Offshore Wind in the EU
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Introduction

Offshore wind development in the European Union is being driven by a number of factors—from energy security to climate change. The previous EU voluntary goal of 21% renewable electricity by 2010 was unlikely to be met, but with new mandatory targets for renewables it has effectively been upgraded to approximately 34% by 2020[1]. Member States are looking to offshore wind technologies to help meet their policy goals and renewable energy targets.

Offshore wind technologies face several challenges: technical performance; competition for space with other users of the sea; compatibility with grid infrastructure and secure integration into the energy system; and full market competitiveness. The quality and quantity of literature related to existing offshore power production and impacts of wind farms is, while improving, somewhat limited. Nonetheless, this paper summarizes the literature available and describes the current status of offshore wind in the EU including: projects, policies and experiences. A document reference list, broken down by subject, is included to aid further research efforts in this area. As China considers offshore wind investments there are a number of lessons to be learnt from European experiences.

Current and Near-Term Projects

The world's first offshore wind farm, an 11-turbine installation in Vindeby, Denmark, has been operational since 1991. At the end of 2007, 22 offshore wind projects in five countries added up to nearly 1103 MW of electricity capacity (Table 1).

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[1] EWEA. Offshore Wind Necessary to Meet EU's 20% Renewables Target, Tuesday 4 December 2007.

	Turbines	Sea dept in m.	Distance to coast in km.	MW	Year
Vindeby (DK)	11 x 450 kW, Bonus	2.5-5.1	2.3	4.95	1991
Lely (Ijsselmeer) (NL)	4 x 500 kW, NEG Micon	5-10	<1	2	1994
Tuno Knob (DK)	10 x 500 kW, Vestas	2.5-7.5	5-6	5	1995
Dronton (Ijsselmeer) (NL)	28 x 600 kW, NEG Micon	5	<0.1	16.8	1996
Bockstigen (S)	5 x 550 kW, NEG Micon	6	3	2.75	1997
Blyth (UK)	7 x 1.5 MW, GE Wind	6-11	<1	4	2000
Utgrunden (Oland) (S)	2 x 2 MW, Vestas	7-10	8	10.5	2000
Middelgrunden (DK)	20 x 2 MW, Bonus	3-6	1.5-2.5	40	2000
Yttre Stengrund (S)	5 x 2 MW, NEG Micon	6-10	5	10	2001
Horns Rev (DK)	80 x 2 MW, Vestas	6-14	14-20	160	2002
Samsø (DK)	10 x 2.3 MW, Siemens	18-20	3-6	23	2002
Ronland (DK)	Mix of Vestas and Siemens	< 1	<1	17.2	2003
Frederikshavn (DK)	Mix of Vestas and Siemens	1-3	< 1	7.6	2003
North Hoyle (UK)	30 x 2 MW, Vestas	12	6-8	60	2003
Arklow Bank (UK)	7 x 3.6 MW,GE Wind	2-5	10	25.2	2003
Nysted (DK)	72 x 2.3 MW, Siemens	6-9.5	10	166	2003
Scroby Sands (UK)	30 x 2 MW, Vestas	2-8	3	60	2004
Kentish Flat (UK)	30 x 3 MW, Vestas	5	8.5	90	2005
Barrow (UK)	30 x 3 MW, Vestas	21-23	7.5	90	2006
NSW (NL)	30 x 3 MW Vestas	19-22	10	108	2006
Lillgrunden (S)	48 x 2.3 MW, Siemens	3-6	7-10	110	2007
Burbo Bank (UK)	24 x 3.6 MW, Siemens	2-8	5-7	90	2007

Table 1: Installed Offshore Wind Parks through 2007. Source: Lemming 2007[2]

These projects contribute 3.3% of all electricity generated by wind power in Europe, despite only accounting for 1.8% of total installed wind power capacity. The deepest site is the UK's 90 MW Barrow wind farm built in 2006—30 Vestas turbines, 3 MW each, are located 7.5 kilometers off the coast in waters 21-23 meters deep. The shallowest site is Denmark's 17.2 MW Ronland wind farm built in 2003—a mix of Vestas and Siemens turbines are located less than 1 kilometer from the coast in waters under 1 meter deep. Denmark also hosts the offshore park with the largest capacity at 166 MW—Nysted, built in 2003, consists of 72 Siemens turbines, 3 MW each, located 10 kilometers from the coast in waters 6-9.5 meters deep.

Several projects are on the horizon and some are nearing completion. Both 2008 and 2009 are set to become large growth years for offshore wind in Europe with a planned total volume of 1507.5 MW of new installations coming online[3]. Sweden's 110 MW Lille Grund project, made up of forty-eight 2.3 MW turbines, is installed and is expected to be complete by the end of the year. Denmark will be adding two large offshore wind parks to its portfolio in the next couple of years, bringing the grand total to ten[4]. Both Horns Rev 2 and Rodsand 2 are in the 200 MW, ninety turbine

2 From presentation Offshore Wind Power Experiences, Potentials and Key Issues for Deployment. Jørgen K. Lemming, Risø National Laboratory, Technical University of Denmark. Presented at IEA and Danish Ministry of Foreign Affairs Workshop, Berlin, December 3, 2007.

3 Renewable Energy World Magazine. 3 Jan 2008. 40,000 MW by 2020: Building Offshore Wind in Europe. Available at <http://www.renewableenergyworld.com rea/news/reworld/ story?id=51595>

4 See Offshore Windfarms in Denmark, Danish Energy Agency. Available at http://www.ens.dk/sw15562.asp

range. The Rodsand 2 offshore wind farm has been given the go-ahead by the Danish government. The large international utility EON hopes to begin construction in 2009 on the 215 MW project. Three prototype 5 MW turbines will complement the ninety 2.3 MW turbines.

Recently, the UK granted permission for the 450 MW Walney offshore wind farm in the Irish Sea. The project is under development by Dong Energy and is expected to cost around £900 million. The first 44-turbine phase, approximately 160 MW, is expected online between 2010 and 2011. The second phase depends on onshore grid upgrades, but the delay might allow for the utilization of higher-capacity next-generation turbines[5]. The Borkum 2 400 MW wind farm, 100 km off the German coast in the North Sea, is scheduled to be operational in September 2009. ABB High Voltage Direct Current (HVDC) Light transmission technology[6]—which gives utilities control over the power supply and increases grid stability—will be utilized at what is to be the most remote offshore wind farm in the world[7].

Each year, about 100 to 200 MW have been added globally over the last few years summing up to an average annual growth of 58 % over the period 2000 to 2007 (Table 2)

YEAR	New Capacity	Total Capacity MW	Yearly growth
2000	**55**	86	199%
2001	**10**	96	12%
2002	**183**	279	191%
2003	**276**	555	99%
2004	**60**	615	11%
2005	**90**	705	15%
2006	**198**	903	28%
2007	**200**	1103	22%
			Average 58%

Table 2: Offshore Wind Growth Rates Offshore 2000 - 2007. Source: Lemming 2007)[8].

5 Offshore Wind and Marine Project Update – Germany's Promise. Renewable Energy Focus, January/February 2008, p. 22.

6 HVDC Light offers a number of environmental benefits including: neutral electromagnetic fields, oil-free cables and compact converter stations. Offshore Wind and Marine Project Update – Germany's Promise. Renewable Energy Focus, January/February 2008, p. 22. More Information available from ABB at http://www.abb.com/cawp/GAD02181/C1256D71001E0037C12568350027FEFC.aspx

7 Offshore Wind and Marine Project Update – Germany's Promise. Renewable Energy Focus, January/February 2008, p. 22.

8 From presentation Offshore Wind Power Experiences, Potentials and Key Issues for Deployment. Jørgen K. Lemming, Risø National Laboratory, Technical University of Denmark. Presented at IEA and Danish Ministry of Foreign Affairs Workshop, Berlin, December 3, 2007.

Outlook for Offshore Wind Power in Europe

Figure 1 compares offshore growth projections from a number of European scenarios. Given the limited distribution of offshore wind in Europe, historical trends, wind potential, projects in planning, industry assessments, and the policies and targets of Member States, the European Wind Energy Association (EWEA) estimates 3.5 GW of offshore wind capacity in Europe by the end of 2010 [9]. On a longer-term basis, current and planned offshore developments could reach 15 GW by 2015—and this only in eight countries. The European Wind Energy Association estimates that 40 GW, supplying 4% of Europe's electricity, could be reached by 2020 if existing barriers are removed[10]. Ultimately, diffusion rates of offshore wind energy will depend heavily on technological learning and development. Market and supply chain development are also critical aspects and as demand outpaces supply, bottlenecks can be expected. However, some relief on the supply chain can be observed recently. For example, wind manufacturers REpower and Multibrid launch series production of 5MW offshore turbines this year. Both companies have established production facilities at the harbor in Bremerhaven, Germany. Each company is planning to produce up to 100 turbines a year by 2010—no small feat considering the complexity and size of the supply chain involved.

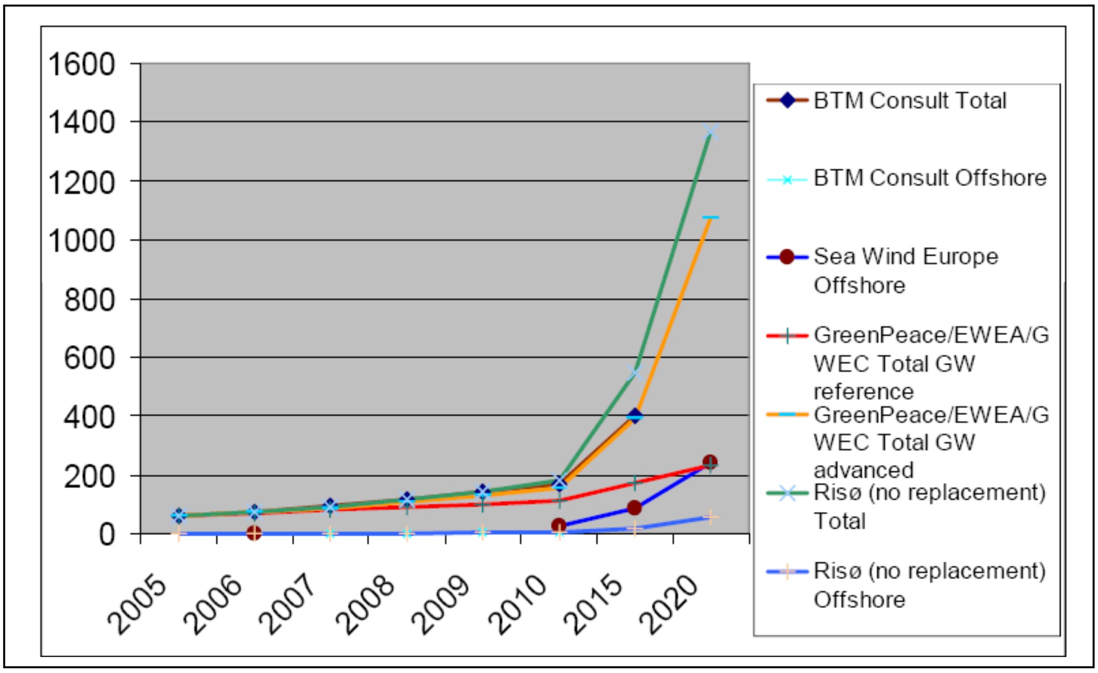

Figure 1: Forecasts for Offshore Wind. Source: http://www.offshorewindenergy.org/Updated 28 June 2007.

[9] EWEA. Delivering Offshore Wind Power in Europe: Policy Recommendations for Large-Scale Deployment of Offshore Wind Power in Europe by 2020. 2007. Available at <http://www.ewea.org/fileadmin/ewea_ documents/images/publications/offshore_report/ewea-offshore_report.pdf>.

[10] 2007 European Offshore Wind Conference & Exhibition. Offshore Bulletin: Get a Closer Look at Offshore Wind. 10/2007.

Despite significant uncertainties the potential for offshore wind is large and is currently untapped. For offshore wind to reach its potential, EWEA cites six complementary aspects that need to be implemented:

1. continued commitment of the EU and its Member States to offshore wind development;
2. technological development and deployment;
3. timely implementation of supply chain capabilities;
4. appropriate planning practices and technological achievements translated into the construction of large-scale wind farms;
5. financing, design and building of grid infrastructures including transmission interconnection; and
6. implementation of more efficient power exchange mechanisms in the EU electricity market[11].

Considering the necessary area to cover the entire power demand of European OECD member states it seems quite reasonable to expect that offshore power can supply substantial shares of Europe's power demand (Figure 2).

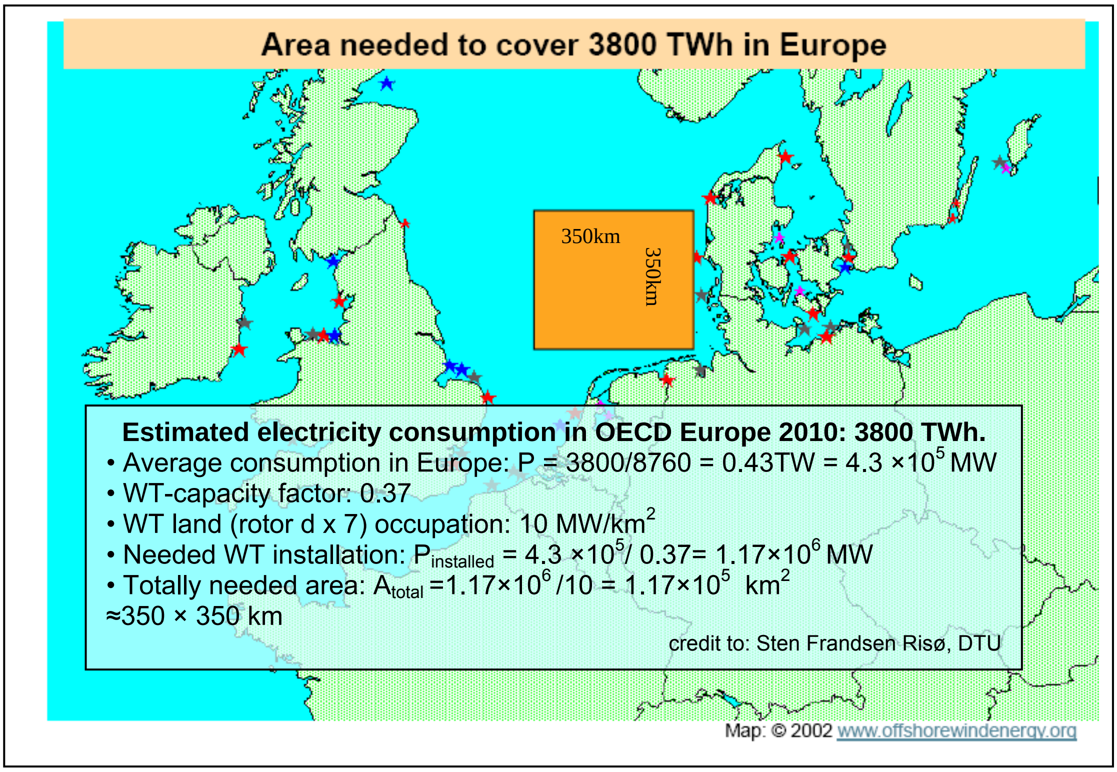

Figure 2: Estimate for the sea area needed to cover the entire power demand of the European OECD member states. Source: Adapted from Lemming 2007[12]

[11] EWEA. Delivering Offshore Wind Power in Europe: Policy Recommendations for Large-Scale Deployment of Offshore Wind Power in Europe by 2020. 2007. Available at <http://www.ewea.org/fileadmin/ewea_documents/images/publications/offshore_report/ewea-offshore_report.pdf>.

[12] From presentation Offshore Wind Power Experiences, Potentials and Key Issues for Deploymen.t Jørgen K. Lemming, Risø National Laboratory, Technical University of Denmark. Presented at IEA and Danish Ministry of Foreign Affairs Workshop, Berlin, December 3, 2007.

Realizing the Potential: the case of the United Kingdom

The United Kingdom opened its first offshore wind park off the coast of northeast England in 2000. The Blyth wind farm is expected to have an annual output of 10,000 MWh. In 2004, the UK passed the Energy Act which allows for development outside of territorial waters. In the same year, 15 projects were under consideration which could provide approximately 7% of the nation's electricity demand. Recently, Shell withdrew from one of the largest offshore projects, the London Array. The UK's quota system, operating under the Renewables Obligation (RO), places an obligation on suppliers to source a growing proportion of electricity from renewables. Renewables Obligation Certificates (ROCs) are generated from renewable sources and can be traded to meet the obligation. The uncertainty of ROC prices, the complexity of the system , as well as difficulties with the planning process continue to restrain offshore development. The government is working to pass a banding that would provide for 1.5 ROCs per MW of offshore and to streamline the permitting process. These two steps, and the easing of bottlenecks in the manufacturing of turbines, could contribute to profitable offshore in the UK.

Realizing the Potential: Necessary Grid Expansion, a German Case-Study[13]

The German National Energy Agency (Dena) funded a study looking at the impact of offshore wind farm grid connections on the German power grid and existing power plant infrastructure14. The study showed that the cost-effective integration of wind energy including substantial offshore expansion with a moderate expansion of the grid is possible. Approximately 850km of extra-high voltage grid will need to be added, corresponding to less than 5% of the existing extra-high voltage grid[15]. Furthermore, the study concluded that there is no threat to critical systems or of blackouts in Germany that cannot be resolved through technical measures. In terms of existing power plants, the study concluded that no so-called dedicated "shadow plants" will have to be built in order to balance load or to provide reserve power.

Until 2006, the connection of an offshore wind park to the onshore electricity grid was the sole financial responsibility of the plant operator. As most of the German offshore wind parks are planned to be erected well over 30km from the coast, the cost of grid connection can account for between 20 and 30 percent of the overall project cost. The Infrastructure Planning Acceleration Act passed at the end of 2006 alters the responsibility for financing and operating connection to the grid. The Act came into effect on 17 December 2006 and obligates the nearest grid network operator to connect the offshore wind park to the grid, i.e. from the substation at sea to the best grid connection point from both a technical and economical point of view[16]. At the same time costs of connections are minimized through coordinated planning (Figure 3). This regulation affects any wind park whose construction will commence before

[13] The study is discussed in detail in the second chapter, Strategy of the German Government. The Berlin University of Technology. 2006. Offshore Wind Energy: Research on Environmental Impacts. Editors: Köller, J., Köppel, J. and Peters, W. Springer, Berlin.

[14] DENA Project Steering Group. Planning the Grid Integration of Wind Energy in Germany Onshore and Offshore up to the year 2020. DENA grid study. 2005. Deutsche Energie-Agentur, Berlin, www.wind-energy.de/fileadmin/documente/Themen_A-Z/Netzausbau/stud_summary-dena_grid.pdf

[15] Total length of German power grid is 18,000km.

[16] Section 17 subsection 2a Energy Industry Act EnWG.

the end of 2011[17]. The cost of grid connection will be carried by the network operator and can also be distributed across all transmission network operators.

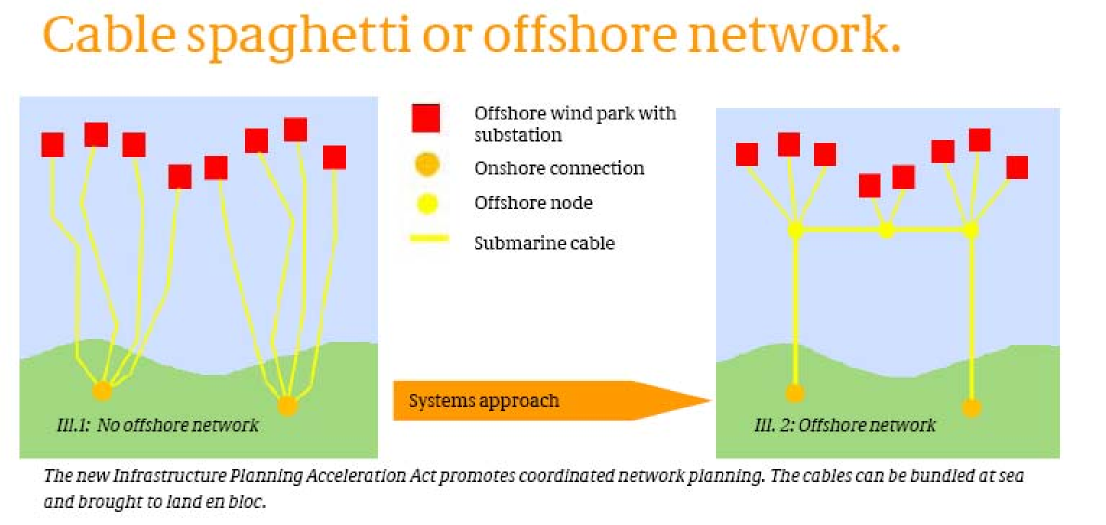

Figure 3: Coordinated connection of offshore wind power plants. Source Dena fact sheets 09/07.

International Cooperation

Offshore wind development in Europe requires international cooperation, in part, due to the close geographic location of the Member States and the proximity of their respective Territorial Seas. The Territorial Sea of a nation is the adjacent first 12 nautical miles off the coast. The Territorial Sea is governed by the respective nation. Therefore, licensing and planning procedures fall under federal or local authorities. The marine area beyond the Territorial Sea is the Exclusive Economic Zone (EEZ) and does not belong to the national territory of a given Member State. The legal situation of activities in the EEZ is more complex than that of the same activities carried out in the Territorial Seas.

However, coastal state signatories to the 1982 United Nations Convention on the Law of the Sea were granted certain use and regulatory powers in the EEZ, including specifically for generating energy from wind[18]. In addition, there are a number of international agreements regarding the protection of marine environments. For example, regional agreements exist to protect the marine environment of the North-East Atlantic and of the Baltic Sea[19]. While these agreements include stipulations for offshore oil rigs, they do not yet include provisions for offshore wind farms[20]. Two European directives are also significant for the licensing eligibility of offshore wind farms—the Bird Directive[21] and the Habitats Directive[22]. It is the opinion of the EU

[17] Section 118 EnWG. This date is likely to be extended due to the delay in construction of offshore wind parks.

[18] cf Articles 56 and 60.

[19] The OSPAR Convention, in force since 1998, protects the North-East Atlantic and the Helsinki Convention, in force since 2000, protects the Baltic Sea.

[20] In 2004, the OSPAR Commission did publish a report entitled "Problems and Benefits Associated with the Development of Offshore Wind Farms."

[21] Directive 79/409/EEC on the conservation of wild birds.

[22] Directive 92/43/EEC on the conservation and the natural habitats of wild fauna and flora.

Commission that both Directives apply not only within the national territory of the EU Member States, but also in the marine areas directly adjacent to the territorial waters[23].

Offshore wind energy is also seen as a critical means to reach collective regional renewable energy and environmental goals. In 2007, EU Member States agreed on a 20% binding target by 2020 for renewable energy[24]. This could mean 34% of electricity in 2020 produced by renewables. Offshore wind will play an increasing role in meeting this target. According to the European Wind Energy Association, wind energy can produce 12% of total electricity – equivalent to more than a third of the electricity target – but only if offshore wind is developed[25].

Since 2002, European Union Member States have been cooperating and have issued conclusions on how to develop offshore wind power through the findings of the 2004 Egmond Declaration[26], the 2005 Copenhagen Strategy[27] and the 2007 Berlin Declaration[28]. In December of this past year, the process evolved further as the European Commission announced an Offshore Action Plan for 2008. The announcement is in response to a series of policy recommendations released by the wind industry[29]. The recommendations look to remove many of the barriers to implementing offshore wind by establishing market support, increasing research and technological development, improving grid integration and streamlining planning procedures.

Regional cooperation, particularly in research, has been furthered by country agreements—such as the trilateral offshore research agreement[30] signed in December

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23 In Germany, sites protected under these Directives have gained support through the Renewable Energy Sources Act (EEG). In 2004, the EEG was amended to exclude wind energy installations licensed after 1 January 2005 in the EEZ or the Territorial Sea which are protected under either Directive. This effectively directs the expansion of offshore wind energy towards areas which are less environmentally sensitive. *See* Chapter 3, the Legal Framework Conditions for Licensing. The Berlin University of Technology. 2006. Offshore Wind Energy: Research on Environmental Impacts. Editors: Köller, J., Köppel, J. and Peters, W. Springer, Berlin.

24 See The 2020 Renewable Energy Targets in the EU memo by the Centre for Solar Energy and Hydrogen Research Baden-Wuerttemberg (ZSW) as consultants to the Center for Resource Solutions and prepared for the Energy Foundation's China Sustainable Energy Program. March 2008.

25 EWEA. Offshore Wind Necessary to Meet EU's 20% Renewables Target, Tuesday 4 December 2007. Available at http://www.ewea.org/index.php?id=60&no_cache=1&tx_ttnews%5Btt_news%5D=562& tx_ttnews%5BbackPid%5D=1&cHash=44bb2e1ab8

26 Available at http://www.offshore-wind.de/page/fileadmin/offshore/documents/Politik_und_Wind/041001_egmond_declaration.pdf

27 Available at http://www.offshore-wind.de/page/fileadmin/offshore/documents/Politik_und_Wind/copenhagen_strategy_on_offshore_wind_power_deployment.pdf

28 The European Policy Workshop on Offshore Wind Power Deployment. 22/23 February 2007 at the Technische Universität Berlin. Documentation available at http://www.offshore-wind.de/page/fileadmin/offshore/documents/Politik_und_Wind/ Berlin_declaration.pdf

29 *See* European Wind Energy Association publication - Developing Offshore Wind Power in Europe: Policy Recommendations for Large-Scale Deployment of Offshore Wind Power in Europe by 2020. 2007. Available at <http://www.ewea.org/fileadmin/ewea_documents/images/publications/offshore_report/ewea-offshore_report.pdf>.

30 EWEA. Offshore Wind Necessary to Meet EU's 20% Renewables Target, Tuesday 4 December 2007. Available at http://www.ewea.org/index.php?id=60&no_cache=1&tx_ttnews%5Btt_news%5D=562&tx_ttnews%5BbackPid%5D=1&cHash=44bb2e1ab8

2007 by Germany, Sweden and Denmark. The agreement replaces a 2005 joint document between Germany and Denmark that aimed to enhance cooperation on offshore wind power issues. The new agreement is aimed at technical and environmental issues as well as other research topics. Other European countries were explicitly invited to join in.

Cooperation can also help ease the financial risk associated with infrastructure investment. In the case of extending the transmission grid offshore, international cooperation can make the difference between an offshore wind farm having a single radial connection to the main onshore network and a loop multi-connection, or true grid connection. The benefits of such cooperation include the potential for trade in renewables electricity, reducing grid system vulnerability and cost-sharing.

One particular collaborative activity is the POWER project. [31] The POWER project unites North Sea regions with an interest in supporting and realizing the economic and technological potentials of offshore wind energy. The project assesses environmental and planning as well as acceptance issues of offshore wind farms, supports the development of a reliable supply chain for the sector, and elaborates skills development measures. Thirty-seven organizations are taking part, with representatives from Germany, the UK, Denmark, the Netherlands and Belgium. Transnational co-operation between these regions is creating a North Sea competence network for offshore wind energy. Offshore wind provides a unique opportunity to regenerate the economies of coastal regions that suffer from high unemployment and economic decline, due to their often relatively peripheral location, the collapse in fish stocks and the decline in the traditional offshore industries. POWER aims to tackle major barriers to the adoption of offshore wind energy at all levels.

Another collaborative activity is BOSEC, or the Baltic Offshore Energy Cluster[32]. The Baltic Offshore Energy Cluster is a group of scientific, financial, industrial and other enterprises, joined for the efficient development of off-shore energy in marine areas of Poland, Lithuania, Latvia and Estonia. This includes establishing off-shore wind parks, wave and stream power stations, etc.; the financing and construction of the East Baltic arm of the Pan European Supergrid; and the logistical arrangement of the European electricity market. The joint activity of BOSEC aims to create synergy by the efficient integration of efforts and abilities of business enterprises, science organizations and European Commission and national government-level policymakers. The aim is to accelerate development of marine energy and European power markets according to priorities and targets set out in the Lisbon strategy[33] and the EU energy strategic plans.

Research & Development

At the European Union level offshore wind research and development has been given priority. Several umbrella organizations, such as the European Technology Platform for Wind Energy and the Joint Research Centre, coordinate efforts between national

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[31] POWER website available at http://www.offshore-power.net/informationsub.asp?Page=70&menu=1&submenu=221&type=menu&print=print

[32] http://www.bosec.lt/AboutBOSEC.htm

[33] Lisbon Strategy for Growths and Jobs aims at European modernization and global competitiveness. *See* European Commission information page available at http://ec.europa.eu/growthandjobs/index_en.htm

institutions. At a 2007 European workshop, the third "European Policy Workshop on Offshore Wind Power Deployment," stakeholders, including government and industry, from twelve European nations highlighted the need for more research on technology, grid integration and environmental aspects. Joint European efforts, such as the European Commission sponsored European Technology Platform for Wind Energy[34] and the 7th framework program that guides the work and funding of the Joint Research Centre[35] are seen as key elements to give high priority to offshore research and development. On grid issues, workshop participants generally supported the designation of a European coordinator on grids for northern European offshore wind power plants; a general study on cross-border offshore grids was mentioned as a needed step to develop a common European offshore policy. There are also a number of bilateral agreements and multi-lateral co-operations to promote offshore R&D in Europe (as detailed below).

Assessment & Innovation: Measuring Environmental Impacts of Offshore Wind

There are a number of potentially detrimental impacts that offshore wind energy installations can have on some species and habitats of concern—especially when no measures are made to prevent or reduce such impacts. Specifically, local bird, mammal and fish species can be disturbed and critical feeding and breeding habitats lost. Benthic communities at the foundation of a turbine will be destroyed and the benthic communities in the vicinity of the wind farms can be impacted by changes in hydrology and sediment. Underwater noise, especially during construction, but also during operation, can affect marine mammals. Artificial electrical and magnetic fields can be disorienting for fish and marine mammals. Also, wind farms do increase the chance of shipping collisions which can threaten very large areas (e.g. the case of an oil or chemical leak). Positive impacts for certain species, such as fish and benthic fauna, in areas that are excluded for other purposes (such as fishing) can also be expected.

Denmark[36], Sweden and Germany[37] have taken serious steps to further critical research and to make information on potential environmental impacts from offshore wind energy publicly available. In Germany, for example, an Offshore Wind Energy Foundation[38] was established to set up test fields for offshore wind turbines. The Federal Environment Ministry (BMU) headed the process in the interest of climate protection and energy supply security. The aim is to promote technological research, ecological research and the exchange and transfer of knowledge. The Foundation acquires the rights for the licensing of the test sites and then leases sites to the operating companies to test multi-megawatt, e.g. larger than 5 MW, turbines. The first of three offshore wind platforms, FIN O1, set up in 2003 in the North Sea off of Germany's coast, was established to examine wave and wind conditions and to

34 http:?www.windplatform.eu

35 http://ec.europa.eu/dgs/jrc/index.cfm?id=1590&lang=en

36 *See* The Danish Energy Authority. 2006. Danish Offshore Wind: Key Environmental Issues. DONG Energy, Vattenfall, the Danish Energy Authority and the Danish Forest and Nature Agency.

37 *See* The Berlin University of Technology. 2006. Offshore Wind Energy: Research on Environmental Impacts. Editors: Köller, J., Köppel, J. and Peters, W. Springer, Berlin.

38 The establishment of the Foundation is discussed in Chapter 2, Strategy of the German Government. The Berlin University of Technology. 2006. Offshore Wind Energy: Research on Environmental Impacts. Editors: Köller, J., Köppel, J. and Peters, W. Springer, Berlin.

determine the effects of wind farms on marine flora and fauna. FINO 2 was set up in 2006 in the Baltic Sea near Kriegers Flak.

For approval of offshore wind farms in the EEZ, the EU's Environmental Impact Assessment (EIA) Directive[39] and, if protected areas are involved, appropriate assessment under the Habitat Directive are legally stipulated. Other requirements such as Strategic Environmental Assessment (SEA) might also be mandatory[40]. These instruments attempt to ascertain the impact on the marine environment caused by the construction, installation, operation and decommissioning of offshore wind farms and to integrate this information into the decision-making process on the authorization of such projects. Again, using the example of Germany, the EIA formulates no standards of its own for the assessment of environmental impacts as a basis for decision-making on the authorization of projects. Therefore, the EIA must be oriented towards the grounds for refusal formulated in the German Marine Facilities Ordinance[41]. The result is that only impacts are to be included in a given assessment which could demonstrably cause such considerable adverse environmental consequences as to constitute a situation of endangerment of the marine environment—making them relevant for the approval process[42].

Adapting administrative and regulatory tools to the marine environment, in the context of licensing procedures, is a critical task[43]. Protected assets and impact factors need to be specifically defined for the marine environment. Impacts of particular importance to the decision-making process should be focused on. As there are thresholds that can be reached with ecosystems, points from which systems can not recover, it is important to know at what step in a cause-effect chain of events danger is imminent and is to be prevented[44]. This requires assessment prior to an activity and further application of the precautionary principle as activities go forward. Long-term monitoring and penalties for damages are ways to prevent these thresholds

39 Information on the EIA can be found online at http://ec.europa.eu/environment/eia/home.htm

40 SEA is a legally enforced assessment procedure required by Directive 2001/42/EC (known as the SEA Directive). The SEA Directive aims at introducing systematic assessment of the environmental effects of strategic land use related plans and programs. It typically applies to regional and local—development, waste and transport plans—within the European Union. SEA only applies to plans that are required by law. Therefore, voluntary national plans and programs are often excluded. Information on the relationship between EIA and SEA in the EU can be found at http://ec.europa.eu/environment/eia/pdf/final_report_0508.pdf in the report "The Relationship between the EIA and SEA Directives: Final Report to the European Commission" Contract No. ENV.G.4/ETV/2004/0020r, Imperial College London Consultants.

41 *See* Approval Procedures of the Bundesamt für Seeschifffahrt und Hydrographie available in English at http://www.bsh.de/en/Marine_uses/Industry/Wind_farms/Approval_Procedure.jsp

42 *See* Chapter 18 EIA in the Approval of Offshore Wind Farms. The Berlin University of Technology. 2006. Offshore Wind Energy: Research on Environmental Impacts. Editors: Köller, J., Köppel, J. and Peters, W. Springer, Berlin.

43 *See* Chapter 18 EIA in the Approval of Offshore Wind Farms. The Berlin University of Technology. 2006. Offshore Wind Energy: Research on Environmental Impacts. Editors: Köller, J., Köppel, J. and Peters, W. Springer, Berlin.

44 *See* Chapter 18 EIA in the Approval of Offshore Wind Farms. The Berlin University of Technology. 2006. Offshore Wind Energy: Research on Environmental Impacts. Editors: Köller, J., Köppel, J. and Peters, W. Springer, Berlin.

from being crossed. Countries such as Denmark are leading the way in developing new techniques to facilitate long-term monitoring of marine environments[45].

Danish Experience: Offshore Wind and the Marine Environment

Using experiences at Horns Rev, a farm consisting of 80 wind turbines totalling 160 MW, and at Nysted, a farm consisting of 72 wind turbines totalling 166 MW, the Danish government, in its 2006 Danish Offshore Wind: Key Environmental Issues publication, has detailed: the configuration and construction of the farms; the environmental monitoring of the sites; key findings related to specific fish, mammal and bird species; and the policy, planning and public consultation process related to the establishment of the sites.

In addition to the publication of the studies, noteworthy efforts were made to provide legitimacy and transparency and to understand the various impacts offshore wind can have on the environment. These efforts include: convening an International Advisory Panel of Marine Ecology (IAPME) to shape and review the environmental monitoring process; Environmental Impact Assessments and environmental monitoring from 1999-2006 (before, during and after construction); development of new monitoring techniques for mammals and birds; a novel quantitative assessment of people's willingness to pay for a reduced visual impact of development; and data rich "Final Reports" available for download.

The general conclusion of the IAPME was that with the use of spatial planning it will be possible to construct offshore wind power facilities in many areas in an environmentally sustainable manner. The authors of Denmark's studies highlight the fact that every local marine environment is different. While some impacts will be similar to all offshore wind farms, such as converting sandy bottoms to solid structure, others will be localized. There are also questions pertaining to the cumulative effects of massive offshore wind development, such as what impact it will have on bird migratory patterns that require long-term, large-scope studies. Denmark has led the international effort to provide a full picture of offshore wind environmental issues. Denmark's efforts serve as a great model for governments considering similar projects.

Overcoming Barriers to Deployment

The main factors affecting renewable energy-sourced electricity (RES-E) deployment, apart from site conditions, are (i) the costs for grid connection, (ii) the unit generation costs, (iii) the respective feed-in tariff or another supporting scheme and (iv) the allocation of costs[46]. The allocation of grid connection costs can form a significant barrier for the installation of new renewable energy-sourced electricity generation, especially offshore wind, if the developer has to bear all the costs[47]. Shifting the cost burden to the respective grid operator and then allowing for the recouping of costs through a consumer tariff effectively removes this barrier.

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45 *See* The Danish Energy Authority. 2006. Danish Offshore Wind: Key Environmental Issues. DONG Energy, Vattenfall, the Danish Energy Authority and the Danish Forest and Nature Agency.

46 Swider DJ, et al. Conditions and costs for renewables electricity grid connection: Examples in Europe. Renewable Energy (2007), doi: 10.1016/j.renene.2007.11.005.

47 Swider DJ, et al. Conditions and costs for renewables electricity grid connection: Examples in Europe. Renewable Energy (2007), doi: 10.1016/j.renene.2007.11.005.

Offshore Wind Pricing in Europe

Denmark[48]

Denmark is set to increase renewables to a 30 % share of all energy consumed by 2025; in the electricity sector a large share of this is to be through the development of offshore wind. There are a number of pricing rules that address offshore. For instance if the offshore turbines were connected to the grid no later than December 31, 1999, plant owners are responsible for the sale of production on the electricity market and for related costs.

Offshore is eligible for a subsidy that combined with the market price comprises 45.3 øre/kWh. The subsidy is payable for 42,000 full load hours. If production is subject to a grid tariff, it is eligible for compensation up to 0.7 øre/kWh.

After all full load hours are used up, a premium up to 10 øre/kWh until the turbine is 20 years old is available. The premium is regulated in accordance with the market price, as the total of the two must not exceed 36 øre/kWh. After January 1, 2005, the permitting process was also streamlined and now permits for the establishment of offshore wind farms are subject to decision by the Minister of Transport and Energy after tendering or application.

Germany[49]

The core elements of the German Feed-In Tariff for renewables (EEG) include:

- Priority connection to the grid for the generation of electricity from renewables;
- Priority purchase and transmission of this electricity;
- Guaranteed fee for this electricity paid by the grid operators, generally for a 20 year period and for commissioned installations, this payment is geared to costs; and
- National equalization of the electricity purchased and the fees paid.

Fees paid for electricity are differentiated by energy source and size of the installation. The later the date of commissioning, the lower the tariff (referred to as degression). Germany's feed-in tariff is routinely cited as the most successful renewables support scheme[50]. However, in the case of offshore, the premium, alone, has not been enough to stimulate offshore development; barriers have included grid extension, siting and planning. Offshore development is now progressing, but Germany is behind schedule. On 9 June 2008 the German Parliament adopted an amendment of the Renewable Energy Sources Act (EEG). The amendment provides a higher feed-in tariff for wind energy, and other measures to stimulate the development of both onshore and offshore wind power. Under the new law set to come into force 1 January 2009, the feed-in tariff for onshore wind farms will be increased from EUR

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48 Danish Energy Agency at http://www.ens.dk/sw23781.asp

49 Discussed in Chapter 3: Legal Framework Conditions for the Licensing of Offshore Wind Farms. The Berlin University of Technology. 2006. Offshore Wind Energy: Research on Environmental Impacts. Editors: Köller, J., Köppel, J. and Peters, W. Springer, Berlin.

50 Swider DJ, et al. Conditions and costs for renewables electricity grid connection: Examples in Europe. Renewable Energy (2007), doi: 10.1016/j.renene.2007.11.005.

8.03 to EUR 9.2 cents/kilowatt-hour (kWh). This tariff will be decreased every year for new installations by one percent, as opposed to the previous two percent. For offshore wind, defined as three or more nautical miles from the shoreline, the initial tariff is set at 15 cent/kWh until 2015. After that it is set to decrease to 13 cent/kWh for new turbines, decreasing by five percent per year.

The German government also approved a climate package in June 2008 which is designed to help it reach a target of reducing carbon dioxide emissions by 40 percent by 2020 compared to 1990 levels. The package, which focuses on the transport and construction sector, builds on the previous climate agreement which emphasised green electricity and making power plants more efficient. The package includes approval for the construction of an an 850 km underground grid to transport offshore wind energy to the country's south.

Sweden[51]

Sweden utilizes an electricity certificate system[52] where electricity users are obligated to purchase green certificates equivalent to a certain percentage of their overall use. One certificate, equivalent to one MWh of renewable electricity, sold for approximately 191 SEK in 2007 and cost the consumer approximately 4 øre per kWh. 61 offshore power plants were given certificates in 2007. In Bill No. 2001/02:143, Cooperation for Reliable, Effective and Environmentally Friendly Electricity Production, the Swedish Parliament has set a national planning target of 10 TWh of electricity from wind power by 2015. Instructed by the Government, the Swedish Energy Agency has proposed a new planning target of 30 TWh of wind power production in 2020. Of this, 20 TWh should be onshore, and 10 TWh offshore. The Swedish Lillegrund wind power farm was built with financial assistance from the state fund (known as the Pilot Fund) for market introduction of wind power. A new funding program has been decided for the 2008–2012 period, and can result in more offshore construction projects. The Swedish Energy Agency proposes several ways in which a substantial expansion of wind power production could be achieved in the next years: 1) the planning application and approval process needs to be streamlined; 2) wind power production should be removed from the Ordinance Concerning Environmentally Hazardous Activities, as it is a ‘clean’ energy source; 3) contacts with public authorities should be channeled through a single entry point; 4) that the quotas in the electricity certificate system should be reviewed by not later than the next review of the system as a whole, and 5) that greater support should be provided for offshore wind power production through new policy measures.

Planning and Construction Experiences

Planning and construction of offshore wind farms compares in complexity to the planning and construction of a conventional power plant. It is important to decrease risk for planning authorities, investors and developers where possible as the offshore business still faces relatively high uncertainties for installation and maintenance. The German Energy Agency sponsored a research project, Case Study of European Offshore Wind Farms, evaluating experiences with the planning and development

[51] http:/www.swedishenergyagency.se

[52] See the Electricity Certificate System 2008, Swedish Energy Agency, at http://www.swedishenergyagency.se/web/biblshop_eng.nsf/FilAtkomst/ET2008_09w.pdf/$FILE/ET2008_09w.pdf?OpenElement

procedures at eight offshore wind farms in different EU countries[53]. The goal of the study was to reduce development costs and increase efficiency. Seven main steps in the realization of offshore wind farms were identified:

- Pre-project planning,
- Detailed project planning,
- Production and procurement,
- Engineering, testing, installation and commissioning,
- Full operation,
- Repowering, and
- Dismantling.

Within each of these steps several work packages were identified that management must consider when going forward with a project (Figure 4). From the offshore wind farms evaluated, the main obstacles in the planning and realization of projects were a general lack of experience, on the part of either the planning authorities or the project developers, and an underestimation of the time required in the tender process and planning stages. The authors made several recommendations in the pre-planning, project planning, management and approval steps including:

- Pre-selection of sites by authorities—helping to avoid conflicts, unnecessary approval procedures and site investigation—leading to a streamlining of the approval process and increased security for the project developer;
- Developer choice of wind technology;
- Some work packages during the "detailed project planning" phase—project approval procedure, site investigation, and the definition of functional requirements of major elements of the wind farm—should be realized in parallel because they are prerequisites for both tendering and contracting;
- Prior to production of wind farm elements: pre-testing of a full-size wind turbine model, testing of the service and maintenance of all main components (pile, nacelle, blade, generator and transformer), testing of access to the wind turbine and training for personnel should be completed;
- Streamlining the approval process—a "one stop shop" office approach is recommended—for the EEZ, the Territorial Sea, the onshore grid connection and cable route has high value for the planning authorities and the developer;
- Government screening—based on methods used in Denmark[54]--allows for the best selection of sites with least impact on the environment and provides a high level of planning safety for the developer; and
- A professional media strategy to increase public awareness and acceptance.

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53 Deutsche WindGuard GmbH, Deutsche Energie-Agentur GmbH (dena), University of Groningen, Gerhard Gerdes Albrecht Tiedeman drs. Sjoerd Zeelenberg. 2007. Case Study: European Offshore Wind Farms- A Survey for the Analysis of the Experiences and Lessons Learnt by Developers of Offshore Wind Farms -Final Report. Available at http://www.ruimte-rijk.nl/index/publicaties/publicaties/final%20report%20case%20studies%20POWER.pdf

54 *See* The Danish Energy Authority. 2006. Danish Offshore Wind: Key Environmental Issues. DONG Energy, Vattenfall, the Danish Energy Authority and the Danish Forest and Nature Agency.

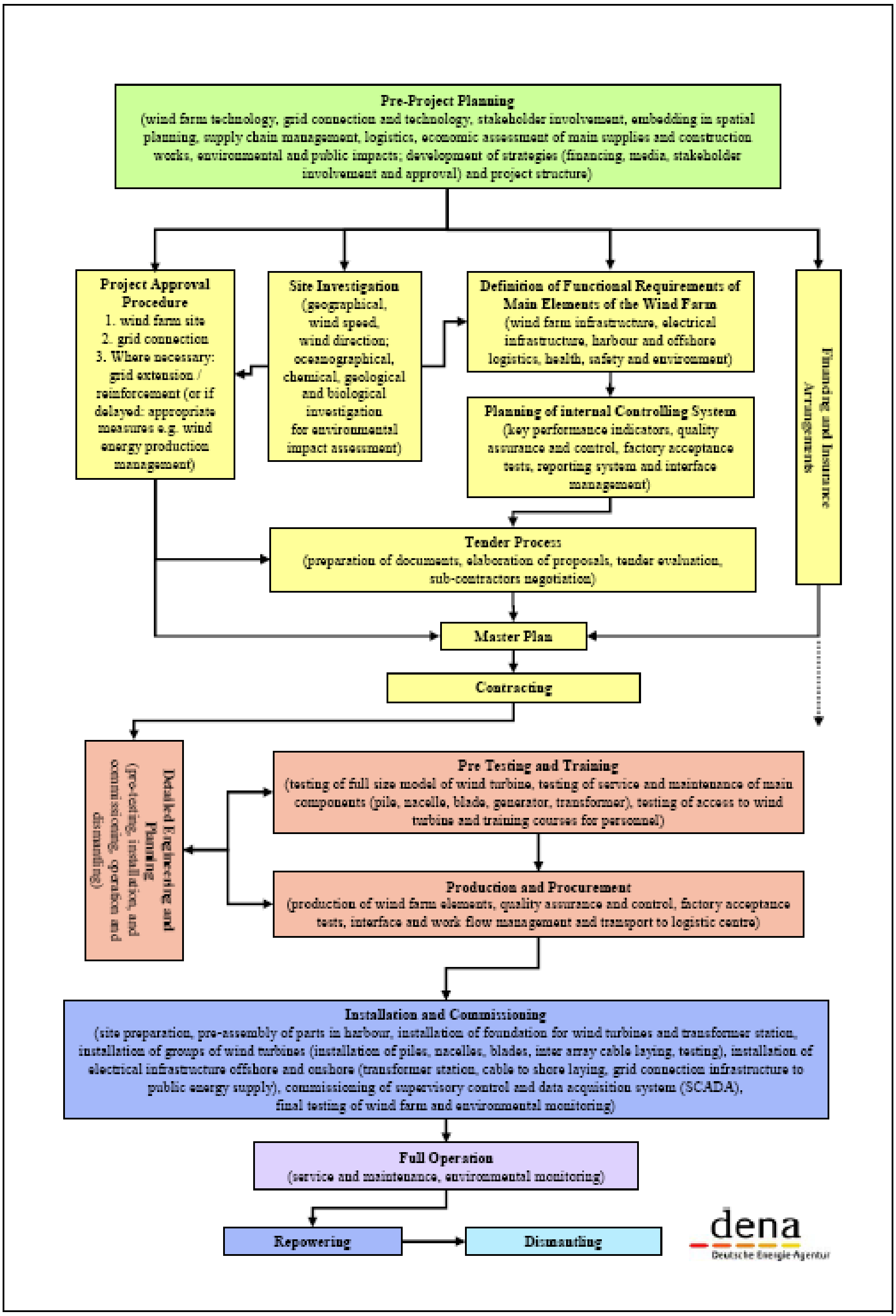

Figure 4: Flow Chart of the Main Work Packages for the Phases of Offshore Wind. Source: Dena 2007[55]

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[55] Deutsche WindGuard GmbH, Deutsche Energie-Agentur GmbH (dena), University of Groningen, Gerhard Gerdes Albrecht Tiedeman drs. Sjoerd Zeelenberg. 2007. Case Study: European Offshore Wind Farms- A Survey for the Analysis of the Experiences and Lessons Learnt by Developers of Offshore Wind Farms -Final Report. Available at http://www.ruimte-rijk.nl/index/publicaties/publicaties /final%20report%20case%20studies%20POWER.pdf

In terms of the procurement and contracting steps, an economic advantage was identified for multi-contractual structures for the procurement of offshore wind farms. A single EPC contract was found to result in a higher sales price of as much as 20% more. On the other hand, if using multiple contracts with different suppliers, the developer must be able to control the various contractors and to share any extra costs, such as those from bad weather. The developer in the multi-contractual approach must also have enough staff with sufficient knowledge during the planning and installation of all main elements of the project. The developer must control every work package in every step and have access to the contractors' design process and quality control. Successful projects carried out in this model therefore require developed capacity and excellent working relationships with all contractors.

It was anticipated that the main difficulties in terms of installation and grid connection would come from offshore logistics. However, experiences in Europe showed that skilled offshore companies were able to plan and execute their duties (Table 3). It was in fact the onshore logistics for transport from manufacturers to harbors, as well as assembly and loading in the harbor itself, that were more complex than expected. Testing of components and complete turbines is essential to a project's success—all repairs done at sea are five times more expensive than onshore. Special attention is to be paid to cable-laying for grid connection as the characteristics of power cables are quite different from those used in telecommunications—often far heavier, stiffer, with larger diameters requiring more time in general and sufficient windows of good weather. Underestimation of onshore harbor logistics was seen as a serious and common mistake. Wind farm installation is a second-priority business compared to long-term harbor activities such as container shipping and the efforts to organize harbor logistics require early planning by experienced project managers. The space typically required to assemble a turbine for offshore installation is 1000 square meters per WTG.

Economic comparisons of offshore wind farms are difficult due to differences in investment costs, subsidies, distances to land, water depths, subsidies for the grid connections and feed-in rates. Grid connection costs can be the determining factor as to whether a distant offshore wind farm in deep waters is to be realized. The total number of wind farms offshore is still relatively small and very individual and specific situations influence the costs of these projects.

		1	2	3	4
Wind farm		Horns Rev	Nysted	Scroby Sands	Egmond aan Zee
Number of turbines	[-]	80	72	30	36
Available installation site at harbour	[sq.m.]	15,000	64,000	30,000	30,000
Total time frame	[days]	126	90	60	60
Installation time	[days]	105	81	55	55-90
Travel time, one way	[hour]	3	17	3	
Gross installation time per turbine	[days/ WTG]	1.09	1,1	1,0	
No. of installation vessels		2	1	1	
Required installation period	[days]	87.2	79.2	30	

Table 3: Logistics with realized offshore wind power plants in Europe. Note Egmond aan Zee had not been built at the time of the publication of the study Source: Dena 2007 [56]

In order to minimize costs, the following additional recommendations were offered:

- To avoid offshore work because the costs of work in factories compared to work at dockside and offshore is about 1:3:5 or more (up to 10).
- Testing of all components and complete turbines is critical;
- To accompany series production with quality assurance and control as well as factory acceptance tests; and
- To provide stable, structured financial support in situations where basic experience in operating and financing offshore wind projects is lacking.

[56] Deutsche WindGuard GmbH, Deutsche Energie-Agentur GmbH (dena), University of Groningen, Gerhard Gerdes Albrecht Tiedeman drs. Sjoerd Zeelenberg. 2007. Case Study: European Offshore Wind Farms- A Survey for the Analysis of the Experiences and Lessons Learnt by Developers of Offshore Wind Farms -Final Report. Available at http://www.ruimte-rijk.nl/index/publicaties/ publicaties /final%20report%20case%20studies%20POWER.pdf

The following table summarizes the economics of the 8 wind farms compared in the dena study.

		1	2	3	4	5	6	7	8
Wind farm		**Egmond aan Zee**	**Thornton Bank**	**Borkum West**	**Butendiek**	**Greater Gabbard**	**Horns Rev**	**Nysted**	**Scroby Sands**
		Netherlands	**Belgium**	**Germany**	**Germany**	**United Kingdom**	**Denmark**	**Denmark**	**United Kingdom**
Number of turbines	[-]	36	6 / 24 / 60***	12 / 208	80	140	80	72	30
Turbine power	[MW]	3	3.6	5	3	3.6	2	2.3	2
Wind farm capacity	[MW]	108	21.6 /120 /300	60 / 1000	240	500	160	165.6	60
Turbine manufacturer	[-]	Vestas *	N.N.	N.N.	Vestas *	N.N.	Vestas	Bonus	Vestas
Expected annual production	[GWh/a]	345	986	260 / 4300		1750	600	480	171
Start of planning	[-]	2000-'02	2002	1999	2000		1998-'99	1998-'99	1993
Start of operation	[-]	2006*	2007*	2003* / 2010*	2008*	2009*	2003	2003	2004
Distance to land	[km]	10-18	27-30	45	34	23	14 - 20	9	3
Water depth	[m]	15-20	30	30	16-20	2.4 - 10	6 - 14	6 – 9.5	3 – 12
Investment costs	[mil. €]	200	100 / / 500	138	420		238	250	116
Specific investment costs	[€/kW]		4630/ /1667** (3472/ /1583)	2300	1750 - 2000		1488	1510	1941
Subsidies	[mil. €]	27	30% grid cost, max. 25	-	-	-	grid cost covered	grid cost covered	-
Feed-in rate	[ct€/kWh]	9.7 + actual electricity rate	10.7 + actual electricity tariff	9.1 for 14 yrs. 6.19 rest	9.1 for 12 yrs 6.19 rest		5.77 for 11 yrs		Re

* planned ** without and with subsidies *** different expansion phases

Table 4: Economics of offshore wind power plants. Dena 2007[57]

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