Julia Köller
Johann Köppel
Wolfgang Peters

# Offshore Wind Energy

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Johann Köppel
Wolfgang Peters

(Editors)

# Offshore Wind Energy

## Research on Environmental Impacts

With 135 Figures

Springer

DIPL.-ING. JULIA KÖLLER
E-mail:
koeller@ile.tu-berlin.de

PROF. DR. JOHANN KÖPPEL
E-mail:
koeppel@ile.tu-berlin.de

DR. WOLFGANG PETERS
E-mail:
peters@ile.tu-berlin.de

Berlin University of Technology

Institute of Landscape Architecture
and Environmental Planning,
Department for Landscape Planning
and Environmental Impact Assessment
Straße des 17. Juni 145
Secr. EB 5
10623 Berlin
Germany

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# Foreword

Accompanying ecological research is an important prerequisite for the sustainable development of offshore wind power. After exaggerated fears of the possible environmental impacts of planned wind farms in the beginning, the results of the first phase of the research projects may contribute to a more differentiated and realistic assessment of the environmental impacts of offshore wind farms. The projects were initiated by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and its results are published in this book.

The research results published here as a synopsis provide an early contribution to a precautionary consideration of possible environmental impacts of the development of wind energy at sea, particularly in the exclusive economic zone. The coherent overall concept for the development of offshore wind energy pursued by the German federal government is remarkable and hitherto unique among large-scale domestic projects. The combination of standardised investigations and the Environmental Impact Assessment (EIA) of each wind farm together with basic examinations for subsequent monitoring during the progress of the wind farms' construction meant the early implementation of certain requirements. In the course of the introduction of the EU's Strategic Environmental Assessment (SEA) process these became mandatory only recently.

Thus, it became possible to plan the accompanying ecological research in greater depth. It also provides early and extensive knowledge for the authorisation process for offshore wind farms on a continual basis; a process which is likewise continuously "learning". The promising combination of rather basic research of the effects, broadly designed surveys for a better understanding of the ranges, for example of marine mammals, and the development of transfer knowledge and methods is particularly appreciative. The latter refers to research contributions designed to translate the gained basic scientific data into information suitable for operations and relevant for the decision-making process. Of course, a long-term uncertainty of the knowledge base is likely, considering the required impact prognoses and the foresight which is always involved with environmental assessments. This also holds true for the risk assessments of ship collisions, which have also been examined.

From the development of inland wind energy we know that with scale leaps from niche production to a large-scale technology, which is particularly pronounced in the offshore area, renewable energies will also have to face the question of whether the desired developments may involve a conflict of goals, for instance with the area of conservation. This question must be seriously addressed. Otherwise, concerns originated in individual cases could rapidly take

on a “life of their own” and significant problems of public acceptability could develop.

Just as well, some European countries such as Denmark or Great Britain have made their contribution to environmental precaution by conducting environmental investigations of offshore wind parks at sites near the coasts. This book also provides an initial overview of the relevant European context, covering Denmark, Great Britain, the Netherlands and Sweden. Initial results of *ex-post* examinations (monitoring) at the Danish sites supplement the prior examinations at the German sites in the Exclusive Economic Zone in the North and Baltic Sea.

With the construction of a research platform, Germany is making an essential contribution to a further target-oriented collection of data in the context of accompanying research.

Last but not least, these early examinations have already led to an initial reordering of priorities in the environmental relevance of the impacts of offshore wind farms discussed. For instance, concerns about the effects of electromagnetic fields of submarine cables as well as other impacts on the benthos and the fish were put into perspective. At the same time, we do not deny the existence of gaps in the research and continue to make the necessary research profile tangible.

The project has been jointly carried out by the responsible ministry in Germany (the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety), the relevant federal agencies (the Federal Nature Conservation Agency and the Federal Research Centre for Fisheries), the Project Management Organisation (the Jülich Research Centre) universities and their associated institutes (the Christian-Albrechts-University of Kiel and its Research and Technology Centre, the Ruhr University Bochum, the University Rostock, the University of Hannover, the Carl von Ossietzky University of Oldenburg, the Hamburg University of Technology, the Berlin University of Technology) as well as non-university research facilities (the German Oceanographic Museum Stralsund, the National Park Administration Schleswig-Holstein Wadden Sea, Institute of Avian Research, the Alfred Wegener Institute for Polar and Marine Research, Germanischer Lloyd WindEnergie GmbH, and the German Wind Energy Institute).

The authors wish to express their gratitude especially to the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, whose responsible program of ecological research made these exemplary investigations, approaches and assessments possible in the first place.

Berlin, March 2006 The editors

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# List of Authors

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| | |
|---|---|
| Udo Paschedag<br>Cornelia Viertl<br>Dr. Guido Wustlich | Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU)<br>Referat KI I 3: Wasserkraft und Windenergie<br>Dienstsitz Berlin:<br>Alexanderplatz 6<br>10178 Berlin, Germany |
| Michael Heugel | Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU)<br>Referat N I 5: Recht des Naturschutzes und der Landschaftspflege<br>Dienstsitz Bonn:<br>Robert-Schuman-Platz 3<br>53175 Bonn, Germany |
| Thomas Merck | Federal Agency for Nature Conservation (BfN)<br>Field Office Vilm<br>18581 Putbus, Germany |
| Dr. Joachim Kutscher | Jülich Research Centre<br>The Project Management Organisation Jülich (PtJ)<br>52425 Jülich, Germany |


### Research on Marine Mammals


| | |
|---|---|
| Anita Gilles<br>Klaus Lucke<br>Dr. Meike Scheidat<br>Stefan Ludwig<br>Dr. Ursula Siebert | Research and Technology Center (FTZ)<br>Christian-Albrechts-University of Kiel<br>Hafentörn 1<br>25761 Büsum, Germany |
| Dr. Harald Benke<br>Christopher G. Honnef<br>Ursula K. Verfuß | German Oceanographic Museum<br>Katharinenberg 14-20<br>18439 Stralsund, Germany |
| PD Dr. Guido Dehnhardt<br>Dr. Wolf Hanke | Department of General Zoology and Neurobiology<br>Ruhr-Universität Bochum<br>44780 Bochum, Germany |

| | |
|---|---|
| Prof. Dr. Dieter Adelung<br>Dr. Gabriele Müller<br>Mandy A. M. Kierspel | Leibniz-Institute of Marine Sciences<br>IFM-GEOMAR Kiel<br>Düsternbrooker Weg 20<br>24105 Kiel, Germany |
| Nikolai Liebsch<br>Prof. Dr. Rory P. Wilson | School of Biological Sciences<br>University of Wales Swansea Singleton Park<br>Swansea SA2 899, Wales, UK |
| Barbara Frank | National Park Administration<br>Schleswig-Holstein Wadden Sea<br>Schlossgarten 1<br>25832 Tönning, Germany |


**Research on Resting and Breeding Birds**


| | |
|---|---|
| Dr. Jochen Dierschke<br>Dr. Klaus-Michael Exo<br>Elvira Fredrich | Institute of Avian Research<br>“Vogelwarte Helgoland“<br>An der Vogelwarte 21<br>26386 Wilhelmshaven, Germany |
| Dr. Ommo Hüppop<br>Reinhold Hill | Institute of Avian Research<br>„Vogelwarte Helgoland“<br>Inselstation Helgoland,<br>PO Box 1220<br>27494 Helgoland, Germany |


**Research on Bird Migration**


| | |
|---|---|
| Dr. Volker Dierschke<br>Dr. Stefan Garthe<br>Bettina Mendel | Research and Technology Center (FTZ)<br>Christian-Albrechts-University of Kiel<br>Hafentörn 1<br>25761 Büsum, Germany |


**Research on Fish**


| | |
|---|---|
| Dr. Siegfried Ehrich<br>Dr. Matthias H. F. Kloppmann<br>Dr. Anne F. Sell | Federal Research Centre for Fisheries<br>Institute for Sea Fisheries<br>Palmaille 9<br>22767 Hamburg, Germany |
| Dr. Uwe Böttcher | Federal Research Centre for Fisheries<br>Institute for Baltic Sea Fisheries<br>Alter Hafen Süd 2<br>18069 Rostock, Germany |

**Research on Benthic Associations**

| | |
|---|---|
| Dr. Alexander Schröder<br>Dr. Covadonga Orejas<br>Tanja Joschko | Alfred Wegener Institute for Polar and<br>Marine Research (AWI)<br>Section Marine Animal Ecology<br>Columbusstraße<br>27568 Bremerhaven, Germany |
| Dr. Ralf Bochert<br>Dr. Michael L. Zettler<br>Dr. Falk Pollehne | Baltic Sea Research Institute Warnemünde<br>Seestraße 15<br>18119 Rostock, Germany |

**Technical Analyses**

| | |
|---|---|
| Gundula Fischer | Germanischer Lloyd WindEnergie GmbH<br>Steinhöft 9<br>20459 Hamburg, Germany |
| Dr.- Ing. Karl-Heinz Elmer<br>Wolf-Jürgen Gerasch | University of Hannover<br>Institute for Structural Analysis<br>Appelstraße 9A<br>30167 Hannover, Germany |
| Dr. Thomas Neumann<br>Joachim Gabriel | Deutsches Windenergie Institut (DEWI)<br>Ebertstr. 96<br>26382 Wilhelmshaven, Germany |
| Dr. Manfred Schultz - von Glahn<br>Dr. Klaus Betke<br>Rainer Matuschek | Institut für technische und angewandte Physik<br>GmbH (itap)<br>Marie-Curie-Straße 8<br>26129 Oldenburg, Germany |
| Florian Biehl<br>Prof. Dr. Eike Lehmann | Hamburg University of Technology<br>Institute for Ship Structural Design and<br>Analysis<br>Schwarzenbergstr. 95 C<br>21073 Hamburg, Germany |

**Planning Aspects**

| | |
|---|---|
| Julia Köller<br>Prof. Dr. Johann Köppel<br>Dr. Wolfgang Peters | Berlin University of Technology<br>Department of Landscape Planning and<br>Environmental Impact Assessment<br>Straße des 17. Juni 145, EB 5<br>10623 Berlin, Germany |

**International Ecological Research**

Elke Bruns
Ines Steinhauer

Berlin University of Technology
Department of Landscape Planning and
Environmental Impact Assessment
Straße des 17. Juni 145, EB 5
10623 Berlin, Germany

**Conclusion and Perspective**

Julia Köller
Prof. Dr. Johann Köppel
Dr. Wolfgang Peters

Berlin University of Technology
Department of Landscape Planning and
Environmental Impact Assessment
Straße des 17. Juni 145, EB 5
10623 Berlin, Germany

# Expanding Offshore Wind Energy Use in Germany

# 1 Offshore Wind Energy Use

Udo Paschedag

The German government attaches great importance to the expansion of renewable energies with a view to effective climate protection, the development of a sustainable energy supply, greater independence from energy imports and the creation of new jobs. The German government's goal, laid down in the Renewable Energy Sources Act (EEG), is to increase the share of renewable energies in the energy supply to at least 12.5 % by 2010 compared with the year 2000, and to double the share to at least 20 % by 2020. With this, Germany is making an important contribution to the EU's goal of increasing the share of renewable energies in electricity consumption from 14 % (1997) to 22 % (2010). Furthermore, the German government has also set itself a long-term goal, within the framework of its Sustainability Strategy, to cover around half of energy consumption in Germany with renewable energies by the middle of this century.

In 2004 renewable energies already accounted for 3.6 % of primary energy and 9.3 % of electricity consumption. In order to achieve the German government's further goals, the potential of various renewable forms of energy must be exploited in accordance with the best-available technology.

Now, that the potential of hydropower in Germany has already been exploited to a large extent, the greatest potential for expansion up to 2020 lies in the wind energy sector, in particular in the field of offshore wind energy. There is both advanced technological development and proven experience with the technology in this field. Other renewable energy sectors also promise comparable developments, for example biomass, solar technology and geothermal power (BMU 2004).

Every form of renewable energy has to contribute to achieving the goal of doubling the renewable share. The only way it is possible to respond to different electricity needs and the related power plant structure (base, average and peak load) is with a mix of all renewable energies. This is why it is essential to use every form of renewable energies in accordance with their level of development.

## 1.1 Wind Energy Use in Germany

In recent years there has been rapid development in the wind energy sector (Fig. 1). This process, in which Germany has played a key role, can be observed both nationally and internationally.

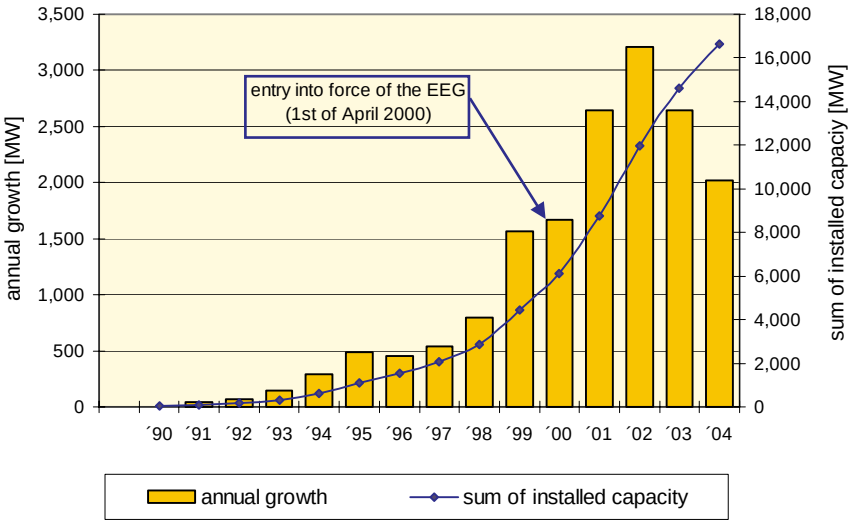


**Fig. 1.** Expanding the use of wind energy in Germany (Source: BWE 2005, BMU 2004)

At the end of 2004 there were 16,543 wind turbines in Germany with an output of around 16,630 MW. They were supplying 4.1 % of gross electricity consumption, corresponding to 44.8 % of electricity from renewables. In an average year, these turbines produce electricity for around 8.5 million households. In comparison with 2002 and 2003 there was a decrease in the newly installed output in 2004. This can primarily be traced to a lack of onshore sites and to as yet only small-scale repowering.

Due to the current market development and the areas designated so far as suitable sites, the potential of onshore expansion is assumed to be around 25,000 MW (Deutsche WindGuard GmbH 2005).

## 1.2 Potential of Offshore Wind Energy Use

In order to maintain a high level of expansion in wind energy use in Germany, the gradual development of suitable offshore sites is also necessary in addition to further expansion at suitable onshore sites and repowering. From a current perspective, the offshore areas expected to be available up to 2010 have a possible capacity of 2,000 to 3,000 MW. If economic efficiency is achieved, 20,000 to 25,000 MW of installed power is possible in the long term up to 2030 (BMU 2002) (see chapter 2).

## 1.3 Level of Offshore Wind Energy Use

So far only one wind turbine with an output of 4.5 MW has been installed in Germany near Emden in the territorial sea, although at a shallow depth near the dyke.

There are still considerable technical uncertainties connected to projects for offshore wind farms in the Exclusive Economic Zone (EEZ). Due to Germany's comparatively short coastline, the location of national parks in the territorial sea and socio-political concerns, the potential sites are almost exclusively those with significant water depth that are located far away from the coast. However, there is no experience in this area anywhere in the world. Project associations are carrying out pioneering work in this field.

Excluding projects already approved, there are currently 21 applications pending at the Federal Maritime and Hydrographic Agency (BSH), of which 17 are for the North Sea and four for the Baltic Sea (see Fig. 2 and Fig. 3).

The majority of these applications concern areas in the North and Baltic Seas that lie far away from the coast or the islands and have a sea depth of more than 30 metres. In addition, nine wind farms with a planned total of over 600 turbines and around 2,600 MW have been approved in the North and Baltic Seas. However, for most of these projects the licence for the cable lines from the respective Federal *Land* is still outstanding. A gradual establishment of the licensed offshore wind farms can therefore be expected from 2007 at the earliest.

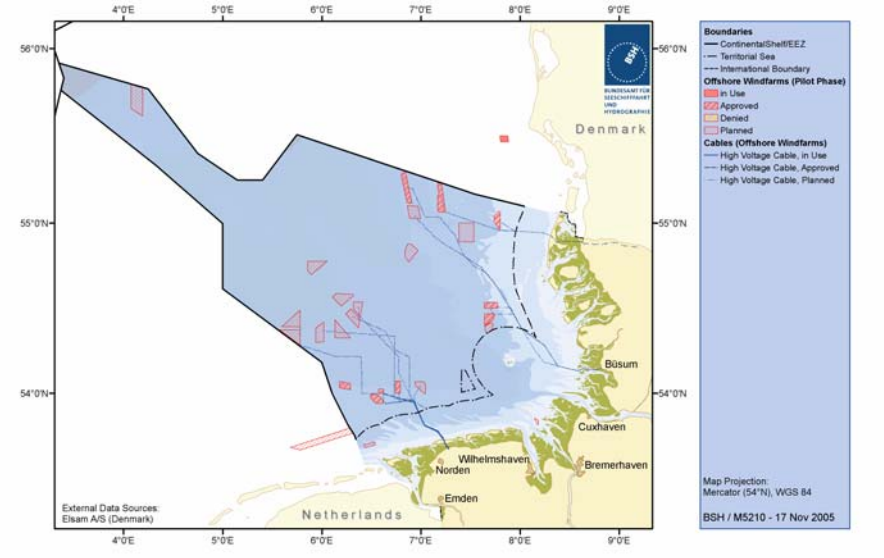


**Fig. 2.** North Sea: Offshore wind farms (pilot phase) (Source: BSH 2005)

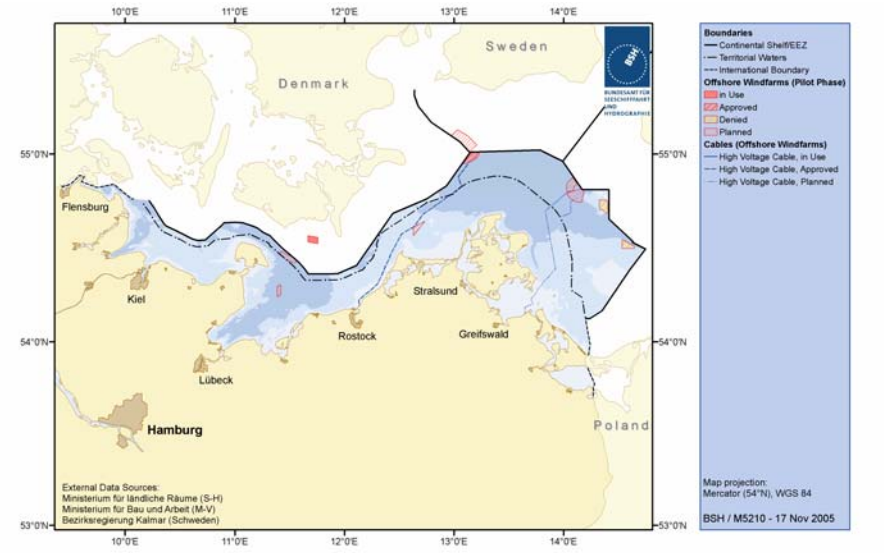


**Fig. 3.** Baltic Sea: Offshore wind farms (pilot phase) (Source: BSH 2005)

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# 2 Strategy of the German Government

Cornelia Viertl

Within the framework of the Sustainability Strategy, the Federal Environment Ministry, as lead Ministry, elaborated a "Strategy of the German Government on the Use of Offshore Wind Energy". This strategy was published at the beginning of 2002 (BMU 2002)[1].

Its aim is to increase the share of wind energy in electricity consumption to at least 25 % over the next three decades. A 15 % share in electricity consumption in Germany is achievable with offshore wind energy alone.

**Table 1.** Gradual development of the use of offshore wind energy

| Phases | Period | Potential capacity | Potential power yield |
|---|---|---|---|
| 1. Preparational phase | 2001 - 2006 | -- MW | -- TWh p.a. |
| 2. First expansion phase | 2007 - 2010 | 2,000 - 3,000 MW | approx. 7 - 10 TWh p.a. |
| 3. Additional expansion phases | 2011 - 2030 | 20,000 - 25,000 MW | approx. 70 - 85 TWh p.a. |

## 2.1 Key Elements of the Offshore Strategy

One fundamental requirement is that the expansion of offshore wind energy use is compatible with the environment and nature, and also economically viable. It is to be carried out in a step-by-step process. Prerequisites were created for the designation of protected areas and provisions for especially suitable areas for wind turbines in the Exclusive Economic Zone. Technical, environmental and nature conservation research was part of the strategy and is to accompany the expansion of offshore wind energy use for a longer period of time beyond the starting phase. In order to take due account of the precautionary principle a step-by-step expansion (first step: maximum 80 turbines) is planned. Reaching the next respective step presupposes a positive and reliable result with regard to environmental impacts.

[1] see: www.erneuerbare-energien.de or www.offshore-wind.de

## 2.2 Successes and Focal Points for Implementation

A range of successes have already been recorded. Twelve applications for offshore wind farms have already been approved (March 2006). In doing so it was possible to enforce the step-by-step principle, according to which a maximum of 80 turbines per wind farm were licensed in the first instance. Once reliable data on the impacts on maritime navigation and the marine environment are available it will be possible to grant licences for larger wind farms.

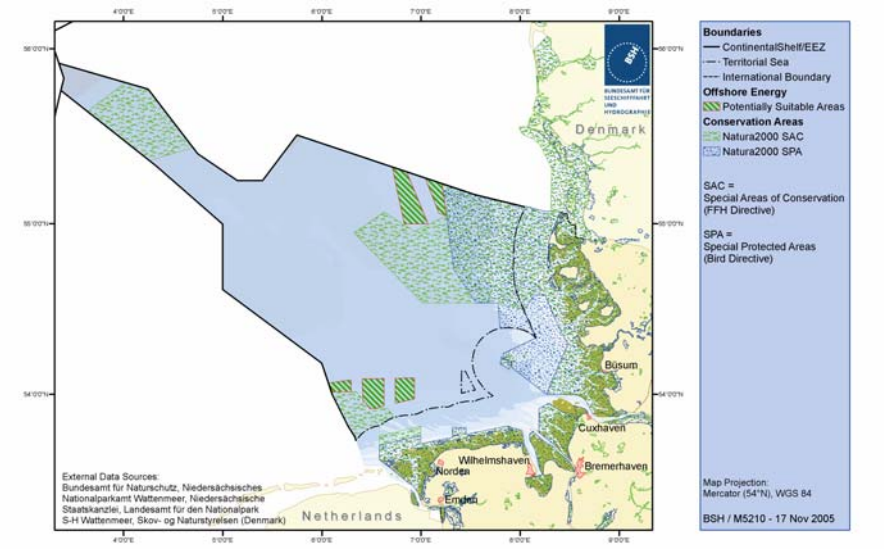


**Fig. 1.** North Sea: Suitable areas for offshore wind energy and conservation areas (Source: BSH 2005)

The identification and selection of German protected sites in the Exclusive Economic Zone (EEZ) for the EU Natura 2000 system has been carried out. In Mai 2004 Germany has nominated eight proposed Sites of Community Interest (pSCI) and two Special Protected Areas (SPAs) in its EEZ of the North Sea and the Baltic Sea to the EU Commission. By this step Germany covers approx. 31 % of its EEZ and by including the current nominations in the territorial seas 41 % of its total marine area by NATURA 2000 sites (see Fig. 4 and Fig. 5).

By the end of 2005 the first especially suited areas are to be designated on the basis of the Marine Facilities Ordinance (SeeAnlV). Furthermore, the legal foundations for long-term regional planning have been created by extending the Federal Regional Planning Act (ROG) to the EEZ (§ 18a), and the regional planning process has started (see Fig. 4 and Fig. 5).

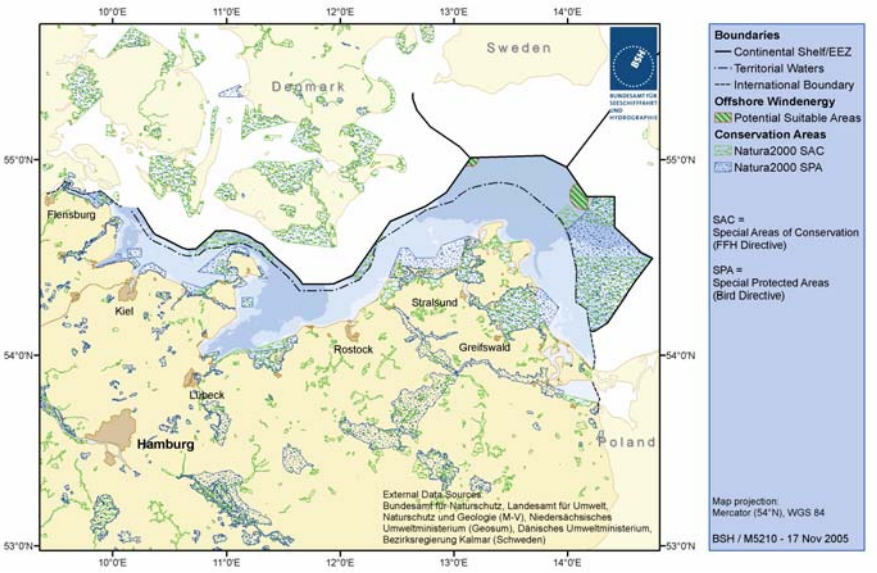


**Fig. 2.** Baltic Sea**:** Suitable areas for offshore wind energy and conservation areas (Source: BSH 2005)

A study initiated by the German Energy Agency (dena) analysed the impacts of the grid connections of offshore wind farms on the German power grid and power plant structures. This study revealed that the cost-effective integration of wind energy with a moderate grid expansion is possible, even assuming a rather high offshore wind expansion scenario (dena 2005). The structural change required for sustainable, decentralised power generation necessitates an adaptation of the German power grid. The necessary extension to the grid at extra-high voltage level identified by the study amounts to around 850 km by 2015. With a total length of the power grid in Germany of 18,000 km, this corresponds to less than five percent of the existing extra-high voltage grid. The study showed that there is no threat of critical system situations or blackouts in Germany as a result of the additional expansion of wind energy use that cannot be resolved through technical measures.

According to the changed structure of existing power plants identified by the experts, there will be no need to build additional conventional power plants (so-called shadow power plants) for the provision of balancing and reserve power. In order to conclude the first part of the grid study within the envisaged time frame, the review of further technically innovative solutions for the integration of electricity from wind energy and the optimisation of the grid expansion was postponed to a subsequent study. This study will address in particular the impacts of cable temperature monitoring, generation and feed-in management, load management and currently available storage technology such as compressed-air storage power plants. This subsequent study is expected to have repercussions on the results of the current grid study and will lead to a significant reduction in the new construction of the grid.

An Offshore Wind Energy foundation was set up by the relevant industry sectors in order to set up a test field for offshore wind turbines. The Federal Environment Ministry (BMU) launched and headed the process to establish this foundation. Its goal is, in the interest of climate protection and energy supply security, to promote sustainable, environmentally sound energy production and supply through improved use of wind energy in the German North and Baltic Seas. With this aim, the foundation aims to promote:

1. technological research, development and innovation in the field of offshore wind energy, taking account of energy transport to the consumer,
2. accompanying ecological research on the impacts of the construction, operation and decommissioning of offshore wind turbines including their cable connection on the marine environment, and
3. the exchange and transfer of knowledge on offshore wind energy between science, industry and other public and private organisations.

The foundation will acquire the rights for the licensing of an offshore wind farm that is particularly suited to the operation of a test field. Following this it will lease the sites at this wind farm to operator companies, whereby the primary goal will be the testing of multi-megawatt turbines (larger than 5 MW).

The accompanying ecological research, the research on the measuring platforms and the further development of turbine technology was secured for the long term through the Future Investment Programme (ZIP) and research programmes on renewable energies.

The first of three research platforms (FINO 1) started operation in 2003 in the North Sea approx. 45 km north of the island Borkum (Fig. 3). For further information see chapter 15.

**Fig. 3.** FINO 1 Research platforms in the North and Baltic Seas

The second research platform (FINO 2) is to be set up early in 2006 in the Baltic Sea near Kriegers Flak. The third platform (FINO 3/Neptun) for the northern area of the North Sea off Sylt is current at the planning stage. This publication provides an overview of the projects concerning accompanying ecological research and their results.

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# 3 Legal Framework Conditions for the Licensing of Offshore Wind Farms

Guido Wustlich, Michael Heugel

## 3.1 The Renewable Energy Sources Act – Support Instrument for the Expansion of Renewable Energies

In Germany, generating electricity by wind-powered plants is promoted by the Act on Granting Priority to Renewable Energy Sources (Renewable Energy Sources Act - EEG). This act is an effective and efficient instrument for increasing the use of renewable energies on the road towards a sustainable energy system. The core elements of the EEG are:

- the priority connection of installations for the generation of electricity from renewable energies and from mine gas to the general electricity supply grids;
- the priority purchase and transmission of this electricity;
- a consistent fee for this electricity paid by the grid operators, generally for a 20-year period, for commissioned installations, this payment is geared around the costs, and
- the nationwide equalisation of the electricity purchased and the corresponding fees paid.

The fee paid for the electricity depends on the energy source and the size of the installation. The rate also depends on the date of commissioning; the later an installation begins operation, the lower the tariff (degression). Since the amendment of the EEG in 2004, power from offshore wind farms will be eligible for an initial rate of 9.1 cent/kWh if the plant is commissioned by 2010 (previously 2006). Wind farms are classified as offshore if they are constructed at least three nautical miles off the shoreline. The initial rate will be paid for 12 years. This period will be extended for installations built at a greater distance from the shoreline and at greater depths. The base rate which follows the initial rate is 6.19 cent/kWh. Altogether a guaranteed price is paid for 20 years.

## 3.2 Licensing Offshore Wind Farms in the Territorial Sea

The territorial sea, i.e. the zone of 12 nautical miles off the German coast, belongs to the territory of the Federal Republic of Germany. The same provisions of the Federation and coastal Länder apply here as on land. Hence, the Federal Immission Control Act (BImSchG) is also applicable for the licensing of wind farms in the territorial sea.

For their construction and operation wind farms require a licence pursuant to Article 4 BImSchG (cf No. 1.6 of the Annex to the Ordinance on Installations Subject to Licensing – 4th BImSchV). In principle, it is not necessary to obtain separate further authorisations from other authorities in addition to the licence under immission control law, because the latter triggers a so-called formal concentration effect under Article 13 BImSchG and incorporates other authority decisions relating to the installation.

The licensing procedure must be carried out by the competent immission control authority of the coastal Länder as a formal procedure pursuant to Article 10 BImSchG. The procedure involves an environmental impact assessment and public participation, since offshore wind farm projects regularly concern the construction and operation of more than 20 wind turbines (cf column 1 of Annex 1 to the Act on the Assessment of Environmental Impacts in conjunction with Article 2 para. 1 No. 1 (c) of the 4th BImSchV).

The licence must be granted if it is ensured inter alia that no harmful effects on the environment may be caused and no other public law provisions oppose the construction and operation of the offshore wind farm (cf Article 6 para. 1 in conjunction with Article 5 BImSchG). Prior to the licence being granted, therefore, there must be an examination into whether the project complies with the regulations of the relevant Land building code, and whether interference with the safety and easy flow of shipping as defined in the Federal Waterways Act can be ruled out. Particular importance is attached to the concerns of nature protection and landscape management. The project must be an admissible intervention in nature and landscape. In the territorial waters of the North Sea which have been designated by Land legislation as Wadden Sea National Parks, the construction and operation of an offshore wind farm is only permissible in exceptional cases.

## 3.3 Licensing of Offshore Wind Farms in the Exclusive Economic Zone (EEZ)

The legal situation in the Exclusive Economic Zone, which covers the marine area beyond the territorial sea, is more complex. The EEZ does not belong to the national territory of the Federal Republic of Germany. Prevailing opinion maintains that national law which applies in the national territory is only applicable in the EEZ if the legislator has expressly declared it to be so. However, the 1982 United Nations Convention on the Law of the Sea which entered into force in 1994 grants coastal states certain utilisation privileges and regulatory powers in these marine areas, including specifically for the construction and operation of installations for the generation of energy from wind (cf Articles 56 and 60). The installations must not interfere with the use of recognised sea lanes essential to international navigation. Due notice of the construction must also be given and permanent warning systems maintained. Furthermore the coastal states can set up reasonable safety zones around the installations in order to ensure the safety of navigation and of the installation itself.

Besides the United Nations Convention on the Law of the Sea there are numerous other international agreements which contain individual regulations on the protection of marine environments or which are generally geared to these concerns. The most important of these for the Federal Republic of Germany, as a contracting party, are the two regional agreements on the protection of the marine environment of the North-East Atlantic and of the Baltic Sea of 1992 – the OSPAR Convention (in force since 1998) and the Helsinki Convention (in force since 2000). While the two conventions and the decisions and recommendations adopted on their basis contain provisions for offshore oil rigs, they do not as yet stipulate any specific requirements for offshore wind farms. However, in 2004 the OSPAR Commission published a report on this issue entitled “Problems and Benefits Associated with the Development of Offshore Wind Farms”.

These conventions are directed exclusively to their respective signatory states. They only become effective within the country when they have been implemented in national law. For the construction and operation of installations in the area of the Exclusive Economic Zone this essentially takes place through the Marine Facilities Ordinance (SeeAnlV), issued on the basis of the Federal Maritime Responsibilities Act. Under Article 2 sentence 1 in conjunction with Article 1 para. 2 sentence 1 No. 1 SeeAnlV, construction, operation and essential changes to fixed or floating fixed