dredging also occurs in shipping lanes to ensure free passage. WINDSPEED maps the known areas of sand extraction in order to understand them as a constraint.
Nature conservation	approx. 13%	growth likely	This sea use function includes the network of protected areas that are identified under the Birds Directive and Habitat Directive (Special Protection Areas and Special Areas of Conservation respectively). WINDSPEED contains information on these two types of conservation area, both current and proposed.
Marine wildlife	present everywhere but not clearly demarcated	uncertain	This sea use function has been developed within the WINDSPEED project to supplement the nature conservation areas described above, based on the lack of firm knowledge that is available regarding the cumulative effects of OWE. It is implemented through a series of nature value/vulnerability maps for birds, fish and benthos that are combined into a wildlife preservation map that shows which areas are most valuable in terms of nature values.
Other offshore renewables	Presently negligible	growth - uncertain scale	A number of other renewable energy sources – such as tidal and wave power conversion devices and algae farms – could develop in the North Sea. However, a lack of available information on their future development excluded them from the WINDSPEED project. Moreover, these sources are generally compatible with OWE sites in terms of co-use of space so are deemed unlikely to impact project results.

Table 6: Overview of sea use functions –current extent, expected development and key characteristics

Furthermore, different sea use functions are present in different portions of the North Sea. Some are predominantly found closer to shore or in shallower depths (areas that could be of interest for low cost OWE), while others are typically further from shore or in deeper waters. This interaction between location and cost is a key aspect of the WINDSPEED project and is discussed further in the following section of this Chapter.

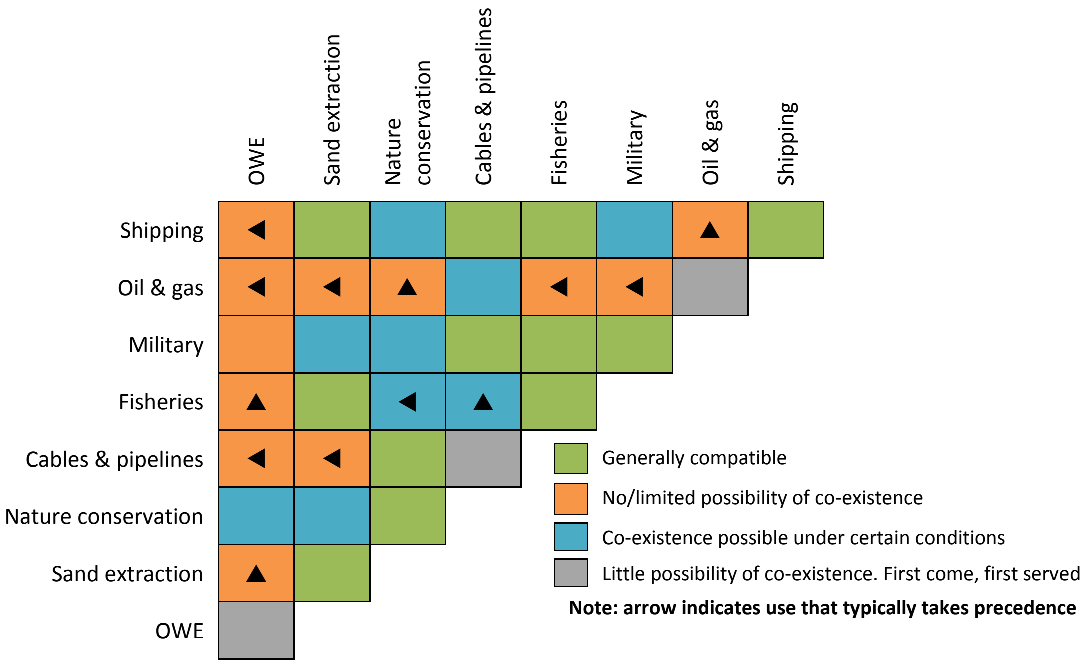


Figure 5: Interactions between sea use functions (source: adapted from van der Wal *et al*., 2009)

Finally, OWE is not the only use function that is anticipating a change in its stake in the North Sea. Other uses such as shipping, cables and pipelines are expected to undergo significant growth over the coming decades, as well as possible changes in the nature of that use (for example trends towards larger vessels). On the other hand, activities such as oil and gas extraction are expected to reduce their spatial claim in the North Sea significantly based on announced decommissioning plans. Yet there is little firm knowledge of exactly when individual platform decommissioning will take place due to ongoing technology and demand changes within that industry. Considerations such as these only serve to increase the challenge to identify future OWE locations in the North Sea. Future developments in non-wind sea uses have been accounted for in the development of the WINDSPEED scenarios, in as much detail as was practicable from the information available at the time of the analysis.

The future of OWE in the North Sea also faces challenges in regards to its interactions with, and impacts on, nature values. These can be both locally, where an individual park is built, and more broadly, based on possible neighbouring effects or impacts on remote, but linked ecosystems. While existing nature conservation areas (Special Protection Areas, Special Areas of Conservation and other nationally defined conservation areas) are presumably sufficient for the current level of commercial activity in the North Sea, there is little information available on the cumulative effects of future large scale offshore wind deployment. This uncertainty makes it difficult to answer important questions such as “What level of nature protection is required in the future?” and “How might this be distributed?” This uncertainty suggests that a conservative approach – which assumes some level of increase in nature conservation areas in the future, as implemented in the WINDSPEED project – has merit.

To do this, the WINDSPEED project introduced a new use function that relates to marine wildlife vulnerability outside of recognised nature conservation areas. A combined map representing the overall vulnerability of bird, fish and benthos species was used to reserve critical areas for preservation. This was done in an effort to anticipate growth in nature conservation areas in the future in recognition of the possible cumulative impacts from OWE on the marine environment. This new use function gives an additional level of nature protection to the North Sea region that is roughly equivalent in size to the current nature conservation areas.

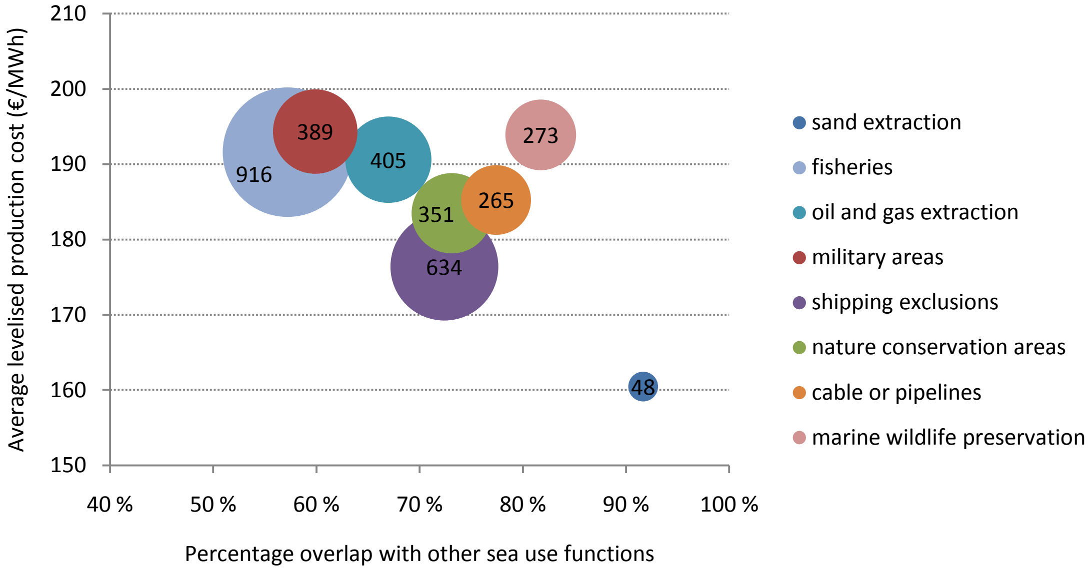


Figure 6: Excluded generation potential (circles labelled in TWh) versus cost and spatial exclusivity - default case (Cameron *et al*., 2011)

Based on the project results, the five largest sea use functions – fisheries, shipping, military areas, oil & gas extraction, and nature conservation areas – are also the most significant spatial drivers with regard to OWE. They are not only the largest, but potentially the most interesting for OWE due to: i) the fact that on average their current locations offer a lower possible electricity cost; and/or ii) they are more 'spatially unique', meaning that they have less overlap with other sea use functions (Figure 6).

However, with this knowledge the question remains of what opportunities these sea use functions offer for new OWE. These could include simple compromise of another sea use function to reduce its extent, relocation of a sea use function, or integration of a sea use with OWE planning. Which of these approaches, if any, may be suitable in a given scenario was an important part of the scenario development process within the project.

Figure 7: Wakes behind wind turbines at Horns Rev offshore wind park

In particular, the opportunities for synergies between OWE and certain other sea use functions through integrated planning deserves further explanation. A fundamental premise of the work undertaken in this project is the inclusion of wind regeneration corridors, in the form of wide multi-kilometre gaps, between wind parks in order to reduce turbulence and inter-park effects and thus maintain the energy yield of neighbouring parks. While existing or planned offshore wind parks typically have densities in the order of 6 MW, or more, per square kilometre, there is a growing body of literature that suggests that such high densities are not sustainable over large areas of deployment. This is because wake effects and wind speed reductions behind consecutive rows of wind turbines begin to detrimentally affect the level of wind resource behind large parks (Phillips *et al.*, 2010).

In view of the recent findings on wakes within offshore wind farms and on wind speed deficits behind these wind farms, the WINDSPEED project considers that, within a defined area, only 30% of the total should realistically be occupied by wind farms. It is assumed that any large scale deployment of offshore wind will likely take the form of multiple wind farm clusters uniformly spaced, allowing adequate distance between each cluster to mitigate the impact of inter wind farm wake losses and the resulting lost production and wake turbulence loading (Jacquemin *et al.,* 2009). The remaining 70% shall provide space for wind speed recovery and dissipation of wake turbulent energy, but also possibly permit some form of navigation throughout the area (Figure 8). This provides opportunities for co-use/co-existence with other sea uses such as shipping and fishing. For example, a more formalised definition of areas for shipping activity (see German spatial planning practice; BSH, 2009) may offer a way to reduce competition for space between shipping and OWE, and provide clarity for wind park developers.

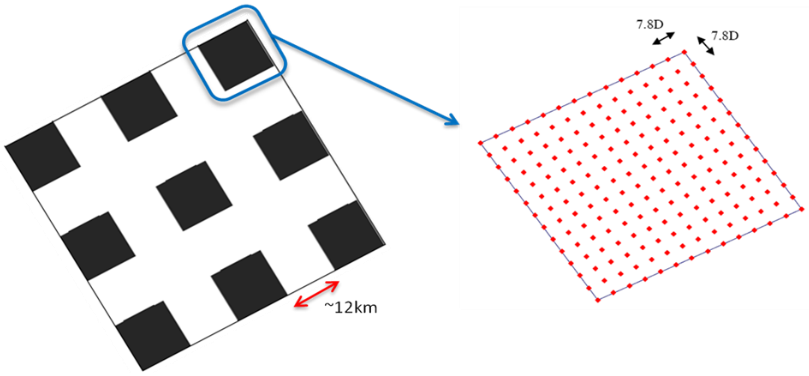


Figure 8: Illustration of wind park clustering (black squares), wind regeneration between parks, and turbines (red dots, 'D' is diameter) (Jacquemin *et al.,* 2009)

Technology and costs

Although OWE is still at a relatively early stage of development in terms of capacity deployed, it can be considered to be on the verge of large scale implementation. That is not to say that the technology is now mature. Instead, the many technical aspects of OWE, ranging from component design to installation techniques to maintenance methodologies, are all progressing and evolving. This reflects changing market requirements in terms of depths, distances to shore, scale of individual parks and delivered electricity costs amongst others.

While offshore wind turbines certainly inherit many design characteristics from onshore wind energy, there are a number of new challenges posed by the marine environment. These include: i) technical constraints on depth for traditional fixed foundations, ii) corrosion, iii) the significant cost penalties associated with operations and maintenance activities offshore, iv) the possibility of large distances to a grid connection point, and v) limited knowledge on the environmental impact of offshore wind turbines, at least compared to onshore.

With regard to operations and maintenance, a number of developments – apart from the improvements in the reliability of the turbines themselves – offer opportunities for cost reductions in the future. To date maintenance crews have been based onshore and have accessed remote sites by boat, but that situation is changing. Wind parks have already begun to look for alternative solutions for offshore intervention including offshore permanent offshore accommodation, helicopter based access, large accommodation vessels moored at sea or permanent 'island' structures constructed closer to wind park locations (Figure 9).

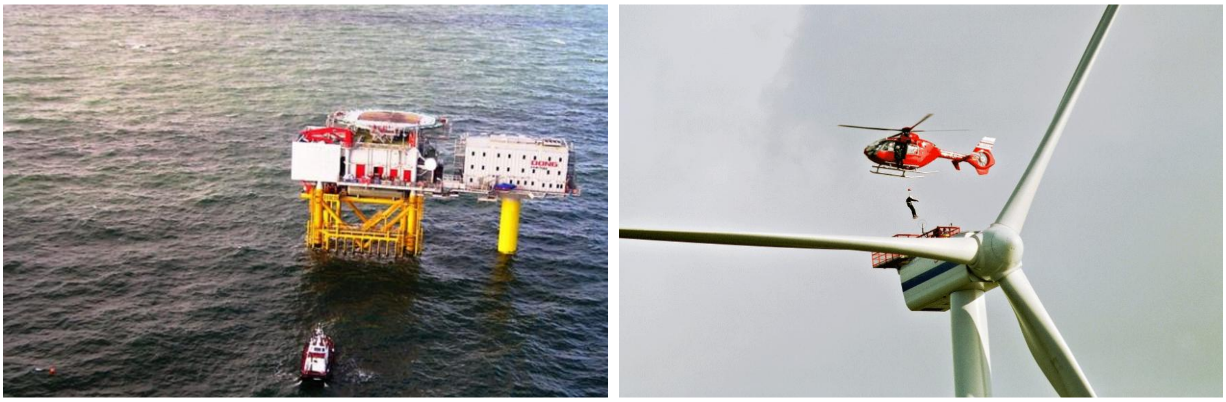


Figure 9: [Left] Offshore substation & living quarters at Horns Rev 2. [Right] Helicopter access for offshore maintenance

Large scale OWE in the North Sea will also require new interconnectors to improve opportunities for balancing of variable wind generation and to allow power to flow to demand centres. However, onshore connections have proven to be difficult to implement in the face of public resistance. This leaves open the possibility for an offshore grid to develop. In addition to reducing the need for onshore transmission reinforcements, offshore meshed grids can i) improve the reliability of power supply and allow more sophisticated power exchange and power balancing options to be implemented; ii) make further offshore areas more accessible; and iii) potentially allow countries with low cost OWE opportunities to export to neighbours.

Such an offshore grid would be based on high voltage direct current (HVDC) technology, and in particular on Voltage Source Converter (VSC) HVDC technology. Today there are more than 100 HVDC transmission links around the world, but nearly all of these are based on Line Commutated Converter (LCC) technology – often referred to as classical HVDC transmission – that has drawbacks in terms of its suitability for use in a (meshed) offshore grid. VSC schemes are superior to conventional LCC technology in terms of independent reactive power control, no need for external voltage source and fast system control. Moreover for LCC, huge space demands are needed for the converter stations, while much smaller spaces are needed for installation of VSC converter offshore platforms. These aspects indicate that VSC based HVDC technology is better suited than LCC technology for remote offshore wind farm connections (Huertas Hernando *et al.*, 2011). However, VSC technology is still in its infancy and the necessary multi-terminal solutions that would allow clusters of offshore wind parks to be interconnected do not exist today. For this reason WINDSPEED considered two pairs of scenarios, one pair that assumes that VSC technology does not become available at reasonable costs and a second pair that allows for the development of an offshore meshed grid in support of far from shore wind parks and improved power exchange and balancing potential.

Recent escalations in the costs of OWE have added further challenges for developers and governments seeking to promote offshore wind generation. Until the middle of the last decade there was optimism within the industry that OWE costs would decline as projects got larger and more wind parks were constructed. This optimism stemmed from observations of early wind parks in Denmark and the UK, and from drawing parallels with the development of onshore wind technology. However, the reality has been that OWE costs in recent years have been significantly higher than in earlier times, with capital costs in the UK in 2008 proving to be twice as high as those seen in 2003. This situation has come about for a number reasons including[5] (Greenacre *et al*., 2010):

- Rising materials, commodities and labour costs

[5] Stated in relation to the OWE industry in the UK, but can generally be considered to apply to the industry more broadly.

- Currency movements (mostly relevant for the UK)
- Increasing prices for turbines over and above the cost of materials, due to supply chain constraints, market conditions and engineering issues
- The increasing depth and distance of more ambitious projects, affecting installation, foundation and operation and maintenance (O&M) costs
- Supply chain constraints, notably in vessels and ports
- Planning and consenting delays

While some of these factors may be out of the control of project developers or policy makers, the possibility for future projects to be pushed towards deeper waters or further from shore locations will have important repercussions for spatial planning, grid connection methodologies and energy costs.

Water depth and distance to shore are two of the most important cost drivers for OWE, and were two of the aspects that are used to differentiate the scenarios used in WINDSPEED. To do this the project developed a bottom-up cost model that could estimate the delivered cost of energy for any site in the Southern and Central North Sea (Figure 10). This allowed the trade-offs between nearer-to-shore/shallow water and far-shore/deep water development to be compared, including interactions with other sea use functions and impacts on electricity costs.

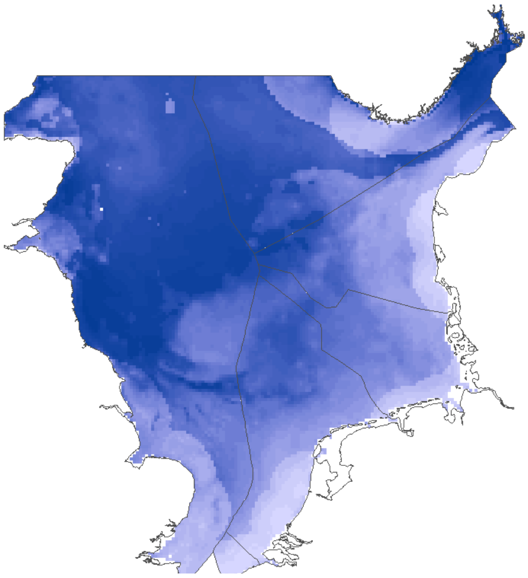


Figure 10: Levelised production cost of electricity in the WINDSPEED area [darker shades show higher costs]

Figure 11: BARD offshore I wind park – first six turbines with tripile foundations

In summary

- The North Sea is home to a wide variety of sea use functions with differing spatial use patterns, characteristics and interactions with OWE.
- These uses are often observed to overlap with each other, complicating the possibility of identifying additional space for OWE.
- It is important to look at future use patterns and requirements, not just the current situation in the North Sea.
- The anticipated densities of offshore wind parks – due to practical issues of wake minimisation – present co-use or integrated planning opportunities with certain other sea use functions.
- There is a balance to be struck on keeping OWE costs low – in terms of identifying space closer to shore or at shallower depths – and the spatial requirements of other uses. Finding the best locations for OWE, from a societal point of view, is contingent on all necessary information on current and future sea uses being made available, which is currently a challenge.
- OWE is still at an early stage of industrial/technological development. Large scale implementation implies overcoming challenges related to reduction of OWE development costs.
- Large-scale OWE in the North Sea opens the possibility of an offshore grid as a connection solution.

4 Looking ahead

This Roadmap aims to show the development pathway for OWE and other use functions for a number of 'development perspectives'. These perspectives differ with respect to policy ambitions, priority given to OWE over other uses, technology development, and assumptions regarding international, cross-EEZ synergies. The set of perspectives and their corresponding pathways roughly indicate the playing field for policy making, with a specification of the entailing development of OWE, a cost assessment for OWE, offshore grid infrastructure implications, and a study of the impacts on other sea uses.

The discussion of policy perspectives and potential pathways for OWE deployment focuses mainly on the timeframe 2020-2030. It is considered that the pathways up to 2020 are less flexible in terms of possible divergence from the trajectories that Member States have presented in their NREAPs. Not only have ambitions over the next decade been declared, but the long lead times in planning, permitting and construction suggest that a timeframe of 2020-2030 is more appropriate to focus on, with greater opportunities for policy changes to have an impact. The NREAPs are an important starting point in developing the policy perspectives in this Roadmap, and it is assumed that the ambitions within them will be met.

How much space is there?

Planning the deployment of new OWE in the North Sea is challenging, particularly when considering medium-term timeframes to 2030. Cost and technological considerations, as well as competition for space, need to be taken into account. Moreover, these aspects can all change over time.

In order to assess the potential for offshore wind deployment in the Central and Southern North Sea, four scenarios were developed within a two dimensional framework. The two dimensions reflect, firstly, various spatial allocation priorities and interaction regimes for OWE in relation to other sea uses and nature conservation and, secondly, differing viewpoints on technology development and costs (Figure 12). These two dimensions reflect two of the key uncertainties that impact the future deployment of offshore wind energy.

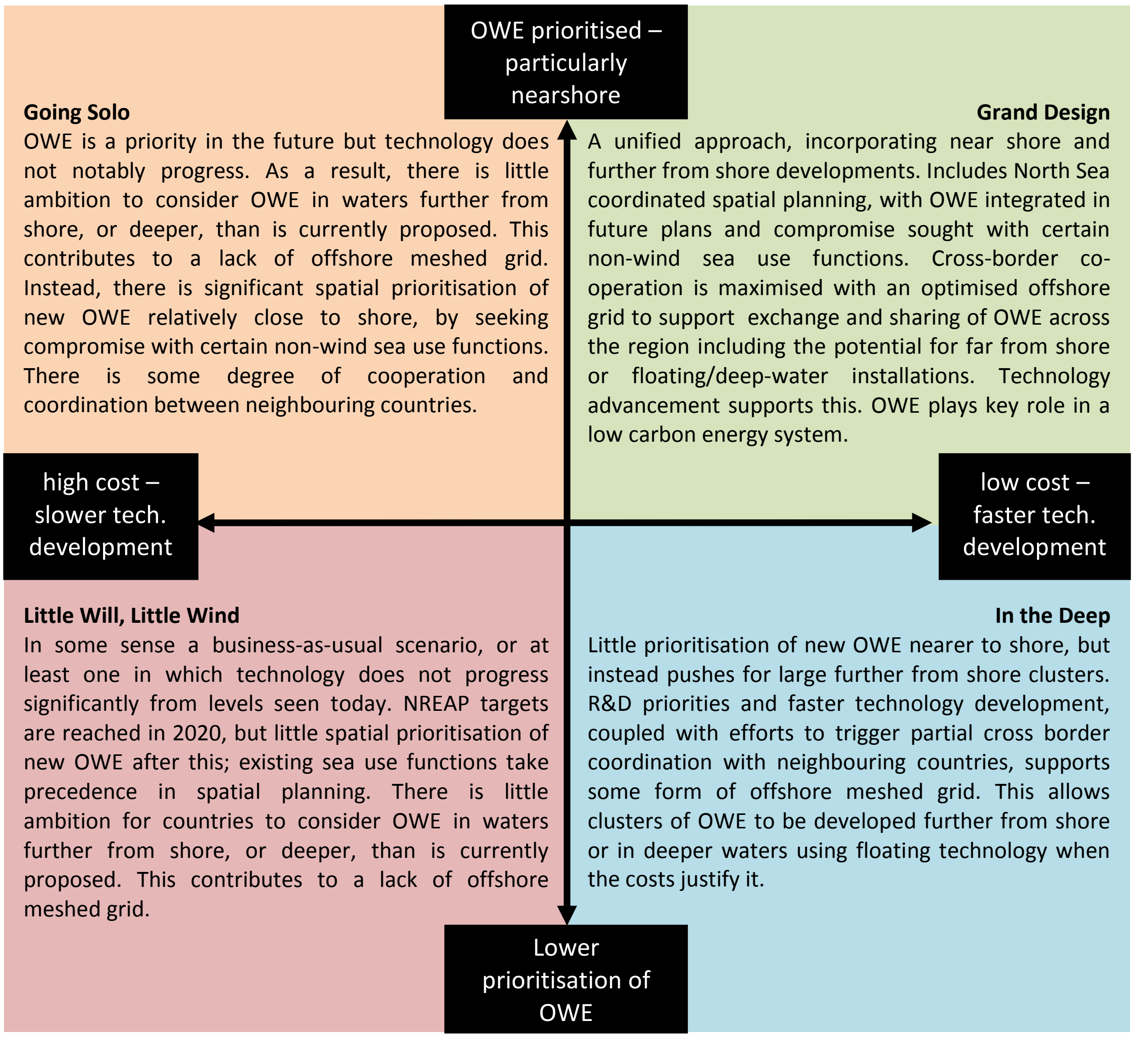


Figure 12: Characterisation of the four scenarios.

The DSS – developed during the course of the WINDSPEED project – was used to map and estimate the spatial potential of the Central and Southern North Sea for incremental OWE in each scenario (Figure 13). The DSS allows a number of input parameters to be changed depending on the technology and spatial assumptions of the scenario. The spatial assumptions determine how the other sea uses in the North Sea interact with and constrain the allowable areas for OWE. The DSS processes the data to perform an exclusion analysis combining all relevant existing sea uses and excluding these from the potential analysis according to the user settings.

A low average installed density of wind turbines is a key assumption. A future is envisaged where clusters of offshore parks are deployed with empty (of OWE) corridors between them to reduce turbulence and maintain wind resource.

Scenario results – combined with a location specific cost calculation for the complete area – are then output in the form of maps showing areas potentially suitable for OWE and those areas that are excluded by other sea uses. The DSS thus provides insight into the trade-offs and the consequences, particularly for OWE potential and costs, of setting different priorities for the allocation of space in the Central and Southern North Sea.

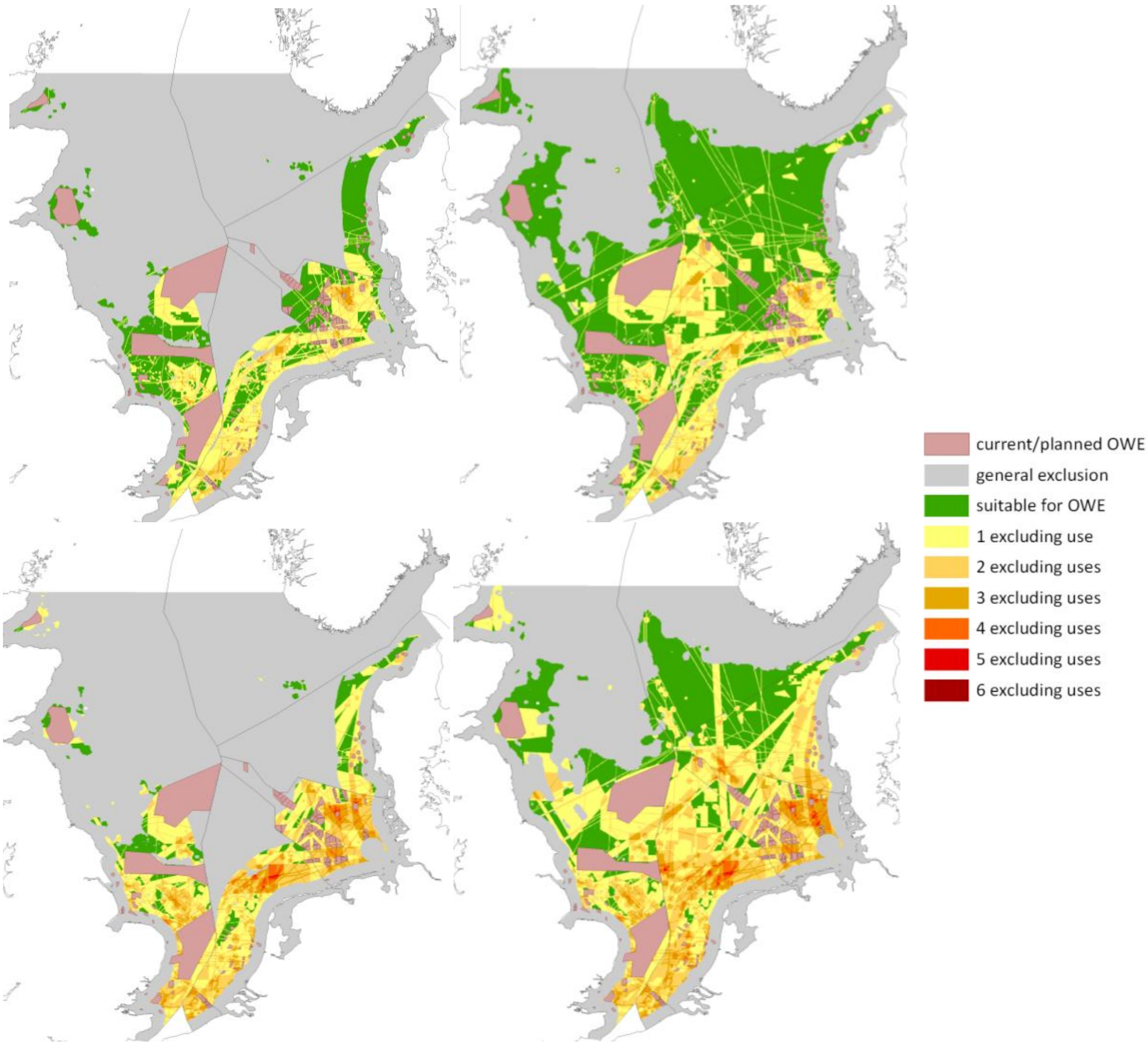


Figure 13: Map of spatial potential in the WINDSPEED area for each scenario: Little Will Little Wind [bottom left], Going Solo [top left], In the Deep [bottom right] and Grand Design [top right].

The maps show the large impact that technology related exclusions – such as permissible water depths and distances to shore – have on the available areas for new OWE. They also allow one to observe the relatively high level of spatial 'congestion' close to the coast of most of the WINDSPEED countries when additional space for OWE is not prioritised, as well as how this can change when some level of synergy and/or compromise is sought with non-wind sea use functions.

The overall spatial potential for OWE in the WINDSPEED study area was determined by combining the results of the DSS, which looks for new areas for deployment, with knowledge of existing and proposed offshore wind parks. Figure 14 shows the spatial potential broken down by country. The UK, which has the largest EEZ in the Central and Southern North Sea, shows the largest spatial potential across all scenarios. While Belgium has little to no potential beyond current plans. Denmark's potential changes vastly depending on the scenario assumptions, as does Norway's. However, for Norway the change in potential is highly dependent on technology assumptions and permissible depths. The Netherlands and Germany both show the largest potential in those scenarios that focus on identifying additional OWE nearer to shore through the prioritisation of space.

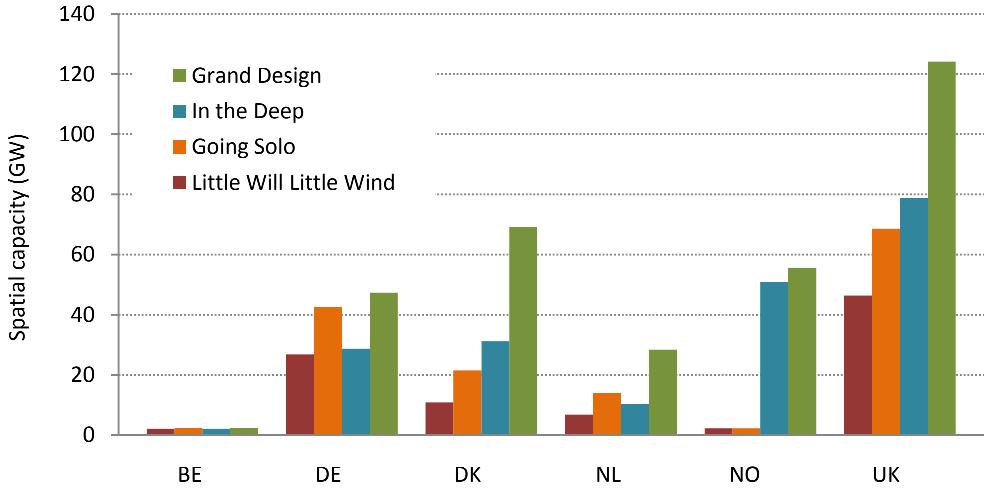


Figure 14: Total potential spatial capacity in the WINDSPEED area for each of the countries in each of the 4 scenarios

The spatial results give rise to a number of important conclusions regarding the potential for further deployment of OWE in the future:

- Without prioritisation of space for OWE there is limited potential for incremental OWE capacity across most of the southern portion of the North Sea when focussing on relatively near-to-shore and radially connected wind parks.
- Changes in the level of prioritisation that is given to new OWE were found to make a large difference to the potential for incremental capacity; particularly for generation at low to moderate delivered electricity costs. Ways to achieve this include looking for co-use with some existing sea uses, integrated planning of wind parks and other uses, or assuming some level of compromise on the extent of other certain uses. Relatively low densities of OWE (at a macro scale) are necessary to preserve the level of wind resource, and this also allows integration or co-use of some other sea uses. For example, the corridors between neighbouring parks can be utilised by other sea use functions such as shipping and fishing.
- Relaxing constraints on the maximum considered distance to the coast – in anticipation of connecting these far from shore areas via an offshore grid – significantly increases the spatial potential. The In the Deep incremental spatial potential is roughly five times that of the Little Will Little Wind scenario (in effect matched scenarios, as both do not spatially prioritise for OWE) and the Grand Design scenario identifies more than three times the incremental spatial potential as the Going Solo scenario.
- Realising floating technologies effectively doubles the total spatial OWE potential in both the In the Deep and Grand Design scenarios. The utilisation of this would be contingent on cost effective floating solutions becoming available. Moreover, the additional capacity is concentrated almost exclusively in the UK and Norway, which suggests that the drive for such technology will likely have to originate in these countries.

Where can we go?

However, spatial considerations alone do not determine a viable economic capacity in 2030. The impact of constraints related to policy support, supply-chain restrictions, transmission and electricity market integration are also important to consider. This was done within the project in two main stages.

In the first step, policy initiatives and growth restrictions were addressed. Availability of RES-E support – in terms of the financial incentives available to RES-E producers – has a significant influence on the development path of OWE. The level of support per MWh of electricity production not only puts a cap on the overall generation capacity, but also influences the choice of where to develop new projects. The speed with which a certain amount of OWE capacity can be realized is also constrained by the speed with which industry can scale up required production levels. Within the project, these aspects were modelled[6] to narrow down the spatial potential to a so called 'first order economic potential'.

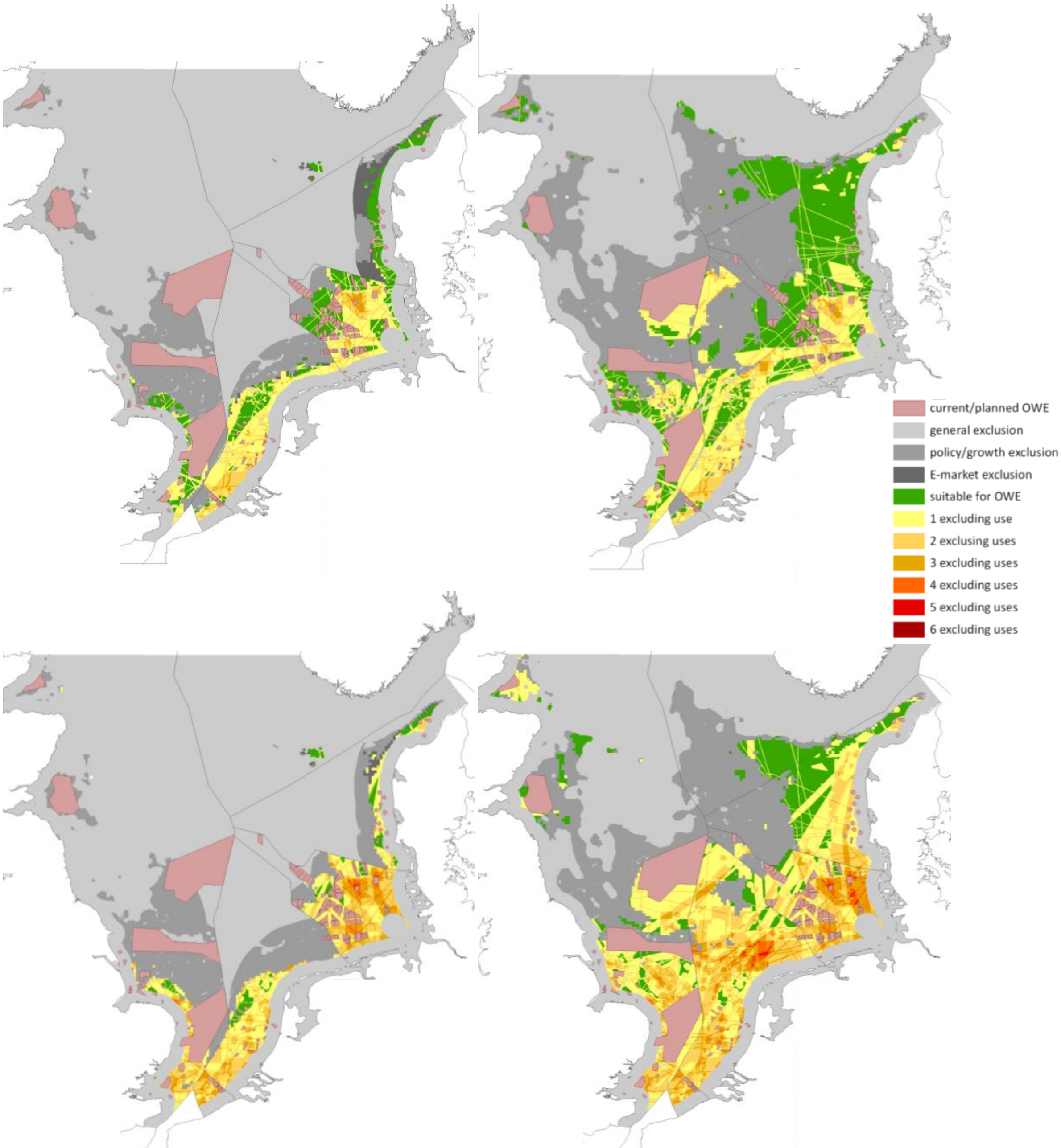


Figure 15: Map of economic potential in the WINDSPEED area for each scenario: Little Will Little Wind [bottom left], Going Solo [top left], In the Deep [bottom right] and Grand Design [top right] (Cameron *et al.*, 2011).

[6] Using the RESolve-E model; based on a dynamic market simulation in which national RES-E supply curves are matched with policy-based demand curves in order to determine a technology mix per country in 2030 (Daniëls & Uyterlinde, 2005)

In the second step, limitations in transmission capacity, particularly between countries, and hour-by-hour market integration with respect to other sources of generation were accounted for (see below 'Connecting the power'). Power produced from a significant installed capacity of OWE requires grid infrastructure to export the electricity to centres of demand. Limitations in both onshore and offshore grid capacity, along with balancing demands, will have an effect on the economically viable OWE deployment; a so-called second order economic potential, or final economic potential (Figure 15).

A key area of differentiation between the scenarios was the assumption of an offshore grid developing in both the In the Deep and Grand Design scenarios, an enabling factor for the further from shore OWE considered in these futures. Such an offshore grid would connect clusters of far from shore OWE in order to improve flexibility, balancing and export opportunities.

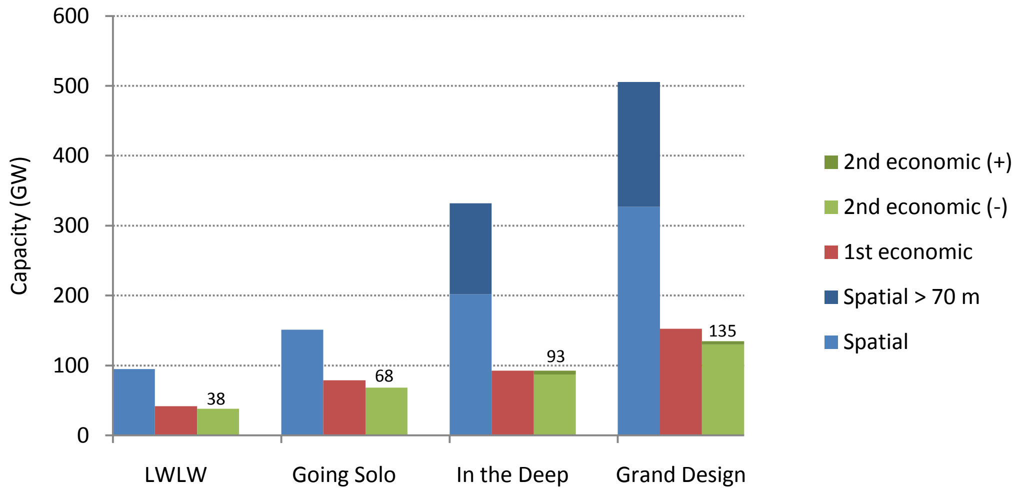


Figure 16: Overview of the different potentials for the six WINDSPEED countries in 2030. The minimum economic potential is indicated by (-), the maximum by (+). The spatial potential is split between that found at less than 70m water depth and that found in deeper waters.

Across all scenarios, these economic potentials show a constraint on the viable level of OWE deployment in 2030; not all of the spatial potential would be feasibly exploited (Figure 16). The final estimated economic OWE capacities in 2030 in the WINDSPEED study area provide the most condensed summary of the results for the four presented scenarios (Figure 17). Distilled down to these four numbers, the scenario analysis in the WINDSPEED project shows that there are large differences in the OWE capacity that could be economically deployed in the future depending on the chosen development perspective.

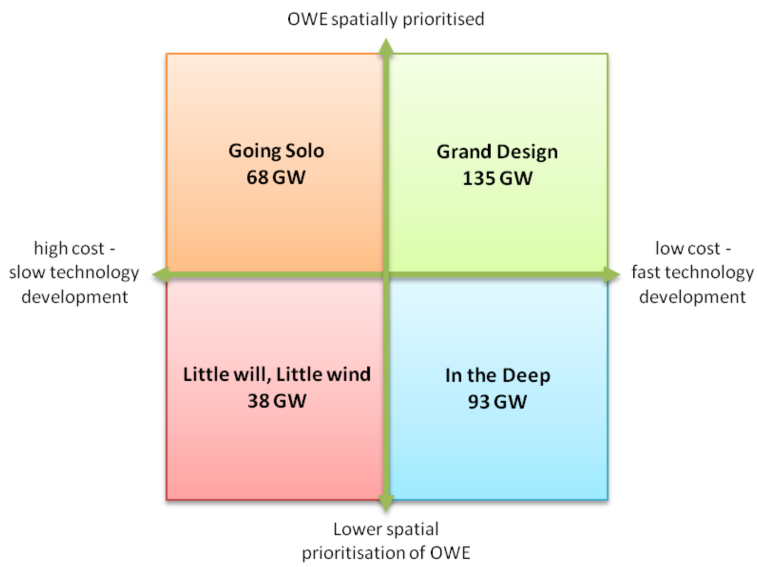


Figure 17: Overview of total 2030 estimated capacities in the WINDSPEED study area for each of the 4 scenarios.

The least ambitious scenario, Little Will, Little Wind, shows limited deployment of incremental OWE after 2020, reaching only 38 GW in 2030. In this storyline there is an initial rush in OWE installations up until 2020, which then slows significantly due to difficulties in finding new space for OWE, insufficient incentivising policy and a connection philosophy that relies on radial connections without direct international OWE flows.

Going Solo focuses efforts closer to shore and prioritises space for OWE by incorporating some non-IMO shipping and fisheries as co-use between wind parks, and also by looking for some compromise with low OWE cost Natura 2000 and military areas. However, the limitations imposed by the radial connection philosophy – i.e. that all countries connect wind parks domestically and that cross-border flows are limited by onshore transfer capacities – act to constrain the capacity to 68 GW.

The In the Deep scenario considers a future where cross-border cooperation has created the enabling conditions for an offshore meshed grid to develop, while closer-to-shore traditional sea use functions have generally taken preference over new OWE. As a result much of the OWE development occurs further from shore in a number of offshore clusters which are interconnected by the offshore grid. With some phase out of conventional generation, up to 93 GW could be market integrated via either radial connections to shore (for near shore resource) or via the offshore grid.

> "...the North Sea could deliver more than 30 percent of the electricity production of the 6 WINDSPEED countries"

The Grand Design scenario shows an estimated capacity of 135 GW in 2030, based on a future where both prioritisation of space for OWE closer to shore and development of and offshore grid occur. However, putting the Grand Design scenario results in context is not easy as there are few firm targets for OWE beyond 2020. EWEA gives a target of 150 GW in 2030 for the whole of the EU, chiefly based on a bottom up summary of planned projects (EWEA, 2009). While an accompanying document to the European Commission's Energy 2020 strategy mentions in excess of 140 GW of OWE plans between member states, but gives no mention of the status of such plans (EC, 2010b). Should ambitions of this magnitude be pursued, it becomes clear that the futures predicted by the Going Solo or In the Deep scenarios are, for the most part, insufficient given the major role that the North Sea is likely to play in OWE.

This would suggest that an approach to future OWE that resembles the Grand Design scenario is necessary; a future in which cross-border cooperation on infrastructure and spatial planning has not only designated appropriate portions of national EEZs for OWE closer to shore, but also supported the development of an offshore grid to allow the large-scale deployment of further from shore OWE. Only by taking on both challenges of increased spatial prioritisation of OWE and offshore grid can the ambitious estimate of 135 GW of OWE capacity in the Central and Southern North Sea be achieved. Should these challenges be addressed, then the North Sea could deliver more than 30 percent of the electricity production of the 6 WINDSPEED countries.

Sharing the sea

The project has revealed the busy nature of the North Sea and, moreover, quantified the impacts of the different sea uses in terms of an opportunity cost for OWE. The DSS maps provide an overview of how the potential for OWE in the North Sea changes depending on the development perspective of any particular scenario. It should be noted that the overarching aim of the project is to produce a policy roadmap rather than identify specific future wind parks. This led to some necessary compromises regarding of the DSS resolution and the addition of relatively novel exclusion layers such as wildlife preservation and fishing. This means that regional or country level interactions with other sea uses are the main focus, rather than site specific impacts, which are difficult to determine from a study such as this. Inevitably some specific areas may be identified as 'suitable' that should, in fact, be excluded due to unforeseen factors and equally, some areas may be excluded that could in the future be developed for OWE.

The impact on other sea uses that could eventuate under the different futures corresponding to the four scenarios was assessed from the final maps (van der Wal *et al*., 2011). The impact of wind park development does not depend solely on the amount of space claimed. Non-wind sea use functions differ spatially in terms of effort (fisheries), density (shipping lanes) or value (wildlife preservation). Therefore, the consequences of OWE encroaching on certain areas differ as well. By considering both aspects, size and the nature of prior spatial usage, the potential impact of wind park development was estimated for each scenario.

The final area of the North Sea used for incremental OWE, in even the most ambitious scenario, is comparatively small.

The final area of the North Sea used for incremental OWE, in even the most ambitious scenario, is comparatively small. A maximum of 10 percent of the total WINDSPEED area is found suitable for OWE development in the time frame to 2030. Although the overall spatial potential of any single scenario may be large or the input assumptions with respect to a particular sea use may seem aggressive, three aspects act to mitigate the overall impact of OWE development. Firstly, the fact that overlapping uses restrict the spatial losses for non-wind sea uses; even though one constraint is relaxed a different sea use may still preserve that area. Secondly, the subsequent constraints related to policy, growth and electricity market integration mean that only some portion of the identified 'suitable' area is ever feasibly developed by 2030. Finally, the low assumed layout of wind parks – with corridors between them for wind regeneration – means that less than a third of the identified area is populated with turbines, greatly the 10 percent maximum figure above and allowing the possibility of integrated planning with shipping lanes.

Additionally, the potential negative consequences for other sea uses of developing OWE parks can be further mitigated through co-use (for example with some forms of fishing) or relocation (for example non-critical military zones that are not location sensitive or sand extraction that could be moved within territorial waters).

Connecting the power

How will future OWE be connected to electricity markets, particularly at large deployments? The scenarios fall into two broad categories in regards to the connection philosophy assumed for future OWE. The first, is for radial connections only, whereby countries continue to connect individual parks back to shore with HVAC or HVDC technology as seen today. The second, is a mix of radial connections (for nearshore resource), along with an offshore meshed grid where further from shore OWE clusters are directly interconnected using HVDC technology.

The Little Will, Little Wind and Going Solo scenarios assume that radial connections remain the dominant mode of connection up to 2030. This poses little constraint at the relatively modest levels of deployment seen in the Little Will Little Wind scenario; each country can integrate the amount of OWE that is estimated to be available to them within their EEZ, in their national grid. However as capacities reach the scale seen in the Going Solo future, onshore transmission constraints begin to restrict the amount of OWE that can be viably installed. Much of this constraint occurs in Denmark; a country that is promising in terms of low cost OWE generation but relatively restricted in terms of national demand for electricity and cross-border connections, compared to the spatial potential of OWE. Furthermore Denmark has additional OWE options outside the WINDSPEED study area (for example the Kattegat or Baltic Sea). These options may, from a Danish point of view, be more attractive due to their proximity to load centres such as Copenhagen. Norway is a minor player in OWE in these radially connected scenarios, due to limits in: demand for additional generation, available potential at today's achievable water depths and opportunities for export of power. Utilisation of the significant potential for OWE from Denmark and Norway is largely contingent on offshore grid development. An offshore grid also allows other WINDSPEED countries, such as Netherlands, Germany and the UK, to develop portions of their EEZ's that are further from shore, increasing their potential installed capacity.

For those scenarios in which some form of offshore grid is assumed to develop – the In the Deep and Grand Design scenarios – the results from the DSS were used to define a number of potential OWE clusters along with onshore connection points. An offshore grid was then designed that interconnects these wind clusters and onshore connection points in such a way as to optimise the investment cost of the grid against the benefit it provides by increased trade opportunities and connections to the new offshore wind generation units (Trötscher and Korpås, 2011). The resulting grid structure for the two relevant scenarios is shown schematically in Figure 18.

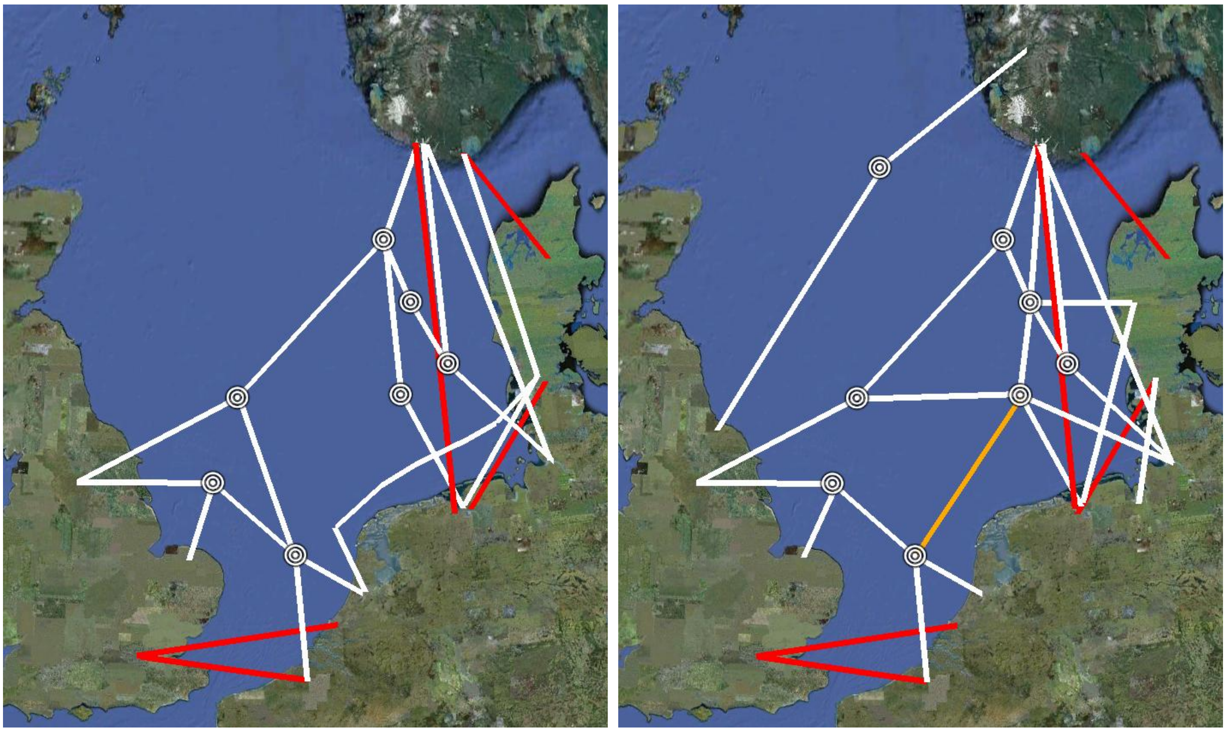


Figure 18: Illustration of the key components of an offshore grid: In the Deep [left] and Grand Design [right] (source: Huertas Hernando *et al*., 2011)

The offshore grid serves a number of ends, firstly, larger overall capacities of OWE can be connected across the North Sea in a transnational fashion. Due to the range of wind-speeds that can be observed across the North Sea basin during most hours of the year, generation may be low in one region of the North Sea, but could be high in another. A meshed grid, therefore, increases security of supply and makes the overall generation output offshore less variable from the point of view of the power system around the North Sea as a whole. An offshore grid can provide high utilization of the installed cable capacity, since the cables are used both for transport of wind power and for power trade between countries. Thus, an offshore grid has the potential of lower total costs than a solution with only radial connections of wind farms and point-to-point interconnectors.

Secondly, cross-border bottlenecks due to limits in onshore transfer capacities, are reduced as OWE can flow to the point of demand directly rather than back to shore via a radial connection and through conventional transmission lines. This means that some countries such as Norway and Demark could effectively act as OWE exporters – Demark, partly due to its comparatively low OWE delivered electricity costs and Norway from the additional benefits that the combination of OWE development with its large hydropower reserves offer regarding potential for transnational power exchange and flexible balancing power. Depending on the amount of OWE potential and resulting offshore grid in each scenario, some countries are net exporters while others are importers. Net cross-border transfers of electricity for the In the Deep and Grand Design Scenario are in the order of 130 TWh and 190 TWh respectively (Figure 19). The grid analysis performed in this project takes into account that supply and demand requirements need to match not only over the year as a whole, but also hour by hour depending on the variability of different renewable sources.

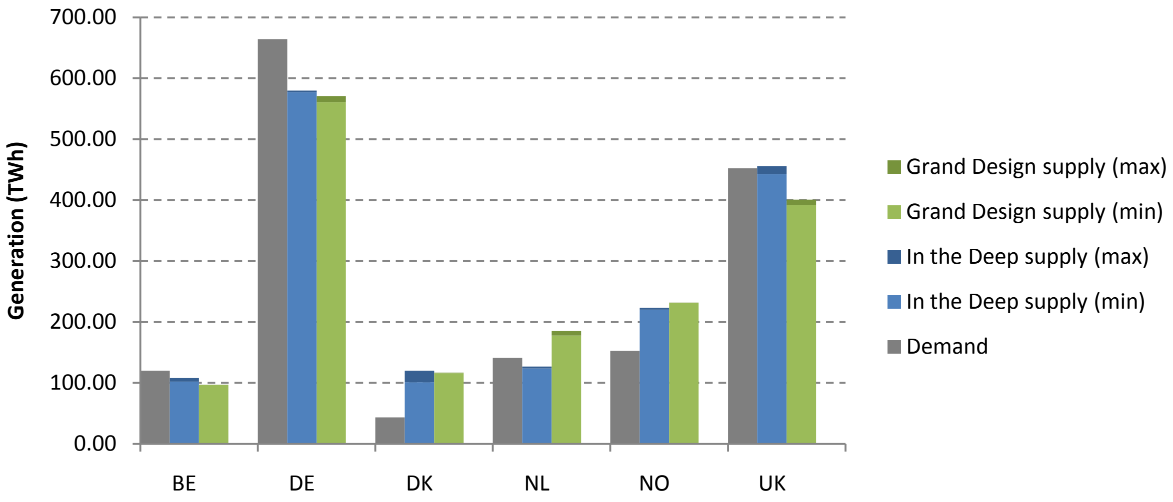


Figure 19: Overview of final demand and generation by country for the In the Deep and Grand Design scenarios (source: adapted from Huertas Hernando et al., 2011)

The grid results also illustrate the need for flexibility in fossil fuel generation in order to allow significant penetrations of OWE. Such flexibility needs appropriate regulations in place to ensure security of supply without overly hindering the ability of OWE be dispatched. This could, for example, include direct support for manageable generation in the balancing market (especially combined cycle gas turbine units), wind curtailment/spillage or some form of demand control (typically only contingency based). Design of future balancing power markets should take into account dynamic allocation of flexible amounts of reserve capacity, depending on installed wind and wind penetration (EPRI, 2010)

There are some notable enabling conditions that are likely to be required for the development of such an offshore grid. Significant improvements in cross-border cooperation would be required in order to ensure compatibility and coordination of national OWE plans with the necessary grid-infrastructure. At the same time there would need to be well defined and centralised responsibility for developing the post 2020 offshore grid. Possibly the responsibility could lie with a single North Sea TSO. There would also need to be robust and transparent methods for distributing investment and maintenance costs in accordance with the received benefits from the operation of such an offshore grid.
From a grid connection point of view, the following main steps should be considered (Huertas Hernando *et al.*, 2011):

i) Planning for T-connections: T-connections should be considered since they are the first steps to allow moving away from nationally driven radial connection strategies towards a transnational fully meshed offshore grid solution. Coordination between the link developers (typically TSOs) and wind farm developers is needed. Investment decisions should consider the profitability of the T-junction as a whole instead of considering the profitability of the link and of the wind farm independently. Coordination at early stages of the development of both projects between link developers and wind farms developers and new market rules that allow trading of power from the link and from the wind farm in the same market, are needed.

ii) Planning for transnational clustering: Transnational clustering should be done in a coordinated manner at an early stage of the development of the wind farms in the different countries EEZ, so the connection to the transnational offshore cluster hub allows for flexible and harmonized technical standards regarding technology and technical choices. Lessons learned from the Kriegers Flag project should be used when developing transnational clusters.

iii) Flexibility of technology choices: Flexibility on the connection choice and technological solution must be considered to allow flexible and harmonized technical standards regarding technology and technical choices. Scalable hybrid solutions combining LCC HVDC, 2-terminal VSC HVDC and multi-terminal VSC HVDC technologies must be possible. Such flexibility should e.g. allow existing T-connections to be upgraded into fully meshed multi-terminal links.

What are the costs?

It is important to understand the possible cost implications of the different scenarios/development-perspectives. There is, arguably, limited value in providing figures for the total absolute costs – for example the sum of all capital expenditure for each scenario. Not only would such numbers be large and difficult to place in context, but they would not reflect the fact that some scenarios with higher deployment should be expected to have higher absolute costs. Nor would total capital cost figures reflect differences in operational and maintenance costs over time. More useful is a comparison of the changes in levelised production cost that are observed between the scenarios, i.e. based on per MWh calculations, as this provides fair basis for comparing each development perspective (Figure 20).

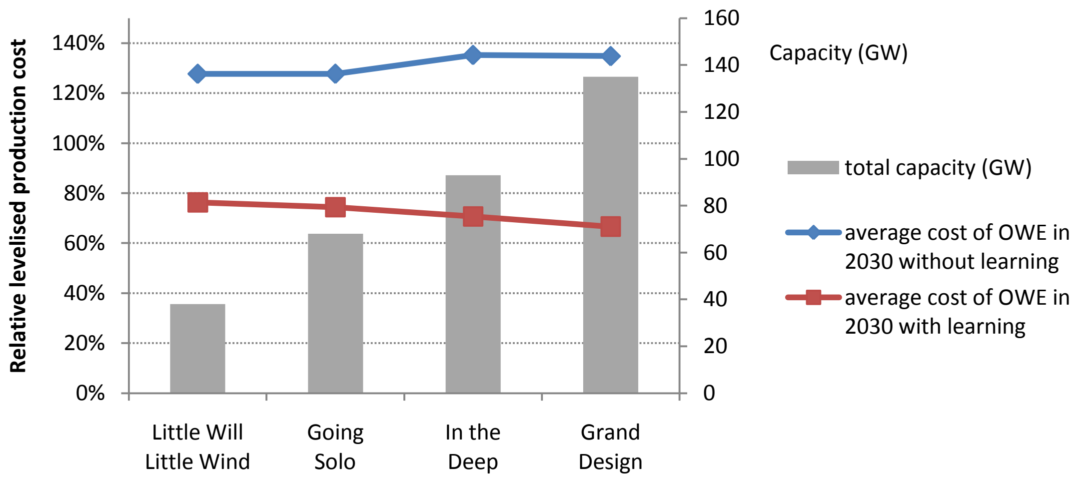


Figure 20: Relative average LPC of OWE in 2030, for each of the four scenarios, with and without learning effects, along with total estimated capacities in the WINDSPEED area (Cameron *et al*., 2011)

Cost figures should be interpreted cautiously, as the bottom-up cost model that is used within the WINDSPEED project is sensitive to a number of factors which are likely to change over time. These include commodity prices, supply chain constraints and financing rates. Figure 20 gives an indication of how the overall average costs may change, in relative terms, depending on the scenario and technology learning assumptions. Figure 20 shows the cost impact of the offshore grid investment, in the form of higher average costs of delivered electricity without learning effects considered. It also shows the overall benefits of increased scale of deployment reflected in lower levelised production costs of electricity in those scenarios that had the highest estimated installed capacities in 2030.

How can we get there?

A number of key assumptions within the progressively more 'pro-OWE' scenarios are premised on the ideas of increased cooperation and coordination between Member States. Somewhat fortunately, these collaboration needs – in both integrating OWE planning with other sea uses and in offshore grid development – occur in a context of a Europe wide push for cooperation.

The three main starting points for these necessary future efforts are, firstly, the current arguably fragmented approach to spatial planning across different North Sea member states. In order to realise significant low cost OWE potential and balance the spatial needs of existing cross-border sea uses, such as fishing and shipping, coordination between member states will be necessary. An optimum configuration of offshore wind parks – with corridors between them to regenerate wind resource – is highly compatible with these sea uses in terms of co-existence but requires high level planning. At the same time, such an approach would address possible issues at EEZ borders in regards to reductions in wind resources in the neighbouring country and also allow cumulative North Sea-wide nature value impacts to be considered more holistically, the so called 'ecosystem approach' to nature management.

A second key area for cooperation is in relation to grid infrastructure. The North Sea Countries Offshore Grid Initiative (NSCOGI) is currently the key driver for coordinated North Sea offshore grid planning. A large degree of cooperation will be needed in order to implement infrastructure of this scale given the many cross-border aspects. These aspects relate not only to cross-border infrastructure but also coordinating OWE planning in the different member states in support of the grid. This is important both in terms of locations and timing of developments.

A third area, which will be triggered by an offshore grid is the implementation of one or more of the three cooperation mechanisms introduced in the Renewable Energy Directive (2009/28/EC). These will need to be operationalised in a manner that supports the development of large clusters of OWE of the type envisaged in combination with an offshore grid. Key issues for these mechanisms will be their ability to incentivise investments in new large RES projects while allowing the costs and benefits – both direct and indirect – to be considered in their negotiation.

In summary, cooperation in relation to North Sea OWE deployment holds a number of potential benefits including:

- Accommodation of co-use of OWE and cross-border sea uses such as fisheries and shipping while optimising the yield from offshore wind parks (through a decrease in wind resource degradation).
- Prevention of potential litigation issues stemming from the alignment of parks close to national EEZ borders and wake effects
- Most appropriately address cumulative effects on nature conservation and marine wildlife preservation in accordance with the ecosystem approach
- Creation of the enabling conditions for the development of an offshore grid to:
    - improve reliability of power supply and allow more sophisticated power exchange options to be implemented with large quantities of OWE in the North Sea;

- make further offshore areas more accessible and potentially alleviate some aspects of near shore competition with other sea uses, most prominently shipping and ports;
- reduce the need for onshore transmission reinforcements between countries and the associated problems of public acceptance;
- allow countries with OWE opportunities to export to neighbours (cross-border trade is a key driver for initiatives to date, such as Kriegers Flak)
- gain higher utilization of the invested assets, as compared with a solution with only radial wind farm connections and point-to-point interconnectors.

- Deliverance of lower overall average OWE costs through the opportunities that cooperation provides for increased deployment and, as a result, improved benefits of scale and learning

The European Commission is currently playing a key role in triggering and facilitating cooperation and coordination, but debatably the most effective driver is when countries *need* or *want* to cooperate in order to meet targets in the most efficient manner. The opportunities for cross-border transfers of low-cost OWE, improved power exchange and resource limits for RES deployment may drive Member States to look 'over the fence', so to speak, to neighbouring countries. One example of this is the case of Belgium who – with their limit for OWE planning already reached in a small and busy EEZ – have shown an early willingness to explore cross-border opportunities for deployment in Dutch waters. In order for countries to find themselves in a position where cross-border cooperation is desirable and viable, they arguably need to be given ambitions beyond what they could cost effectively achieve in isolation. This suggests that post 2020 renewable energy targets are needed, so that Member States will be driven to look for enhanced solutions. Such solutions may lie in finding more space for OWE or taking advantage of a neighbour's resources. Given the long time frames for large offshore infrastructure development and the considerable associated level of cooperation that needs to develop, such targets would be most beneficial when agreed promptly.

"...post 2020 renewable energy targets are needed, so that Member States will be driven to look for enhanced solutions, be these finding more space for OWE or taking advantage of a neighbour's resources"

Key findings

- There are limited areas close to shore for incremental OWE without prioritisation of space for OWE.
- Looking for co-use with some existing sea uses or assuming some level of compromise on the extent of other certain uses can make a large difference to the potential for incremental OWE; particularly for generation at low to moderate delivered electricity costs.
- Going further from shore creates opportunities for 2 to 5 times more incremental deployment but the realised capacity depends on a number of factors including: availability of deeper water technology, development of an offshore grid and advancement in the supporting HVDC technology.
- Realising floating technologies effectively doubles the total spatial OWE potential but, the additional capacity is concentrated almost exclusively in the UK and Norway.
- Large clusters of wind parks will need spacing between them to allow for wind resource recovery, this triggers the opportunity for co-use/integrated-use; the corridors between neighbouring parks can be utilised by other sea use functions such as shipping and fishing. This not only helps ensure optimum energy yields but also minimises impacts on other sea use functions.
- Moving parks further from shore will make cross-border planning more important, in particular for the development of an offshore grid.
- The infrastructure costs of an offshore grid are shown to be more than compensated for by the learning effects of the additional permitted capacity. Noting, that regulatory incentives are needed that support investment in an offshore grid.
- Cross-border cooperation will play a key role in realising the most ambitious scenarios, both in terms of cross-border MSP and on the necessary electrical infrastructure.
- Differences in wind resource and marine environments could make countries such as Denmark and Norway exporters of OWE, but this is dependent on finding cooperation mechanisms that support such investment and integrate it with the development of an offshore grid.
- Only by taking on both issues - of increased spatial prioritisation of OWE and offshore grid development - can the ambitious estimate of 135 GW of OWE capacity in the Central and Southern North Sea be achieved.
- OWE can play a large role in the future energy systems of the 6 WINDSPEED countries, supplying more than 30% of their electricity consumption. However significant challenges must be overcome in terms of finding additional space through integrated and coordinated MSP, developing appropriate offshore electrical infrastructure and implementing cooperation mechanisms.

5 Paving the way for offshore wind deployment

OWE is in the process of establishing itself as a key contributor in the EU's efforts towards a sustainable, secure and competitive energy system. The Central and Southern North Sea has taken on a leading role in this process. With its favourable features, this sea basin is well positioned to continue this leading role. However, the time has now come for surrounding countries to establish longer term and coordinated efforts to develop this technology to its full potential. This final chapter presents the two most important elements of any Roadmap; namely "where do we want to go?" and "how do we get there?".

Roadmap "destination"

The WINDSPEED analysis has looked at several possible destinations with respect to OWE deployment, and considers a deployment of 135 GW of OWE to be an ambitious yet achievable target for 2030 in the Central and Southern North Sea. This target is premised on two key assumptions. Firstly, a deployment of this magnitude can only be achieved if countries are willing to increase spatial prioritisation of OWE (closer to shore). Secondly, large clusters of parks, in further from shore locations and in potentially deeper waters, must be developed along with an offshore grid. Furthermore, availability of cost-effective offshore technology components is a prerequisite for far from shore developments.

How far we want to go in terms of OWE deployment is closely linked to policy ambitions and priorities. The 135 GW Grand Design scenario combines developments in near and far from shore locations. Alternatively, policy makers could choose only one of the two pathways – additional nearer to shore developments or additional far from shore developments. The maximum capacity that can be achieved is a lot less in these two scenarios compared to the most pro-active scenario. Keeping in mind the challenges we face with respect to climate change and secure energy supply, it seems certain that we must aim to exploit RES technologies, including OWE, to their maximum.

Enabling policy initiatives

The last decade has shown a development of 1.8 GW in the North Sea. In the next decade, the NREAPs of the countries included in the WINDSPEED area envision a total of 32 GW of OWE capacity in their sea basins by 2020. Should this be achieved, the subsequent achievement of a target of 135 GW implies a growth of more than 100 GW of OWE in the period 2020 - 2030. Such a deployment will require a whole new approach and policy framework to promote OWE than what we see today.

The pathway to 2020 is, to a large extent, cast in stone. This is due to the long lead times in developing offshore wind parks and grid connections (typically between 8 - 10 years per project considering the investment decision, application and construction phases). With respect to "how do we get there?", the focus must, therefore, be on what policy instruments are needed for the deployment of more than 100 GW in the time frame 2020 - 2030. However, it is foreseen that most of these new policies will need to be implemented before this time period.

This Roadmap focuses on the following core areas where policy measures are required:

- Ambitions and support schemes;
- Maritime spatial planning;
- Grid configuration; and
- Research and development.

Coordination and cooperation needs are not considered separately, but addressed within each of the four above-mentioned areas.

Ambitions and support schemes

Targets have proven to be a strong driver for the development of RES, if complemented by an effective and stable policy framework that incentivises investment (EC, 2006). Long term targets not only provide the industry and developers with better investment certainty, but also a basis upon which to plan and time the expansion of RES technologies; such as OWE and required grid development. The current EU policy framework - RES Directive (2009/28/EC) - includes national binding RES targets for 2020 and NREAP projections on the contribution of various RES technologies towards these targets. Although a strong driver, the problems with the current framework are two-fold. Firstly, the short time frame and, secondly, the lack of coordination between countries in establishing their NREAP trajectories for RES technologies. To promote 135 GW of OWE by 2030, a similar approach should be implemented for the time frame to 2030 (or longer), with stronger requirements on countries to address, in their NREAPs, both synergies and benefits of jointly developing RES technologies in a given geographical region, such as OWE in the Central and Southern North Sea.

WINDSPEED has shown that relatively low cost OWE deployment opportunities are unevenly distributed between the countries due to, amongst others, variations in EEZ size and differing characteristics of the national sea basins. Belgium has very little potential for further development beyond the 2020 projection, whereas Denmark and Norway have relatively large OWE potentials, often at comparatively low costs. These potentials could be exploited to increase the shares of RES in other EU countries. Therefore, increased efforts should be made to implement cooperation mechanisms that are appropriate for considerable OWE transfers between neighbouring countries and provide the incentive for additional OWE capacity for export. OWE, together with interconnectors to different markets, is an interesting case study for developing such cooperation mechanisms.

Recommendations

- **Extension of current approach with national binding targets for RES to 2030 (or beyond), coupled with stronger requirements for countries to establish NREAPs in a coordinated manner, with a view to jointly developing RES technologies in a given geographic region, such as the Central and Southern North Sea.**
- **Require Member States to set up stable and long-term economic incentives for OWE investment and grid infrastructure build-up.**
- **Implement cooperation mechanisms in the context of offshore wind parks with connection to different national markets.**

Maritime Spatial Planning

Scaling up OWE deployment in the time period 2020 – 2030, while taking into account the spatial needs of non-wind sea use functions, is best done through MSP. The WINDSPEED project has identified a number of areas which are not sufficiently addressed in existing MSP processes to accommodate large scale OWE deployment over a broad geographical region in the time frame to 2030. These are:

Identifying co-use opportunities: Building on existing MSP processes, efforts should be taken to find low cost wind energy opportunities, giving explicit attention to wind recovery between parks and the potential for co-existence with other sea uses, such as shipping and fisheries. MSP processes should also investigate further additional multi-use opportunities between OWE and other uses, such as oil and gas extraction. A decommissioning of oil and gas platforms is expected over the next decades. Planning a phasing out of oil and gas platforms with the introduction of new offshore wind parks, as well as addressing synergies between these two sectors, should be given more attention. This will require more transparency in decommissioning plans.

Finding compromise solutions: As a newcomer to the sea, OWE must compete with traditional uses, which have been allocated space through earlier decisions. These decisions, covering both scope and zoning of areas for other uses, such as military activities and sand extraction, have often not taken into account ambitions for OWE and the underlying policy objectives of promoting OWE. Uses which are not location sensitive, or can be relocated or decreased in size without undue impact, should be re-examined with a view to finding space for additional low cost OWE.

Accommodating OWE clustering: Large scale clustering of offshore wind parks is likely to be the way forward in developing an OWE capacity of 135 GW in 2030. MSP will have to accommodate the expected changes in the way OWE will develop. In particular, accommodating flexibility in design and layout of parks in the planning process could give a number of benefits, such as allowing parks in a certain area to share electrical infrastructure and/or achieve lower O&M costs. For example, establishing live-in quarters that could facilitate O&M requirements of clustered parks within a given area. This benefit could be extended if such a facility could accommodate a broader cross-border area of clustered wind parks.

Addressing cumulative effects: Understanding the cumulative pressures resulting from uses and how these will evolve in the future is important, in particular when large expansion plans are foreseen, such as for OWE. Many activities are transnational and can have cross-border impacts. A transnational approach should be adopted to deal with cumulative effects. This entails sharing information, developing a common policy toward the management of certain activities, identifying common resource use and protection objectives.

Several sea uses, including OWE, are expected to increase their demand for space at sea (see Table 6). In order to reach 135 GW by 2030, OWE will have to expand significantly. Since many of the sea uses have important cross-border implications, steps should be taken to foster cooperation and to reap the benefits of a broader coordination of MSP processes. As for increasing demand for space, solutions will have to be sought as to how the different use functions can expand in a compatible and sustainable manner. A joint analysis should be undertaken to derive at efficient and sustainable future (cross-border) use patterns. Given that there is currently no Member States group covering the field of MSP in the North Sea, a first step should be to set up such a working group, similar to the NCSOGI, to reach a common understanding on how to accommodate future growth in demand for sea space.

For the expansion of OWE, a suitable way forward is to continue the increasing trend in the designation of suitable areas for OWE. Designating suitable areas has a positive impact on investment certainty. If designation is done in consecutive rounds of zones, it will allow new knowledge to be taken on board regarding the impact on other uses, cost reductions and new technology solutions as the industry matures. To give more momentum and to speed up the process of coordination, the European Commission should establish guidelines to encourage better coordination between countries in the timing of the identification of new zones.

Recommendations

- **Examine MSP with a view to finding additional space for OWE deployment as well as optimal zoning and layout of new wind parks; addressing opportunities for co-use, compromise, and clustering of OWE as well as cumulative effects.**
- **Continued designation of suitable areas for OWE; preferably in a consecutive manner to allow new knowledge to be taken on board regarding the impact on other uses, cost reductions and new technology solutions as the industry matures.**
- **Establish a transnational MSP forum for the joint analysis of future spatial demands in the North Sea**
- **Establish policy guidelines at EU level to encourage streamlining of new zones for OWE.**

Grid configuration

A deployment of 135 GW of OWE in the Central and Southern North Sea will result in the flow of large quantities of OWE. Considerable investments will be required in onshore and offshore grid infrastructure to accommodate for the large expected expansion in offshore wind generation. Timing and foresight are crucial elements to enable sufficient and efficiently developed grid. Onshore connections and reinforcements will be necessary to bring the generation to load centres. Offshore grid infrastructure will be necessary to provide flexibility and improved power exchange of (remote) generation to large demand areas across a larger geographical region. An offshore grid should also be developed to exploit the storage/balancing opportunities of hydro power in Europe, in particular in Norway.

Due to the transnational dimension, optimal expansion of an offshore grid is best considered from a transnational perspective rather than at a national level. The establishment of the NSCOGI is an important first step towards increasing coordination efforts in order to establish appropriate offshore grid infrastructure for OWE. However, to plan an optimal grid topology for OWE in the North Sea basin, knowledge is needed on the quantities and location of offshore wind parks in the medium to long term. This knowledge is best acquired through an integrated planning approach based on a long term target or vision for OWE across the whole Central and Southern North Sea basin. This should be taken into account in the ongoing work of the NSCOGI.

The planning of T-connections will be an important first step in moving from radial connection an offshore grid with interconnectors. Planning of T-connections should be coordinated between the link developers (typically TSOs) and wind farm developers. Investment decisions should consider the profitability of the T-junction as a whole instead of considering the profitability of the link and of the wind farm independently. Coordination is needed at the early stages of the development of projects between link developers and wind farms developers, and also for new market rules that allow trading of power from the link and from the wind farm in the same market. At the same time, sufficient incentives for OWE investors need to be kept in place, or improved.

There is currently no regulatory regime facilitating the association of offshore grid with offshore renewable projects across national sea basins in the Central and Southern North Sea. Whereas onshore grid networks are well established and operate with national regulations and regulatory bodies in place, offshore grid is essentially starting from scratch. A transnational regulatory framework is needed and in establishing this, it is important not to “think inside the box” and/or attempt to extend national onshore regulatory regimes to offshore. Instead it is important to think of new solutions tailored for offshore grid development. This regulatory framework needs to cover a number of aspects, such as clear guidance of how to share the costs and benefits, including indirect costs and benefits, of new infrastructure. Grid codes and market arrangements to allow the flow of electricity to different markets should also be addressed. Clear responsibilities must be defined and a North Sea TSO should be considered for this sea basin, as opposed to coordinating national TSOs. Changes in the support mechanisms are needed, in particular removing the requirement of offshore wind farms to feed its electricity to the grid of the country through which they are subsidised. In anticipation of the necessary offshore grid solutions, EU and relevant Member States should consider pilot schemes to test possible solutions with a view to establishing long term changes in the regulatory framework for establishing an offshore grid. As a part of their tasks, the NSCOGI should define a clear and transparent approach for establishing an offshore regulatory framework for the Central and Southern North Sea.

The EC should continue its role in identifying and funding projects of a European interest in the Central and Southern North Sea basin, at least in the time frame to 2020.

Recommendations

- **Planning for T-connections as the first steps in moving away from nationally driven radial connection strategies towards a transnational fully-meshed offshore grid solution.**
- **Coordination between the link developers (typically TSOs) and wind farm developers at early stages of the development.**
- **Planning for transnational clustering & coordinated development of grid infrastructure projects to allow for flexible and harmonized technical standards regarding technology and technical choices. Lessons learned from the Kriegers Flag project should be used**.
- **Establish a dedicated transnational regulatory framework for offshore grid, which include clear and transparent guidelines on how to share costs and benefits, including indirect costs and benefits, of cross-border offshore grid and new market rules to allow trading of power from subsea links and from wind farms into a common market. The transnational regulatory framework should ultimately also include the creation of a transnational European Offshore TSO for the North Sea (as well as for other sea basins).**
- **Pilot schemes to test possible solutions with a view to establishing long term changes in the regulatory framework for establishing an offshore grid**
- **EC continue to play role as facilitator and provide funding to offshore grid projects, which are considered to be projects of European interest.**

R&D and cost reduction

In the last decade, the OWE industry has achieved significant technological progress. However, cost reductions, improved reliability, and availability of offshore grid and deep water technologies are areas which will require continued R&D efforts. Bringing the cost of delivered energy from OWE down to a level where it can compete in the market with little or no subsidies is a key challenge for the industry. Cost reductions could be achieved through improved foundation and turbine design as well as better construction and O&M strategies. Reliability is of key importance for offshore applications due to limited accessibility, especially for parks located further from shore. The availability of deep or floating water technologies could significantly increase the deployment potential for OWE (Norwegian and UK sea basins). Extensive research and funding is needed to develop floating technology solutions, which for a large part are still at a conceptual stage.

Important lessons have been learned through government and EU-funded demonstration projects. These projects have included testing turbines, foundations, layout, O&M strategies and other aspects. The technological innovation necessary to allow for an ambitious deployment, such as achieving 135 GW by 2030, will require significant and targeted R&D investment. Due to the high capital costs involved as well as risks and uncertainties, Public Private Partnerships should be encouraged to trigger the industry to develop more demonstration projects, in particular for deep water technologies. Efforts should also be made to strengthen and build on existing instruments, such as NER-300.

The European Commission is now deciding on the financial mechanisms for the period 2014-2020. In the new financial period, priorities should be set to speed up R&D efforts to promote technologies of European interest, such as OWE and offshore grid.

Recommendations

- **Dedicated and simplified demonstration programme for offshore renewable technologies in Member States and at EU level (extend NER-300 for OWE and make criteria more flexible and less administratively burdensome).**
- **Increased use of Public Private Partnerships to encourage demonstration projects.**
- **Standardised and scalable solutions combining HVAC, LCC HVDC, 2-terminal VSC HVDC and multi-terminal VSC HVDC technologies should be made cost-effective.**

Actions and milestones

In Figure 21, the recommendations above are fleshed into actions, indicating the time frame (short, medium and long term) in which these actions should be carried out and which stakeholders should take lead responsibility in carrying out these actions.

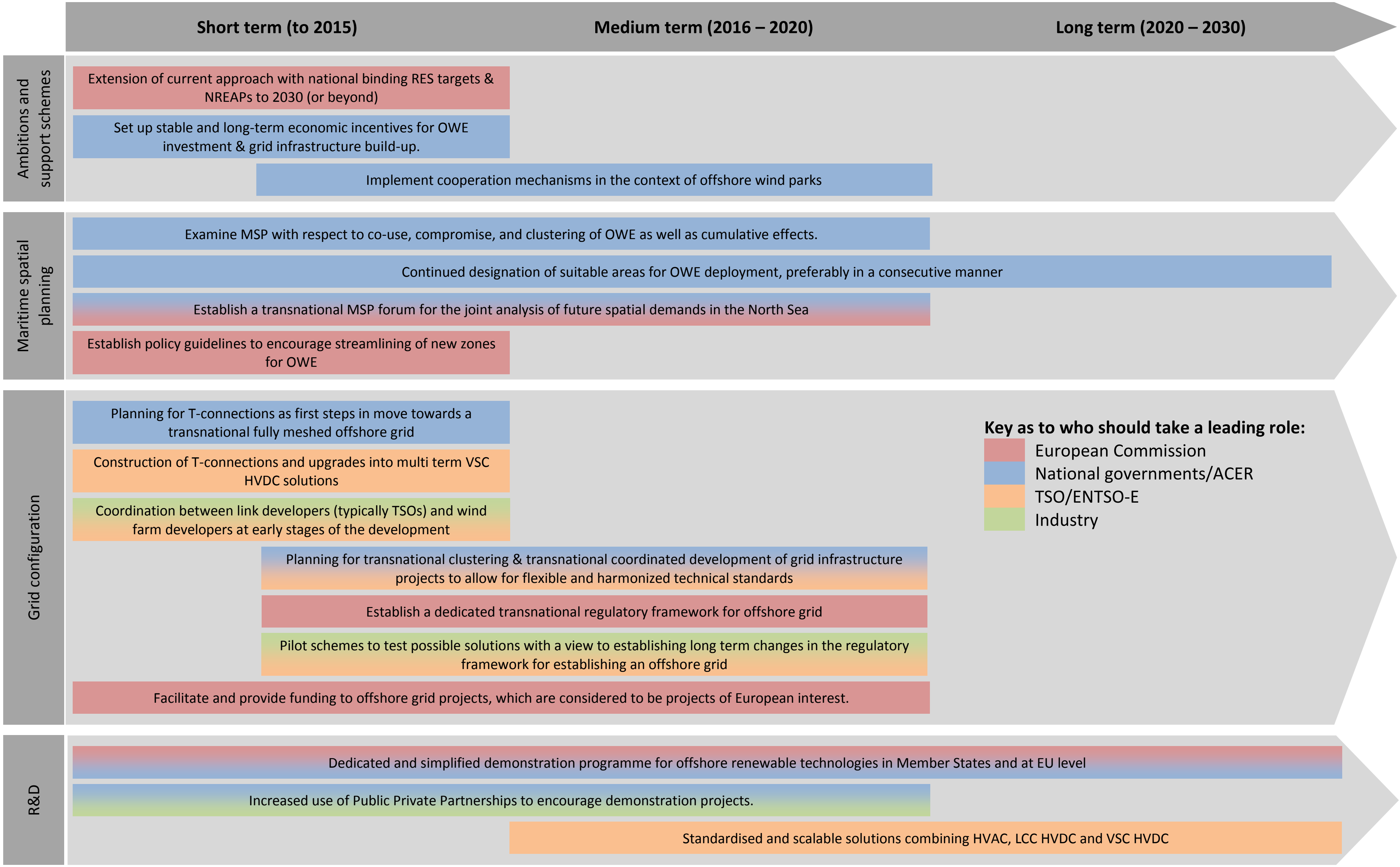


Figure 21: Actions, time frame and responsibilities

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