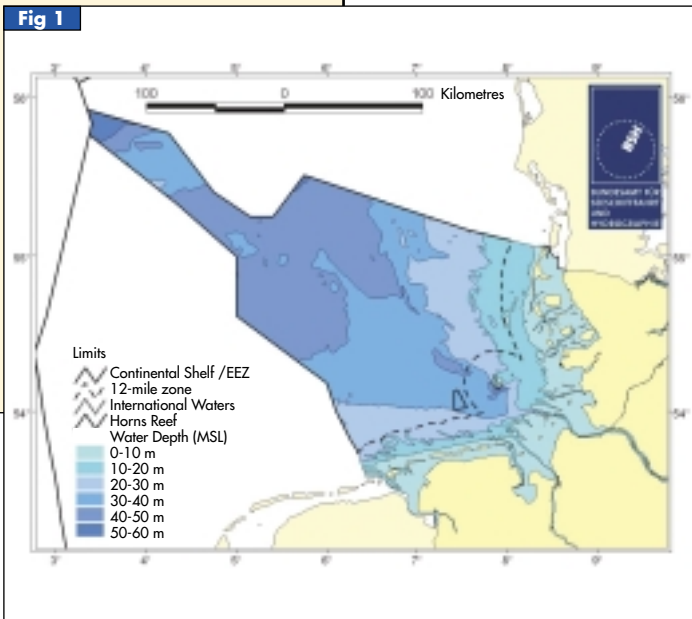


Offshore Wind Energy

Fig 1



- ▶ **The potential for wind energy in Germany is offshore greater than on land**
- ▶ **An offshore wind farm can generate significantly more electricity than a land-based facility**
- ▶ **Because of their location, offshore wind farms face more rigorous technological conditions**
- ▶ **Careful consideration of nature protection needs is a key acceptance factor**

Germany's Exclusive Economic Zone (EEZ) in the North Sea (Source: Federal Maritime and Hydrographic Agency [BSH], Hamburg and Rostock)

Wind energy supplied around 4 per cent of Germany's electricity in 2002. Long-term forecasts for the period up to 2030 say that figure could increase to 25 per cent. If the forecasts hold true, only 40 per cent of wind-generated electricity will come from land-based wind farms. Offshore facilities will provide the other 60 per cent. Offshore wind farms play an ever-increasing role in plans to expand the use of wind energy in Germany. Since the mid-1990s, energy research by the Federal Ministry for Environment, Nature Conservation and Nuclear Safety (BMU) has focused on the fundamental technological and environmental issues involved in offshore wind farms. The planning process began in the late-1990s and some 29 applications (status May 2002) have since been submitted to the Federal Maritime and Hydrographic Agency (BSH). The first pilot wind farms were approved in 2001: one, Borkum West, lies some 45 km north of Borkum and another, Butendiek, is located 34 km west of Sylt. The first of three planned offshore research platforms is slated to be built in 2003: in a range of interdisciplinary research projects, the platform will be used to develop scientific and technological standards for the approval process and to research technical, ecological and marine issues involved in offshore wind farms.

In Germany, new locations for land-based wind farms are already becoming scarce in coastal areas, and this situation is likely to spread inland. Additional potential could be gained by replacing older, smaller facilities with new and more powerful ones ('repowering'). In 2002, the average total output from existing wind farms was 900 kW. The output from new facilities built that year was 1,400 kW. Multi-megawatt turbines in excess of 2 MW are now coming onto the market, and tests are currently under way on even more powerful ones. Repowering would increase the share of wind-generated electricity, reduce the number of wind farms and allow revision of planning laws to ensure that new wind farms are better integrated into the landscape.

Most applications for offshore wind farms in Germany involve areas in the Exclusive Economic Zone (EEZ), which is beyond the 12-mile zone. More so than its European neighbours, Germany is venturing into ever-deeper waters – especially in the North Sea. An area of between 4 to 5 per cent of the EEZ could generate 15 per cent of Germany's electricity needs from offshore wind farms. This would further increase wind energy's contribution to climate protection, afford the wind industry an opportunity for ongoing, sustainable development and significantly boost its export potential.

► The Planning and Approval Framework

Most of Germany's offshore wind farms are to be erected far from the coast. The German government committed to offshore wind energy in its strategy paper on the use of wind energy at sea in 2002, which provides for phased development and expansion of wind energy capacities (Fig. 2). From a legal standpoint, only the area within the 12-mile zone – from the coastline seawards – is German sovereign territory and falls under the planning sovereignty of the respective Federal Länder(states). All laws that apply on land thus apply in the 12-mile zone. This is largely comprised of protected areas (e.g. national parks) and shipping lanes for entry to German har-

Fig 4: View of the First Research Platform (FINO 1) in an Area North of Borkum

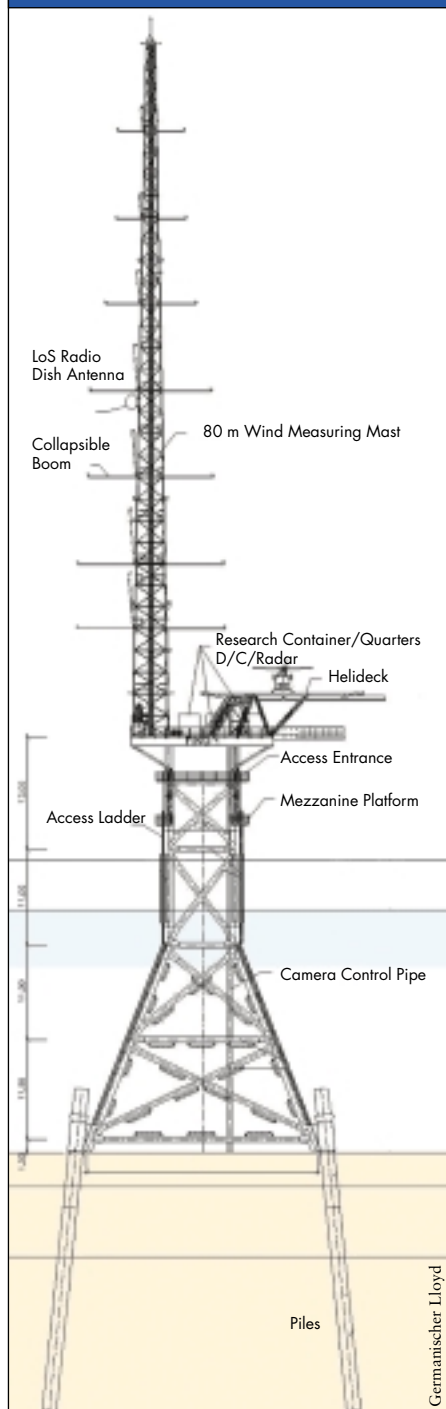


Fig 2: Phased Development of Offshore Wind Energy (1 TWh = 1 billion kWh)

Phases	Period	Potential Capacity [MW]	Potential Output [TWh/year]
Preparation Phase	2001 - 2003	-	-
Start Phase	2004 - 2006	min. 500	approx. 1,5
First Expansion Phase	2007 - 2010	2.000 - 3.000	approx. 7 - 10
Subsequent Expansion Phases	2011 - 2030	20.000 - 25.000	approx. 70 - 85

bours. The responsible Länder (states) are currently surveying a number of areas within the 12-mile zone as to their suitability as sites for offshore wind facilities.

Fig 3: Conflicting interests in the EEZ



Germany established its North and Baltic Sea EEZ in 1994 under the UN Law of the Sea Treaty. The EEZ extends up to a maximum of 200 sea miles seaward from the 12-mile zone. While the EEZ is not strictly German sovereign territory, Germany has the right to use it for economic gain.

Fig. 1 shows the EEZ in the North Sea region. Building an offshore wind farm in the EEZ requires approval by the Federal Maritime and Hydrographic Agency (BSH), granted in accordance with the Marine Facilities Ordinance (SeeAnIV), which provides for a legal right to approval of use for economic gain. An application may only be rejected if it encroaches on shipping safety and access or if it is seen to pose a risk to the marine environment (including bird migration). Because cables placed on the sea bed to connect offshore wind farms in the EEZ to the electricity grid must run through the 12-mile zone, these are subject to Länder planning and approval.

The German government's strategy aims to exclude wind energy facilities from national parks and NATURA 2000 areas. Alongside specific planning applications, an additional aim is to identify and designate areas that are generally suitable for offshore wind energy use. Conflicting interests will be taken into account (Fig. 3). Planning will be accompanied by comprehensive environmental and technological research projects which include the building of three research platforms in the EEZ (Fig. 4).

► Technical Requirements

The average wind speed at sea is higher than on land, with estimates of around 8 to 9 m/s for the North Sea 10 km from the coast. Masts for offshore facilities do not need to be as tall as on land because at sea, wind speed increases more rapidly with increasing height in view of the lower surface roughness and lower turbulence. Offshore wind load on turbines is generally greater. What must be taken into account, however, is that the class of turbine needed for commercial use at sea – in the region of between 4 and 5 MW – has a blade sweep area of up to 10,000 m².

Foundations

The masts and foundations of an offshore wind farm must be strong enough to cope with the pressure from wave surge. In the EEZ, turbines are erected at depths of between 15 and 40 m. Turbines must with-

stand a tidal surge of up to 4.5 m in the North Sea and ice pressure in the Baltic. Maximum wave height (monster waves) can reach up to 20 m in the North Sea and about 7 m in the Baltic. Planning calculations must take special account of the dynamic pressures from constant submergence in water, wave movement and the problem of the mast's own natural frequency of oscillation.

Three different foundation-laying methods are suited to the depths cited above in the German region of the North and Baltic seas. 'Monopile' is a free-standing steel pipe that is driven about 20 m down into the sea bed using hydraulic rams. It is characterised by its 'soft' sway and is suited to depths of around 25 m. 'Tripod' is a steel pipe supported by a three-legged construction (Fig. 6). Its erection may involve drilling into the sea bed to accommodate its 'rigid'

sway. Tripod is suited to extreme water depths. A lattice-type construction can also be used.

Offshore wind farms must be resistant to corrosion from salty sea air, have a closed, generator-powered cooling system and be equipped with remote maintenance and troubleshooting systems. Maintenance ships must be able to dock and a winch must be available. Structures must be so designed to cause minimum possible damage to a ship's hull in the event of a collision.

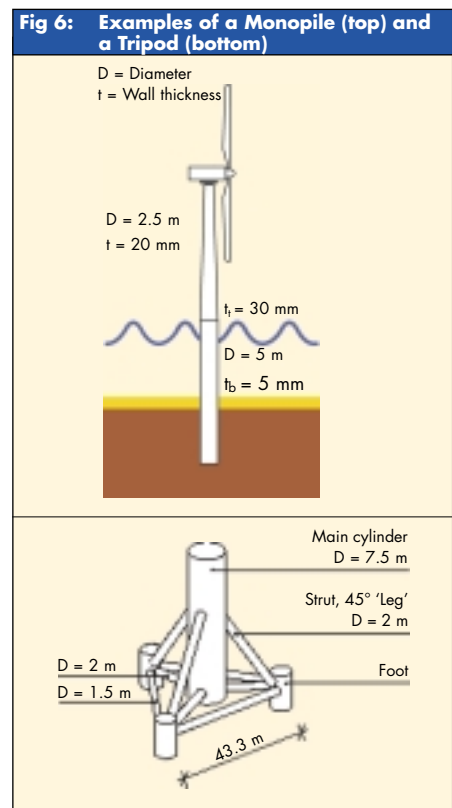
Feeding into the Grid

Offshore wind farms will generate an output similar to that of large power plants.

The electricity must be fed into the grid on land. Transfer of electricity is best done at high voltage to avoid loss of power, and cable laying in national parks must be kept to a minimum. Wind parks must thus feed their electricity into sea-based transformer stations. It is then fed from a central facility into the land-based grid. The first wind farms will probably operate by feeding three-phase current along cable bundles laid on the sea bed in a redundant configuration. High voltage transmission serves greater distances. Land-based substations must be connected to both the high and super-high voltage grid.

Fig 5: Offshore wind farms involve costs in addition to those incurred with land-based facilities. The following values serve as an indication of the additional cost to be expected (German Wind Energy Association [BWE e.V.]

Distance from Coast	30 km	50 km	70 km
Foundations	35 - 38%	43 - 51%	39 - 48%
Installation	9 - 13%	11 - 19%	10 - 23%
Grid Connection	31 - 67%	44 - 83%	57 - 114%
Other Expenses	7 - 24%	7 - 24%	7 - 24%
Total	83 - 143%	106 - 176%	113 - 208%



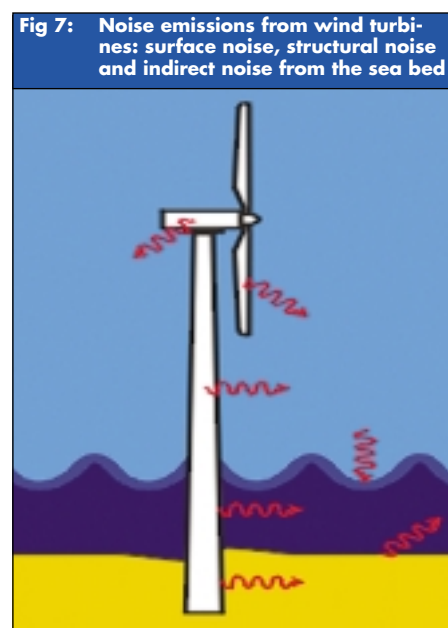
► GIGAWIND Research Project

GIGAWIND focuses on construction and environment-specific issues involved in offshore technology. The project comprises four institutes from the universities of Hanover and Essen. The aim is to obtain reliable data to allow planning and development of offshore wind farms, to make the data available as simulation software, and to make recommendations as regards construction techniques and environmental thresholds.

GIGAWIND involves fundamental research work on the impact from ocean currents, tidal flows and wave surge on offshore wind farms, and emissions of underwater noise. Other key areas of focus are geotechnical surveys of the sea bed, and load and fatigue analyses on foundations and towers under extreme conditions. The results of research conducted on the platform will, among others, be integrated into the GIGAWIND project as shown in the following two examples.

Underwater Noise

In contrast to land-based facilities, offshore wind farms not only emit noise above the surface but also under water. Alongside surface noise penetrating under water, noise may also be caused by vibrations in the turbine housing (Fig. 7). Multiple noise reflections on the ocean surface and on the sea bed must also be taken into account.



The GIGAWIND research project will study the strength and frequency of underwater noise and its range during building and operation. The project's development target is to publish recommendations on technically and biologically justified thresholds for noise emissions from offshore wind farms and, among others, to make simulation soft-

ware available to allow reliable forecasts of potential noise pollution from operations in offshore wind farms. Noise from offshore facilities can, for example, distort echolocation in porpoises that live in the North Sea.

Fatigue

Foundations and masts in offshore wind farms are subject to heavy loads from wind and waves (both separately and in combination) and from facility operations. This is what sets them apart from land-based wind farms and oil drilling platforms. The loads depend on parameters such as water depth, wave height, geological formations and the type of wind farm. To estimate the load, data on the rotor blades and the electrical components are needed which only the manufacturer can supply (Fig. 8).

The research project aims to provide reliable base data for forecasting vibrations and fatigue in offshore wind farms. This a key aspect of wind farm design, approval and commercial viability.

Fig 8: Mass Estimates for Machinery in Wind Farms

Type of Wind Farm	approx. 2 MW	3 - 3.5 MW	4.5 - 5 MW
Rotor blade diameter	70 m	100 m	approx. 120 m
Nacelle mass	70 t	164 t	254 t
Blade mass	7 t	20 t	34 t
Total	90 t	223 t	355 t

► Conclusion and Outlook

Many questions remain unanswered as regards offshore wind energy. On the one hand, data is lacking from supporting ecological research to prevent or reduce conflicts of interest between wind energy and nature protection. Where are the most important resting places for bird populations located? Will foundation struts provide habitats for animals and birds that are not already native to the North Sea? Gaps in knowledge also exist in other areas. These include representative time series for average wind conditions and wave profiles in the EEZ. The offshore research platforms will thus provide a range of key data in all areas concerned and will verify the results of the GIGAWIND project.

There are still many details to fill in regarding offshore wind technology. While the requirements for offshore facilities may be high, they are not unachievable. The main issue is economic viability, which is largely dependent on factors like water depth, grid connection, wind farm size and local conditions. While offshore wind farms can generate up to 40 per cent more electricity, it is evident that greater effort is needed before a further reduction in the forecasted electricity generation costs can be achieved.

With its offshore wind farms, Germany will have a safe, climate-friendly, home-grown source of energy. This provides for ongoing development in the wind industry and the new maritime services sector.

About a dozen offshore wind farms are currently in operation in Denmark, Great Britain, Sweden and the Netherlands. They are all situated closer to the coast in shallower waters. Germany's planned offshore facilities will open up a new dimension for offshore wind-generated electricity. One thing must not be forgotten, however: on a global scale, land-based wind farms will remain the first choice in many countries. Only a few will exploit the potential of offshore facilities.

Fig 9: Offshore Park Utgrunden in the Swedish Baltic Sea



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► ADDITIONAL INFORMATION

Offshore on the web

- www.gigawind.de – the GIGAWIND project internet forum offers current information on all aspects of offshore research.
- www.offshore-wind.de – the Federal Energy Agency (dena) internet forum, offers current information and a range of documents for download.
- www.fino-offshore.de – an internet forum on sea-based research platforms.
- www.bsh.de – the web site of the Federal Maritime and Hydrographic Agency (BSH) offers current information on offshore planning.

Service

- For further information, including literature, addresses of project participants and links, and information and links to offshore wind farms, please visit www.bine.info (click on 'Service/InfoPlus') (in german)