

REPORT 2005

OFFSHORE WIND
IMPLEMENTING A NEW POWERHOUSE FOR EUROPE

GRID CONNECTION, ENVIRONMENTAL IMPACT ASSESSMENT & POLITICAL FRAMEWORK

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" Offshore Wind Energy - Implementing a New Powerhouse for Europe"

Grid Connection, Environmental Impact, Assessment, Political Framework

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Foreword from Greenpeace

The Kyoto Protocol has now come into force, paving the way for the international community to take significant steps towards curbing harmful greenhouse emissions and combating climate change. Climate change is an undeniable reality and its impacts are now being felt across the world. Now is the time for the world to take action.

According to the Intergovernmental Panel on Climate Change Third Assessment Report (2001)[1] the global average temperature had already increased by ± 0.6° C by the end of the 20th century, and it is estimated that due to the greenhouse gases already emitted into the atmosphere we are irrevocably committed to 1.2 or 1.3° C warming, even if all emissions were stopped immediately.

The longstanding policy of the Climate Action Network[2], of which Greenpeace is a member, states that the objective of climate policy should be to keep global mean temperature rise from human-induced climate change to less than 2° C above pre-industrial levels. This was recently reinforced by the report from the US, UK and Australian International Climate Change Task Force[3], which said, "Above the 2° C level, the risks of abrupt, accelerated or runaway climate change also increase. Although there are serious damages associated with temperature increases of between 1 and 2° C, impacts rapidly become more severe above this level of warming.

Point of no return

There is a limited time window for limiting global mean temperature warming to less than 2° C, and on the basis of current knowledge of the climate system means that concentrations of greenhouse gases in the atmosphere must peak at or near 400 ppmv and be decreased as rapidly as possible thereafter. To meet this target calls for dramatic action in the next one to two decades to cut emissions in the industrialised world, to level of the growth in rapidly industrialising economies, and reach global emissions reductions on the order of 50% by mid-century.

Over the same time frame, utilities and politicians will be making the regulatory and investment decisions which will determine what the next generation of power plants will look like. The decisions they make, and in particular whether they choose to embrace offshore wind technology, will determine whether or not we and our descendents face a future of catastrophic climate change.

Offshore wind – a crucial tool in the race to cut our carbon emissions

Wind power is the fastest growing energy technology in the world. It has proved that renewable energy is ready and able to match conventional energy technologies euro for euro, kilowatt for kilowatt. The industry has now developed technology of sufficient size, reliability and efficiency that it is ready to unlock the vast offshore wind resources that exist around the world. In Europe alone, the North and Baltic seas boast massive wind resources that have so far remained largely unexploited.

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1 See http://www.ipcc.ch

2 See "Preventing Dangerous Climate Change: CAN position on adequacy of commitments", at: http://www.climnet.org/resources/futurecommitments.htm

3 See "Meeting the climate challenge: Recommendations of the International Climate Change Taskforce", at: http://www.tai.org.au/WhatsNew_Files/Whats_New.htm

The ‘repowering debate’ in Europe has already begun. Roughly two-thirds (100GW) of the overall installed coal-fired generating capacity within the 25-member EU is provided by power plants that are over 20 years old. This means that between 75 and 100 coal-fired plants will retire within the next two decades. Europe’s power sector must seriously consider offshore wind farms, as offshore wind is ideally positioned to replace this retiring capacity. The wind industry itself is ready, but only if supported by European energy policy. Greenpeace is therefore calling for a drastic policy shift.

Offshore wind is one of the most important technologies in the switch from fossil and nuclear fuels to clean, renewable energy sources.

Greenpeace has been pushing the possible boundaries of offshore wind technology for a long time. This report was commissioned as part of a series of well-received reports that look at the various technological and regulatory barriers that need to be overcome for offshore wind to fulfil its potential. The present report should be read in the context of the existing Greenpeace publications:

North Sea offshore wind – A powerhouse for Europe, a report published by Greenpeace in October 2000 and written by the German Wind Energy Institute (DEWI), reveals that the technology and economics of wind power make it well able to tap the North Sea's vast quantities of wind energy. It also tackles in detail the environmental impacts of offshore wind farms on bird life, marine mammals, fish and other marine ecosystems, setting out guidelines for environmental best practice in future development. This report found that exploitation of an additional 1% per year, up to 2012, of the total offshore wind resource available to the six North Sea countries could save 186 million tonnes of CO_2 emissions a year – equivalent to 10.3% of the annual CO_2 emissions of these countries.

Sea wind Europe is a vision for offshore wind energy commissioned by Greenpeace from UK wind energy consultants Garrad Hassan and published in March 2004. It assesses whether it would be possible to supply 30% of EU electricity demand – 720TWh/year – from offshore wind by 2020. This scenario entails the installation of 240GW of generating capacity by 2020, which is approximately ten times more than the present combined amount of installed on- and offshore wind power in the EU. The report notes that it would require “50,000 of the largest offshore turbines placed in 3% of the EU's seabed. This capacity would generate 720TWh of electricity.”

Windforce 12 is a joint report from Greenpeace International and the European Wind Energy Association – the latest edition was launched in May 2004. Windforce 12 is a “blueprint to achieve 12% of the world’s electricity from wind power by 2020”. This report demonstrates that there are no technical, economic or resource barriers to supplying 12% of the world's electricity needs from wind power alone by 2020, even when set against the challenging backdrop of a projected two-thirds increase in electricity demand by that date. Again offshore wind farms play a vital role in this vision.

Implementing a powerhouse for Europe

Offshore wind energy technology is a new technology created by the merging of classic wind energy technology and offshore technology of the kind used to construct and install oil and gas platforms. Although the technology is still fairly new, experiences from the first offshore wind farms in Denmark, the United Kingdom, Ireland and Sweden – with a total capacity of more than 600MW – give cause for optimism that large-scale applications at sea are a very feasible prospect. However, there are still significant obstacles to overcome. The present report identifies some of the most pressing problems and gives some background information on the major aspects of grid integration and ecological compatibility. Urgent political action is needed on these issues in order to pave the way for the phasing out of fossil and nuclear fuels.

In collaboration with Deutsche WindGuard GmbH, Greenpeace has compiled information on state-of-the-art technology to connect offshore wind farms to the onshore electricity grid; and a comprehensive overview of the ongoing work of Environmental Impact Assessments (EIA) within North European countries.

What are the obstacles hindering the implementation of offshore-wind?

New offshore wind projects face a number of problems, such as confused legal frameworks, lengthy planning processes and uncertainty over long-term electricity prices.

- institutional framework and administrative procedures: specifically the lack of well-established and harmonised planning rules;
- the difficulty of obtaining bank loans and insurance;
- power transmission, including grid connection as well as grid integration; and
- Environmental Impact Assessments: in particular, different national standards, and the need for offshore wind priority zones.

The present report focuses on the issues of marine grid connection and environmental impact assessments only.

Grid connection for offshore wind farms – a national debate with international relevance

The difficulties of connecting large-scale offshore wind capacity to the existing grid are hindering the growth of offshore wind power. Although the situation in each European country is different, it is clear that structural changes in the electricity supply system are needed in all cases. European utilities have reacted to this challenge in a variety of ways. While smaller utilities in the Netherlands and Denmark do not see major economic or technical barriers, large utilities companies such as the German-based E.on have said that integrating large-scale wind developments would cause serious difficulties at an unacceptable cost. However, a recent study of grid issues from the German Energy Agency (DENA) finds no grounds for such claims.

The main results of this study ("Energy supply planning for the integration of wind energy into the grid in Germany") were as follows:

- The integration of wind energy would require the rebuilding of approximately 5% of Germany's existing high-voltage transmission lines by 2015. This would mean additional costs for the average household of less than €1 per year in 2015 – which could be covered simply by not leaving the TV set on standby.

- In total, 850km of new high-voltage grid will be required to accommodate the projected expansion of wind by 2015[4]. Costs per year would be €110 million. In comparison, grid operators invest €2 billion every year in the whole 1.6 million kilometre-long grid.
- Accelerated network expansion must begin immediately.
- The additional costs of expanding wind energy will fall by more than half by 2015, based on a very conservative assumption of oil and gas price increases of 1.5% per year. Costs for balancing power and reserve capacity are already factored into these numbers.
- Additional power stations are not required to balance wind energy. The integration of existing wind capacity has led to stability problems: however this was the result of the grid structure and the behaviour of the utilities rather than the inherent nature of wind power technology.

The DENA study looks at how the onshore grid needs to change to integrate large-scale wind development quickly and economically. The present report complements DENA's findings by looking at what needs to happen in order to construct a large-scale offshore wind grid infrastructure that can provide access to the integrated onshore grid outlined in the DENA report. Together, these reports outline what is required for Germany to exploit its entire wind resource, both onshore and offshore, to the full.

More wind power leads to less need for backup capacity in Germany

The technological advances incorporated into modern turbines enable them to provide considerable support to the grid. In fact the required backup capacity for dispatch within the German grid has decreased over the last two years by 12%, during which time 6GW of new wind power capacity was installed.

No time to waste!

This report takes the logical next step of looking into the development of an offshore wind grid. The integration of offshore wind requires urgent action and long-term planning. The initial proposals for projects totalling approximately 6 GW should experience no significant difficulties. However, according to the European Wind Energy Association, offshore wind capacity is planned to increase to 70 GW by 2020. Additional grid infrastructure will undoubtedly be necessary to integrate this capacity within Europe. Governments, utilities and grid operators must start preparing now in order to be ready to connect more than six gigawatts of clean electricity after 2010. Every delay, every obstacle, every postponement of the necessary expansion of offshore wind will reduce our ability to combat climate change.

Key findings of the report

The report concludes that currently planned offshore wind projects in the North and Baltic Seas and the North Atlantic should be constructed as soon as possible to garner more experience. For these projects, the problem is not grid integration but rather finance and insurance. To overcome these barriers, grants from national governments are required.

However, the report also finds that a European offshore electricity grid will be required to integrate the offshore wind farms needed to meet the offshore wind targets (e.g. Germany 25 GW by 2025, Netherlands 6 GW by 2020, UK 7 GW by 2015 – the overall target from

[4] Total wind capacity in 2015 (onshore and offshore) should be 36,6 GW

EWEA for Europe is 70GW) which are in turn necessary to meet long-term CO_2 reduction targets. Planning and preparation of this grid must start now to guarantee an environmentally sound construction.

The report also provides an overview of nearly 100 research studies relevant to offshore wind development in Northern Europe.

Offshore wind – the way forward

From a technical perspective, offshore wind is a proven technology. In terms of protecting the environment from climate change, as well as from atmospheric pollution and radioactive contamination, offshore wind is part of the solution. Economically, offshore wind is competitive. Now it is the task of politicians to ensure that the renewable energy revolution, spearheaded by offshore wind, is given the chance to succeed.

Demands from the international wind sector for policy measures to facilitate implementation:

1. More uniform procedures and practices throughout Europe e.g. EIA, zoning, approval procedures.
2. Increased transparency, continuity and simplicity of legal procedures.
3. Measures to reduce the risk for financiers and insurance companies.
4. Provision of common grid facilities: an offshore grid and high voltage connections for offshore wind farms.

Policy recommendations to the EU:

1. The adoption of ambitious, legally binding long-term targets for renewable energy sources and for the decrease of energy consumption.
2. The removal of market barriers which hinder the growth of clean energy, including putting an immediate end to subsidies for dirty energy sources (fossil fuels and nuclear energy).
3. The reform of national export credit agencies to give priority to renewable energy development and energy efficiency programmes. All energy-sector financial support should include targets for the uptake of renewable energies as reliable, modern energy sources for on-grid, industrial and residential applications.

Sven Teske,
Greenpeace International
March 2005

Greenpeace Policy on Marine Reserves and Renewable Energy Developments in the North Sea and the Baltic

Greenpeace believes that to address the crisis in the North Sea and the Baltic it is absolutely vital to encourage the development of large-scale marine reserves which protect species and habitats and allow fish populations depleted by over-fishing to regenerate. Greenpeace defines marine reserves as areas that are closed to all extractive uses, such as fisheries, oil and gas production or sand and gravel extraction and mining, as well as any form of disposal activity. Within these areas there would be core zones which are free from any human use, for instance areas that act as scientific reference areas or areas where there are particularly sensitive habitats or species. Human activities such as wind power installations, tourism, safe shipping, etc. would be permitted in the these marine reserves outside of the core zones.

Greenpeace's proposals for marine reserves apply to the whole of the North Sea and the Baltic. They are large areas linked in a network and incorporate the German government's proposed sites for the NATURA 2000 network's Special Areas of Conservation (SAC) under the Habitats Directive and Special Protection Areas (SPA) under the Birds Directive. Greenpeace supports these proposals. The location of the core zones inside the reserves Greenpeace proposes must be prescribed by scientists. As matters now stand, the proposed SAC and SPA areas in the NATURA 2000 network are potentially core zones and thus areas in which no human uses ought to be allowed.

In the same way as Greenpeace supports the development of marine reserves it supports the development of renewable sources of energy (Germany targeting 25,000 to 30,000 megawatts from wind power by 2030). It is now undisputed that our climate has got out of control. To limit the scale of this, discharges of greenhouse gases, particularly carbon dioxide, have to be very greatly reduced. Should the discharge of greenhouse gasses continue unabated, however, whole ecosystems are threatened with irrevocable destruction. The eventual damage as a result of climate change will at the same time cost Germany alone up to 137 billion euros by 2050. To check this development, renewable sources of energy must be developed on a huge scale in addition to seeing that energy is used more efficiently. It is feasible and sensible in the long term (by 2010) for energy to be supplied entirely from renewable sources.

Given the urgent threat posed by climate change it is absolutely essential to develop renewable energy facilities. On account of the severity of the problem it may be necessary to make an exception and sometimes place wind plants in core zones, provided that:

- There is no feasible alternative. A 'feasible alternative' must be broadly similar to the originally proposed site (depth, current, wind conditions, grid access, etc.) and not present practical obstacles which prevent the scheme from going ahead.
- Potential impacts are subject to both a Strategic Environmental Assessment (SEA) and an Environmental Impact Assessment (EIA). Both should be completed before permission for construction is granted. The SEA is an assessment of government plans and policies carried out prior to their implementation, the EIA is carried out by a developer in support of an application for project consent. The EIA must address the cumulative impacts of many development sites in a specific area and not just assess the impacts on a case-by-case basis. The responsibility for any cumulative impacts assessment should always lie with the most recent developer (so that earlier developers do not have to rewrite their EIAs).

- Where possible, severe ecological impacts of renewable energy developments should be mitigated and/or compensated for as much as is reasonably possible.

The development of renewable energy facilities in core zones should never be taken as a precedent for any other kinds of development in these areas. It is only the extreme seriousness of the climate crisis that means that a broad ecological analysis will sometimes favour renewable energy developments in core zones. There should be no automatic renewal of development permission at the end of a facility's life.

But in order not to have to fall back on core zones for wind power, potentially suitable areas for wind installations which are outside the proposed SAC and SPA areas should be designated. In the case of Germany such areas could ensure the production of 25–30,000 megawatts by 2030 and at the same time ensure the preservation of marine biodiversity.

The costs of developing wind power in these suitable areas will probably be higher since, in the case of German EEZ, these areas may lie further offshore. But the marine environment cannot be preserved unless there are protected areas free from any human use.

The approach outlined above is indispensable if climate change is to be stemmed and seas securely protected.

Cable lines for offshore wind installations ought to:

1. be grouped together
2. go through the Wadden Sea national park as little as possible
3. not go through protected area 1 of the national park
4. not go through the core zones of the reserves, i.e. not through the SAC and SPA protection areas as they are now proposed.

1 Introduction

Offshore wind power is one of the largest-scale solutions for a nuclear- and pollution-free electricity supply in the future. Moreover, offshore wind power is essential to achieve the CO2 emissions reduction targets of the European countries and their individual member states, which came into force along with the Kyoto protocol. It has the potential to become an essential part of global electricity supply. A report by Garrad Hassan, commissioned by Greenpeace in 2004, concluded that almost a third of Europe's total electricity demand could be met from clean, renewable offshore wind power by 2020. That is enough to supply electricity to every single one of the 150 million EU households [Ref 1].

The worldwide potential for offshore wind is vast and the implementation of the first offshore wind farms has already begun. Nevertheless offshore wind energy still faces questions and difficulties concerning technical, environmental and economic viability. The intention of this study is to look at current offshore wind energy development activities in Europe and to consider the impediments that lead to a prolonged development phase. In particular, the constraints around power transmission, grid connection and grid integration, and the potential environmental implications are addressed in more detail. Finally, strategies have been presented to overcome these constraints in order to realise the nationally set targets.

Chapter 2 begins by presenting the EU targets for shares of electricity generated from renewable energy sources according to the European RES-E Directive from 2001. It then looks at ongoing activities and plans for offshore wind energy exploitation in several European countries, along with specific national political targets. In 2003 the European Wind Energy Association (EWEA) announced that it had increased its European target for installed wind power capacity by 2010 to 75GW, of which 10GW should be realised by offshore installations. Achieving this target would mean that wind power alone would meet one-third of the EU's total Kyoto commitment by 2010. For 2020 the target is set to 180GW total installed wind power capacity, of which 70GW should be realised offshore. 70 GW could generate approx. 10% of the EU´s electricity demand (Basis 2000).

Chapter 3 introduces several of the constraints to offshore wind power development. It then examines in detail those constraints concerning power transmission, grid connection and integration, European and national legal framework conditions for environmental impact assessment (EIA) and project financing.

However, the move to offshore wind power means losing one of the big advantages that onshore wind energy offers over conventional power generation, i.e. that electricity can be generated in the same place that it is consumed. As offshore wind farms will initially be situated at some distance from the coast, the length of the cable routes required to transmit the energy to land will range from around 10km to more than 100 km. This distance becomes even longer, when we consider transmission directly into main energy consumption areas, as is the case in particular in the UK.

Classic high voltage direct current systems based on thyristor technology are currently the only method for transmitting high capacities over large distances between wind farms and land. The alternative high voltage direct current transistor systems do not have these disadvantages, as they can transmit energy in both directions and can provide capacitive as well as inductive reactive power. The disadvantage to these systems is their limited transmission capacity, which at present lies at 250–300MW. Onshore grid connection causes further significant restrictions. The need for balancing energy is addressed, along with potential wind turbine refinements, which may be able to support grid stability.

National rules dictate EIA requirements. Special attention has to be paid to any international or EU treaties or conventions in the implementation of offshore wind farm projects. In this context the European Council Directives 85/337/EG and 97/11/EEC (including amendments) are mentioned. Since EU Directives are incorporated into the national legislation of individual countries, legislation and regulative bodies differ from country to country and an overview is provided for some European countries (the UK, Denmark, the Netherlands, Ireland, Belgium and Germany).

There is a need to creating more security in the project planning process in order to overcome the financial obstacles to development. Firstly, questions over grid connection should be resolved. Secondly, insurance coverage has to be fair and realistic. Thirdly, planning security needs to be increased by guaranteeing power purchase agreements or feed-in tariffs. To bring this about, countries must establish appropriate remuneration systems, including stipulations that ensure that electricity supplying companies and grid operators are obliged to purchase electricity generated by offshore wind power. A tariff-based system is therefore most suited to promotion of this new market, as has been shown by the onshore wind sector in Denmark, Germany and Spain.

Chapter 4 comes back to the issues of electricity transmission over long distances, grid connection and grid integration. Several types of transmission systems and cables, suitable for offshore wind power applications, are considered. Modern methods of offshore cable laying are also addressed.

Two main types of transmission systems exist, high voltage alternating current (HVAC) and high voltage direct current (HVDC) systems. Both systems, HVAC and HVDC may be based on high or extra high voltage level. A high transmission voltage reduces transmission losses in the cables.

Theoretically, the voltage of HVAC systems can reach up to 800kV; however, for offshore applications such a high voltage level is not realistic, as the enormous level of insulation needed for sea cables would not be mechanically feasible. There are basically two types of AC sea cable, the three-conductor cable and the single-conductor cable. The great advantage of the three-conductor cable is that the electromagnetic field of the three conductors is almost neutralised at the surface of the cable, and plastic is used instead of oil as stabilising material to fill the hollow space, preventing broken cables from emitting oil into the sea water. The single-conductor cable is a cable with just one conductor for a single phase, so that three single-conductor cables are required for a three-phase system. The advantage of this type of cable is its high transmission capacity, even though the absolute losses rise with increasing transmission capacities. For three-phase AC transmission, as the cable length increases so does the reactive power, causing higher losses. Reactive power compensation can only take place at either end of the cable, and the reactive power in the cable drastically reduces the ability to transmit power through a very long AC cable. These losses mean that the maximum practicable length of a three-phase AC sea cable is approximately 120km. Additional limiting parameters for sea cables are the weight and stiffness of the cables, which can cause problems while laying them.

For transmission of electricity over long distances, high-voltage DC transmission is therefore preferable. There are however only a limited number of systems with capacities large enough for undersea power transmission. Two quite different systems exist: thyristor HVDC and

Insulated-gate bipolar transistor HVDC transmission (HVDC-IGBT). HVDC systems are far more expensive than HVAC. HVDC systems are usually designed to be bipolar, which allows a higher transfer voltage at lower insulation levels. As both converters work fully symmetrically, no current flows to ground level. A big advantage of classic HVDC is the high transmission tension. A disadvantage is that it cannot generate a three-phase grid voltage to the offshore wind farm and cannot provide reactive power. To generate an AC voltage at fixed frequency offshore and to provide reactive power to start up the wind turbines, a separate diesel generator is needed. Another option is the installation of an AC cable parallel to the DC sea cable, to provide a voltage and reactive power source. However, this increases the number of cables needed. In contrast to thyristors, IGBTs can, by means of pulse-width modulation, generate sinusoidal AC voltages, which means that energy transfer is possible in both directions and in both regions, inductive and capacitive respectively. In offshore wind farms this feature makes it possible to generate a grid without an additional AC connection or diesel generator and to deliver reactive power if desired.

DC sea cables have similar structural elements compared to AC ones, but are different in electrotechnical design. DC cables have no induced voltages and currents and thus no losses from their metal jackets. To avoid the impact of electromagnetic fields on environment by DC cables, the two poles of a DC system, the forward and the return conductor, have to be installed parallel and close to each other in order to neutralise each other: this is called a bipolar system. In monopolar systems, strong electromagnetic fields are generated along the single cable and electrolysis occurs at anode and cathode of the return conductor, the sea water. These effects mean that monopolar systems are not suitable for offshore wind farm use. Other than this, the different transmission systems described present no clear favourite. Systems should be chosen on the basis of transmission distance and capacity and their particular advantages and disadvantages. Cables in coastal waters must be routed so as to avoid major conflicts with shipping and the natural environment.

Depending on the situation, three options are possible for transport on land: reinforcing existing lines to permit higher voltages, extending high-voltage overhead lines, or continuing the offshore transport system on land. As offshore wind farms will probably use HVDC systems offshore, the same systems could be used for direct overland connection to the main consumption areas.

Cable routes are mainly determined by environmental and safety conditions. Several criteria need to be considered during cable laying and operation. The depth of the cable trench is determined by substrate type and by environmental, economic and safety factors. Digging and trenching methods are reviewed. The big advantage of trenching is that it can be applied to existing submarine cables, as well as having a low impact on the marine environment.

Within chapter 5, the ecological aspects are investigated. Considerable efforts have been made to study the influence of offshore wind farms on various areas of marine flora and fauna, the environment and maritime safety. No universal conclusions are possible at the moment. A major requirement identified for the future is therefore the continuation of these investigations. Much of the research so far conducted has been in the context of offshore projects that have now been constructed. Further research has been carried out in other offshore fields. This pool of research should be taken into account in order to make maximum use of the knowledge and insights that have already been gained. Moreover, some non-offshore related studies contain valuable and occasionally transferable knowledge. The magnetic fields of buried submarine cables are small or even zero, and it can be assumed that the electromagnetic fields of submarine cables for offshore wind power will not have any significant effects on the marine environment. However, more research could help to understand the effect of electromagnetic fields on marine life. The impact on the environment by noise and vibration constitute another topic that needs to be addressed seriously. During the construction phase of a wind farm, in particular, some species may be disturbed. It is therefore important to time construction activities around any seasonal migration so as to minimise the effects. Devices to scare vulnerable species, so as to force them temporarily to leave the area under construction, should also be considered. Generally, however, a conscientious approach should be able to keep the effects to an acceptable degree.

Studies on the subject show that any impacts on birds are expected to be negligible especially compared to statistics on bird mortality from other anthropological influences.

Mammals form an important group, as they are in physiological terms highly vulnerable to underwater noise. The timescale is important, as no long-term (10–20 years) observations currently exist on behavioural change. Many species are not shy and may partially return to baseline levels within the wind farm area at the end of construction. However, further research should be conducted into this. During noise-intensive activities the exclusion of specific species from that area should be considered. Common seals and grey seals seem not to be significantly disturbed by the presence of offshore wind turbines, however, central corridors for movement between foraging areas and haul-out banks should left undisturbed and timing of engineering activities should allow for parturition seasons, mating seasons. Consideration should also be given to zones of special ecological value.

The noise emitted from wind turbines could potentially have an effect on the navigation and behaviour of fish, depending upon the frequency, intensity and duration. Fish may leave an area permanently, which would have a major impact on the whole food chain. Significant noise effects in the relevant frequency range are expected to being confined to the immediate vicinity of the wind turbines, with a radius of no more than several hundred metres. Moreover, due to the distances that the low-frequency hydrodynamic/acoustic fields will extend from the windmills, fish will perceive them as very different to the low-frequency sound emitted by other animals. Therefore, it is not expected that fish will be impaired in their ability to detect and interpret low-frequency sound from other marine animals. Furthermore, fish may become habituated to wind farm noise due to its continuous nature, as has been substantiated by one study. Nonetheless, it is recommended that more research is carried out into the impacts on fish species, because of the variation in potential effects from species to species and the influence of migrating fish species on the food chain and hence the whole ecosystem.

Research has shown that the benefits to benthic species by settling on the wind turbine structures predominate the possible impact by noise and vibration. As benthos is an important part of the food chain, the influence of changed benthic population on marine life in the wind farm environment should be considered.

The knowledge that has been accumulated concerning the influence of offshore wind farms on marine fauna and flora and on maritime safety is already reflected in most of the approval procedures for offshore wind farms. The environmental impact regulations have been made rather comprehensive, so as to avoid any serious impacts. However, as all research up until now has been conducted on comparatively small offshore wind farms, future EIAs need to take into account the cumulative effects of numerous installations. They will accordingly need to be carried out across national borders, which is particularly relevant in the case of the Wadden Sea. To guard against long-term environmental damage, continual and regular monitoring is required after the first wind farms have been installed.

Chapter 6 deals with strategies for reducing the obstacles to offshore wind farm development. For environmental, technical and economic reasons the linking of the cable systems of a number of separate wind farm projects to a common grid connection offers a good solution. If project developers are not themselves in a position to realise such a common approach, then governmental measures may instead be an effective means of achieving common grid connections or a common offshore grid.

It is predicted that, in contrast to the upward trend in prices of conventional energy sources, the price of wind energy will decrease. Unlike conventional energy prices, wind energy prices are not determined by external factors such as political instability and rising energy demands in other regions of the world. The cost of electricity generation by wind energy is very stable and mainly depends just on the manufacturing costs for wind turbines, a fact, which will grow very important for those countries that lack the resources necessary for conventional energy. The low energy amortization time of wind turbines that is required to repay the energy needed for manufacturing and construction, and which amounts to a few months only,, contributes to the cost stabilising effect of wind energy.

The solution to the question of grid connection could be the installation of a combined offshore-interconnected network, to which different wind farms can connect to, or the approval of large-capacity cable routes to separate wind farm areas. A government financial guarantee would allow the installation of an offshore extension to the onshore grid, without the need for the wind farm projects to have finalised approvals and finance. The security of knowing that a grid connection point was to be provided would give project development companies a secure basis on which to proceed with their wind farms.

EU programmes, networks and incentives on technical, political, social and environmental issues create platforms for discussion, research, and knowledge transfer and exchange, as well as a basis for transnational initiatives. These transnational initiatives have a synergic effect and form a common lobby for pushing forward national and European offshore wind power plans and targets, while helping to reduce the legal and administrative constraints by improving transparency, continuity and simplicity.

Principle findings:

Technical aspects:

One of the most challenging aspects is the transmission of electricity from the offshore wind farms to the onshore interconnected grid. The present study gives an overview of the technologies available for high-voltage transmission with high capacities over long distances, and also of the technologies to lay sea cables with a minimum impact on marine life. A comparison shows the advantages and disadvantages of alternating and direct current systems as well as the differences in semiconductor applications.

The transmission of electricity to land can be carried out with low impact on the environment. Modern conversion and transmission technologies allow the environmentally friendly and ecologically safe transmission of electricity through vulnerable ecosystems and habitats. However, the huge total capacity of the offshore wind farms planned in the North Sea will lead to a large number of cable routes. Depending on the technology chosen and the degree of combined planning, the number of cables required could vary substantially. As long as no governmental development plan is generated, developers of different offshore wind farms will plan their cable routes independently.

Politics:

The framing conditions for offshore wind farm approvals are in place. This is of course a great advantage for the future offshore development. In addition, in some countries the economic conditions are already established to operate offshore wind farms on an financially viable basis. There are however still some considerable political obstacles to offshore wind energy development. These obstacles arise from the connection of wind farms to the onshore interconnected network. The first problem lies in the approval of the cable routes, which politicians can resolve by implementing development plans for sea cables in coastal areas. The second problem lies in the integration of large-scale wind energy capacities into the onshore interconnected network. Utilities are concerned about the large share of the grid that wind energy will have. They argue that system stability will decrease drastically and that large capacities of control power will be needed in the grid. However, a recent grid study in Germany has shown that the necessary technical grid improvements will be financially possible. In addition the technological advances of modern turbines enable them to provide greater support to the grid and, as recently recognised by the Bundesverband Windenergie (German Wind Energy Association), control power in the German grid fell by 12% over the last two years, while during the same period 6GW of new wind power capacity was installed. Whilst utilities claim that the integration of large-scale wind energy will significantly increase energy costs to consumers, the recent German study showed that these increases will be marginal: an average household will have to bear an additional €1 a month of costs in 2015. In addition the recent increase in energy prices caused by rising fossil fuel prices (for households in Germany in 2004, an increase of 8% for natural gas and 4.4% for electricity on average) suggest that it is not unlikely that that one of the very few energy sources with a stable or decreasing price in the foreseeable future will be wind energy.

Technologically we are ready for offshore wind energy. Environmentally offshore wind energy is one of the few options, as it enables us to combat climate change while avoiding pollution and radioactive contamination. Economically it is competitive. Now it is the task of politicians to pave the way for offshore wind energy against the bias of inflexible traditional industries.

Ecological aspects:

A broad range of investigations and studies into the impacts of the installation and operation of offshore wind farms on nature and environment accompanies the planning, development and installation process. Studies are on one hand collected in the frame of approval of single wind farm projects, on the other hand within a broad range of research projects and programmes. The present study gives an overview of these investigations and research and of the great variety of topics that have been covered in nearly a hundred studies.

Brief details of 99 studies are presented in tabular form, covering accidents and pollution; barrier effects on fauna; the benthos; seabed life and reefs; birds; risks of collision by ships; SEA and Natura2000 guidelines; electromagnetic fields, cables and grid; fish; hydrography; mammals; noise and vibration; and sediment and substrate. A short outline of most of these studies is given in the appendices. This snapshot of the numerous investigations that have been conducted gives an idea of the tremendous effort, which has been and continues to be made to investigate all the possible impacts on nature and the environment that offshore wind power could have.

In addition to the studies reviewed, which are mostly publicly available, numerous EIA studies have been conducted by offshore wind farm developers. National EIA standards demand a baseline survey for up to two complete successive years before approval of a wind farm. The surveys to be performed cover the bird, fish, mammal and benthic life in the area of the proposed wind farm and a reference area of equal size. After the construction of an offshore wind farm monitoring continues for several years, to serve as input for future approvals of offshore wind farm installations or extensions. The enormous amount of information gathered by this large number of studies and assessments offers a range of insights into the coastal marine fauna and flora, which would not have been gained for decades without the efforts of the wind energy sector.

So far the results of these studies show that many areas far out to sea are unproblematic for wind energy use. The continuation of these investigations now that the first wind farms have been installed is a major demand of ecological organisations, which is already reflected in most of the approval procedures for offshore wind farms. From the studies and research programmes collected in the present report it can be concluded, that the process of installing offshore wind farms in European waters is accompanied by a responsible, careful and expertly conducted assessment and monitoring process.

2 Offshore Wind Power Development in Europe

In line with the Kyoto Protocol, which came into effect on 16 February 2005, the European Union (EU) is obliged to achieve an 8% reduction in its CO2 emission equivalents ($CO_{2\ eq}$) by 2012, as compared to 1990 levels. The target of the European Union for 2020 is a reduction of 30% $CO_{2\ eq}$, with 60% to be achieved by the year 2050.

Table 1 shows the reductions that several EU Member States will have to achieve by 2012:

Member State	$CO_{2\ eq}$ reduction by 2012
Belgium	-7.5%
Denmark	-21.0%
Germany	-21.0%
Finland	0.0%
France	0.0%
Great Britain	-12.5%
Greece	25.0%
Ireland	13.0%
Italy	-6.5%
Luxemburg	-28.0%
Netherlands	-6.0%
Austria	-13.0%
Portugal	27.0%
Sweden	-4.0%
Spain	15.0%
EU-15 Total	**-8.0%**

Table 1: $CO_{2\ eq}$ emission reduction targets of several EU Member States by comparison to 1990 levels[5].

A proportion of these reductions should be achieved by increased energy efficiency in industrial processes (technology, replacement materials, etc) and by the modernisation of existing power plants. However, a significant part of the reduction is intended to be achieved through increased use of renewable energy sources. In 2001, after long discussions between various institutions, the EU issued a directive on the promotion of electricity produced from renewable sources (the RES-E Directive). This directive sets out to create a framework, which in the medium term will facilitate a significant increase in renewable electricity generation within the EU. It constitutes an important milestone in shaping the regulatory framework for renewable electricity in the EU. Table 2 below shows the projected share of total electricity to be generated by renewable sources by 2010 in several EU Member States.

[5] http://www.ises.org/CDM/Mueller_German.pdf at 06/03/2005

	RES-E % 2010
Belgium	6%
Denmark	29%
Germany	12.5%
Finland	31.5%
France	21%
Great Britain	10%
Greece	20.1%
Ireland	13.2%
Italy	25%
Luxembourg	5.7%
Netherlands	9%
Austria	78.1%
Portugal	39%
Sweden	60%
Spain	29.4%
EU-15 Total	**22%**

Table 2: Proportion of total electricity to be generated by renewable energy sources by 2010, according to the 2001 European RES-E Directive[6].

The RES-E Directive sets the target that 22.1% of overall electricity consumption should be provided by renewable energy sources by 2010. The directive offers a broad definition of renewable energy sources. It includes biomass (solids, bio fuels, landfill gas, sewage treatment plant gas and biogas), solar (PV, heat, thermal electric), geothermal, wind, hydroelectric (large- and small-scale), wave and tidal power.

However, offshore wind power seems to be one of the most economically attractive and viable options for renewable energy generation in the short and medium term. Other studies show that by 2020 offshore wind power in Europe could provide 30% of the EU's electricity, which is just a fraction less than is currently supplied by nuclear power. Success on this scale would not only deliver enormous environmental benefits from this clean, safe energy source, but would also generate an economic boom in Europe worth hundreds of billions of euros and creating up to 3 million jobs [Ref 1].

The first European countries began to look at offshore wind power as early as the late 1980s. The first pilot projects were carried out in Denmark (Vindeby, 1991). Other European countries followed closely with the Netherlands setting up three projects (Lely, 1994; Dronten, 1996 and Medenblik 1990ties), both of them in inshore waters. In Sweden the first single offshore wind turbine was erected in 1990, and in 1997 the first commercial offshore wind farm was completed (Bockstigen).

In 2003 the European Wind Energy Association (EWEA) announced that it had increased its 2010 target for European installed wind power capacity to 75GW, of which 10GW was to be provided by offshore sources. Achieving this target would mean that wind power would meet one-third of the EU's total Kyoto commitment by 2010. For 2020 the target is set at 180GW total installed wind power capacity, of which 70GW should be in the form of offshore sources

[6] http://www.eufores.org/→ EU Policy on RES → Legal Documants at 06/03/2005

[Ref 2]. 70 GW offshore wind power could generate approx. 10 % of EU´s electricity demand (Basis 2000).

This chapter presents an overview of the current development of offshore wind energy in Europe.

2.1 Sweden

Sweden has a national target of 10 TWh wind annually by 2015, of which at least half is expected to be from offshore wind. The energy agency has identified areas of national interest for wind development both on- and offshore. Sweden has identified it as a source of electricity generation that could replace nuclear, coal and oil. The state has earmarked funding for research and development of offshore wind power. Many political and other groups are lobbying in favour of offshore wind power, and have proposed legal and regulatory changes to encourage it. Some of the groups involved represent developers and manufacturers with vested interests in promoting offshore wind technology, and some claims for future growth are considered unrealistic [7]. The following Fig. 1 presents the offshore wind power projects that are completed (3, red), those that are approved (1 yellow) as well as those, which are planned (10, white). The total capacity of all 14 projects amounts to about 2'5GW [Ref 3]. However, probably not all the planned projects will receive approval.

2.2 Denmark

Offshore wind power is expected to play a dominant role in the future electricity supply pattern in Denmark. The following Fig. 1 presents the offshore wind power projects that are completed (7, red) and those that are planned (2, white). No approved projects currently exist. The total capacity of all 9 projects amounts to about 809MW [Ref 3]. Further wind farms are planned; their realisation depends on the future political goals for offshore wind power in Denmark.

2.3 Germany

A serious debate about offshore wind energy started at the end of the 1990's against the background of a decreasing annual installation onshore, which was expected to happen within the next years. In 2002 the German Government set a target of creating the institutional framework conditions for the realisation of 20 GW to 25 GW installed offshore wind power capacity to be realised by 2025 or 2030. The obstacles posed by power transport, grid connection and grid integration arose with progressing approval procedures[7]. The following Fig. 1 presents the offshore wind power projects that are approved (9, yellow) as well as those, which are planned (31, white). The red marked project refers to a single near shore wind turbine. The total capacity of all 41 projects amounts to about 70GW [Ref 3]. However, by far not all projects will be realised, as not all planned projects will receive approval. Therefore this number is beyond realistic predictions of the future installation capacities. The more realistic goal is the political target of 20-25GW by 2025-2030.

[7] http://www.bmu.de/files/pdfs/allgemein/application/pdf/windenergie_strategie_br_020100.pdf at 06/03/2005

Fig. 1: Offshore wind power development in northern Europe. [Ref 3]

2.4 The Netherlands

The Dutch Government is taking steps to stimulate the large-scale adoption of renewable electricity generation. The application of offshore wind energy is part of this policy.

The construction of the Near Shore Wind Farm (NSW) demonstration project will be an important first step in the development of offshore wind energy in the Netherlands. This project aims to gain the knowledge and experience necessary for the construction and operation of large offshore wind farms. In addition, the Government is taking steps to encourage the development of 6 GW of offshore wind power by the year 2020[8]. Fig. 1 above presents the offshore wind power projects that are completed (3, inshore red), those that are

8 http://www.offshorewindenergie.novem.nl/default.asp?DOC_ID=27918 at 06/03/2005

approved (2, yellow). There are very preliminary initiatives proposing 19 offshore wind farms since 1.Jan.2005.

2.5 Belgium

The Belgian Government has issued a zoning plan to facilitate a total of 2 GW of offshore wind power[9]. Fig. 1 above presents the offshore wind power project that is approved (1, yellow) but none has so far been completed and no more are yet at the planning stage. The total capacity of the approved project is 600 MW [Ref 3].

2.6 United Kingdom

In total the British Wind Energy Association (BWEA) projects, that offshore wind will contribute 4% of the Government's 2010 targets for renewable energy[10]. The following Fig. 2 presents the offshore wind power projects that are completed or under construction (4, red), those that are approved (9, yellow) as well as those, which are planned (17, white). Projects with planning consent but awaiting construction total over 1 GW, and a second round of offshore tenders by the Crown Estate (for which applications have not yet been made) will add a further 7.2 GW, in total equivalent to 7 % of UK supply. The total capacity of all 30 projects amounts to about 8.9 GW [Ref 3]. How many of the planned projects will be approved is not clear yet.

2.7 Ireland

In Ireland 2GW of capacity are expected from already granted exploration licences[11]. The following Fig. 2 presents the offshore wind power projects that are completed (1, red), those that are approved (1, yellow) as well as those, which are planned (6, white). The total capacity of all four projects, whose installation capacities are known, amounts to about 1.3 G W, however, the capacity of further planned projects and hence also the total capacity, is estimated only [Ref 3].

[9] http://home.wxs.nl/~windsh/offshore.html at 06/03/2005
[10] http://www.bwea.com/offshore/info.html at 06/03/2005
[11] http://www.ewea.org/documents/0927-Offshore WD FINAL.pdf at 06/03/2005; Background paper - Offshore Policy Workshop

Fig. 2: Offshore wind power development in the United Kingdom and Ireland. [Ref 3]

2.8 France

The French Government announced in August 2003 that it aims to develop 500MW of offshore wind power in domestic waters with projects in the Mediterranean Sea, North Sea and Atlantic Ocean[12]. The following Fig. 3 shows the two planned offshore wind power projects marked in white, though none has yet been approved or completed. The total capacity of the two planned projects amounts to 60 MW [Ref 3].

2.9 Spain

Spain has no national plans or specific incentives for offshore wind energy development[13]. Six projects are at the planning stage (see Fig. 3). No projects have yet been completed or approved. The total capacity of all six planned projects amounts to about 2.6 GW [Ref 3].

Fig. 3: Offshore wind power development in south-west Europe. [Ref 3]

[12] http://home.wxs.nl/~windsh/offshore.html at 06/03/2005

[13] http://www.offshorewindenergy.org/ca-owee/indexpages/Activities_and_Prospects.php?file=actpros_p4.php at 06/03/2005

2.10 Overview of offshore wind energy projects in Europe

In order to meet the EU's agreed Kyoto targets as well as those stipulated within the European RES-E Directive, the European Wind Energy Association has declared targets for wind power development as shown in Table 3[14]:

Year	Total installed capacity (MW)	Installed Off-shore (MW)
2010	75.000	10.000
2020	180.000	70.000

Table 3: Latest EWEA targets.

To achieve the EU and EWEA targets, the realization has to be pushed at an early stage. Therefore, in addition to the defining of common targets, the developing of common approaches between EU Member States may be beneficial in some areas. Increased dialogue around a range of trans-boundary aspects may pave the way for such common approaches by simplifying and harmonising administrative procedures and institutional frameworks as well as improving transparency and continuity. This approach may be particularly beneficial with regard to: environmental impact assessments; assignment of areas to be developed, cable routes, traffic routes and shipping areas; and safety standards.

14 http://www.ewea.org/documents/13190_policy briefing_4.pdf at 06/03/2005

Table 4 gives key information about the offshore wind energy projects so far developed within the EU, while Table 5 lists all the offshore wind energy projects mentioned in sections 2.1 - 2.9 and shown in Fig. 1 - Fig. 3 above.

Project	Country	Completed	Capacity [MW]	Turbines (amount, type)	Water depth [m]	Distance from coast [km]	Operator	Total investment in millions of euros*	Investment per MW in millions of euros*
Vindeby	Denmark	1991	4.95	11 * Bonus 450 kW	3 – 5	1.5	Energi E2	10.25	2.1
Lely (Ijssel Lake)	The Netherlands	1994	2	4 * NedWind 500 kW	5 – 10	0.75	Nuon	4.5	2.3
Tuno Knob	Denmark	1995	5	10 * Vestas V39 / 500 kW	3 – 5	6	Midtkraft	10.4	2.1
Dronten (Ijssel Lake)	The Netherlands	1996	16.8	28 * Nordtank 600 kW	5	0.02	Nuon	20.5	1.2
Bockstigen	Sweden	1997	2.75	5 * WindWorld 550 kW	5.5 – 6.5	4	Vindkompaniet	4.7	1.9
Utgrunden	Sweden	2000	10.5	7 * Enron Wind 1.5 MW	8 – 10	8	GE Energy	13.9	0.97
Blyth	United Kingdom	2000	4	2 * Vestas V66 / 2 MW	8.5	1	Blyth Offshore (Amec Wind, Powergen, Shell, Nuon)	6.32	1.11
Middelgrunden	Denmark	2000	40	20 * Bonus 2 MW	4 – 8	2	Middelgrunden Wind Turbine Cooperative, Energi E2	51.3	0.9
Yttre Stengrund	Sweden	2001	10	5 * NEG Micon 72 / 2 MW	7.5 – 8.6	5	Energi E2	13	1.3
Horns Rev	Denmark	2003	160	80 * Vestas V80 / 2 MW	6 – 14	14 – 20	Elsam, Eltra	300	1.31
Samsø	Denmark	2003	23	10 * Bonus 2.3 MW	11 – 18	2.5	Samsø Havind	35	1.07
Frederikshavn	Denmark	2003	10.6	2 * Vestas V90 / 3 MW, 1 * Bonus 2.3 MW, 1 * Nordex N90 / 2.3 MW	1	0.5	MBD / Elsam	n.s.	n.s.
Nysted	Denmark	2003	165.6	72 * Bonus 2.3 MW	6 – 10	9	Energi E2, Dong, Sydkraft	268.8	1.19
Arklow Bank	Ireland	2003	25.2	7 * GE 3.6 MW	2 – 5	12	GE Energy, Airtricity	n.s.	n.s.
North Hoyle	United Kingdom	2003	60	30 * Vestas V80 / 2 MW	8 – 12	7 – 8	RWE npower renewables	105.7	1.23
Emden	Germany	2004	1	1 * Enercon E-112, 4.5 MW	3	0.01	Enova	n.s.	n.s.
Scroby Sands	United Kingdom	2004	60	30 * Vestas V80 / 2 MW	2 – 12	2	E.ON UK	107.1	1.25
Total			**601.4**	**326**					

* Source: Garrad Hassan

Table 4: Offshore wind energy projects so far completed within the EU. [Ref 4]

Number	Project Name	Project Developer	Number of Turbines (in brackets: extension phase)	Capacity [MW] (in brackets: extension phase)	Status
Sweden					
1	Bockstigen	Vindkompaniet	5	2.75	built in 1997
2	Utgrunden	GE Energy	7	10.5	built in 2000
3	Yttre Stengrund	Energi E2	5	10	built in 2001
4	Utgrunden II	Airicole	24	90	approved
5	Klasarden	Vindkompaniet	16	44	approved
6	South Öland	Airicole	50	180	planned
7	Southeast Öland	Airicole	21	75.6	planned
8	Northeast Öland	Airicole	21	50	planned
9	Blekinge	Airicole	30	108	planned
10	North Midsjöbanken	Airicole	79	280	planned
11	South Midsjöbanken	Airicole	227	820	planned
12	Smygehamn	Airicole	28	100.8	planned
13	Lillgrund Bank	Eurowind	48	110	approved
14	Kriegers Flak	Sweden Offshore Wind	128	640	planned
Denmark					
15	Vindeby	Energi E2	11	4.95	built in 1991
16	Tuno Knob	Midtkraft	10	5	built in 1995
17	Middelgrunden	Middelgrunden Wind Turbinen Kooperative/Energi E2	20	40	built in 2000
18	Horns Rev	Elsam/Eltra	80	160	built in 2002
19	Nysted	Energi E2/Dong/Sydkraft	72	165.6	built in 2003
20	Samsø	Samsø Havind	10	23	built in 2002
21	Frederikshavn	MBD/Elsam	4	10.6	built in 2003
22	Horns Rev II	not given away yet	ca. 80	200	planned
23	Nysted II	not given away yet	ca. 80	200	planned
Germany, North Sea					
24	Emden	Enova	1	4.5	built in 2004
25	Butendiek	OSB Offshore-Bürger-Windpark Butendiek	80	240	approved 2002
26	Borkum West	Prokon Nord	12 -208	60 (1040)	approved 2001
27	Wilhelmshaven	Winkra/Enercon	1	4.5	approved
28	Borkum Riffgrund West	Energiekontor	80 -458	280 (1800)	approved 2004
29	Borkum Riffgrund	Plambeck	77 -180	231 (746)	approved 2004
30	Amrumbank West	Rennert Offshore/Eon Energy Projects	80	400	approved 2004
31	Nordsee Ost (Amrumbank)	Winkra	80 -250	400 (1250)	approved 2004
32	Sandbank 24	Sandbank 24/Projekt GmbH	120 -980	420 (4720)	approved 2004
33	Dan Tysk	Geo	80 -300	400 (1500)	planned
34	Meerwind	Windland	75 -234	265 (819)	planned

Number	Project Name	Project Developer	Number of Turbines (in brackets: extension phase)	Capacity [MW] (in brackets: extension phase)	Status
35	Weiße Bank 2010	OSB Offshore-Bürger-Windpark Butendiek	540	2700	planned
36	Forseti	Prokon Nord	1750	17500	planned
37	Globaltech I	Nordsee Windpower	80 -320	360 (1440)	planned
38	Offshore North Sea Windpower	Enova	45 -251	2025 (1255)	approved 2005
39	Hochsee Windpark Nordsee 54°25'	EOS Offshore	119 -508	5355 (2286)	planned
40	Godewind	Plambeck	80 -224	320 (896)	planned
41	Uthland	Geo	80	400	planned
42	Weiße Bank	Energiekontor	80–90 - 170	280-315 (595)	planned
43	Jules Verne	Plambeck	3000	13500	planned
44	Ventotec Nord 1	Arcadis (Deutsche Bank	50 -200	150 -600	planned
45	Ventotec Nord 2	Arcadis (Deutsche Bank	50 -200	150 -600	planned
46	Nördlicher Grund	Geo/ABB/Global Renewable Energy Partners	87 -402	360 (2195)	planned
47	Hochsee Windpark He dreiht	Eos Offshore	119	535.5	planned
48	TGB North	ep4 offshore	287 -596	10045 (2549.5)	planned
49	H2-20	Geo	80 -800	400 (4000)	planned
50	Nordergründe	Energiekontor	25 -45	125 (270)	planned
51	Riffgat	Enova	44	220	planned
52	Bard Offshore I	Bard Engineering	80 -320	400 (1600)	planned
53	Austerngrund	Rennert Offshore	80	400 (400)	planned
54	Deutsche Bucht	Rennert Offshore	80	400 (400)	planned
Germany, Baltic Sea					
55	Arcona Becken Südost	AWE (Eon Energy Projects	80 -201	400 (1005)	planned
56	Pommersche Bucht	Winkra	70 -200	350 (1000)	planned
57	Adlergrund	OWP	80 -160	280 (720)	planned
58	Beltsee	Plambeck	25 (59-83)	75 (415)	planned
59	Kriegers Flak	Offshore Ostsee Wind AG	40 -80	140 (320.5)	planned
60	Ventotec Ost 2	Arcadis (Deutsche Bank	50 -200	150 (600)	planned
61	Sky 2000	Geo/Eon Energy Projects	Mai 50	10 (100)	planned
62	Baltic I	Offshore Ostsee Wind AG	21	51	planned
63	Breitling	Offshore Ostsee Wind AG	1	2.3	planned
64	Wismar	Arcadis (Deutsche Bank	1	2	planned
United Kingdom					
65	Blyth	Eon UK/Amec/Shell/Nuon	2	4	built in 2000
66	North Hoyle	RWE npower renewables	30	60	built in 2003
67	Scroby Sands	Eon UK	30	60	under construction
68	Kentish Flats	Elsam/Global Renewable Energy Partners	30	90	under construction
69	Solway Firth	Offshore Energy Ressources	60	216	approved
70	Barrow	Centrica/Dong/Statkraft	30	108	approved
71	Burbo Bank	Elsam/Seascape Energy	30	90	approved

Number	Project Name	Project Developer	Number of Turbines (in brackets: extension phase)	Capacity [MW] (in brackets: extension phase)	Status
72	Rhyle Flats	RWE npower renewables	30	150	approved
73	Scarweather Sands	United Utilities	30	108	approved
74	Gunfleet Sands I	GE Gunfleet Ltd.	30	108	approved
75	Cromer	Norfolk Offshore Wind	30	108	approved
76	Lynn	Centrica/AMEC	30	108	approved
77	Inner Dowsing	Centrica/Offshore Wind Power	30	120	approved
78	Shell Flat	Cirrus Energy	90	324	planned
79	Teeside	Northern Offshore Wind	30	90	planned
80	Walney	Dong/Statkraft	k.A.	450	planned
81	West Duddon	Scottish Power	k.A.	500	planned
82	Gwynt y Mor	RWE npower renewables	200	750	planned
83	Thanet	Warwick Energie Ltd.	k.A.	300	planned
84	London Array	London Array	300	1000	planned
85	Gunfleet Sands II	Delatic	k.A.	64	planned
86	Greater Gabbard	Airtricity/Flour	140	500	planned
87	Sheringham	Ecoventures	60–80	315	planned
88	Docking Shoal	Centrica/AMEC	k.A.	500	planned
89	Lincs	Centrica/Offshore Wind Power	k.A.	250	planned
90	Race Bank	Centrica/AMEC	k.A.	500	planned
91	Dudgeon East	Warwick Energy	k.A.	300	planned
92	Triton Knoll	RWE npower renewables	k.A.	1200	planned
93	Humber	Humber Wind Ltd.	k.A.	300	planned
94	Westernmost Rough	Total	k.A.	240	planned
Ireland					
95	Arklow Bank	GE Energy	7 -200	25 (545.2)	built in 2003
96	Kish Bank	Kish Konsortium	n.b.	50	planned
97	Blackwater Bank -1	Wind Farm Development (first right)	n.b.	n.b.	planned
98	Blackwater Bank -2	Harland & Wolf (2nd right)	n.b.	n.b.	planned
99	Codling Bank	Harland & Wolf	220	660	planned
100	Bray Bank	Kish Konsortium	n.b.	25	planned
101	Dundalk Bay	Sure Partners Ltd	n.b	n.b	planned
102	Gaoithe Sceirde Teo	Skerd Rocks	n.b.	n.b.	planned
The Netherlands					
103	Lely (Ijsselmeer)	Nuon	4	2	built in 1994
104	Dronten I (Ijsselmeer)	Nuon	28	16.8	built in 1996
105	Ijmuiden / Q7	Evelop	60	120	approved in 2004
106	NSW (Demonstrationsprojekt)	Noordzeewind (Shell/Nuon)	36	100	approved
	19 new projects are very preliminary proposed initiatives				
Belgium					
107	Thornton Bank	C-Power	60	300	approved in 2003
France					
108	La Rochelle	Universität La Rochelle	1	2	planned
109	Port La Nouvelle/ L'Aude	Total	16	58	planned

Number	Project Name	Project Developer	Number of Tur-bines (in brackets: extension phase)	Capacity [MW] (in brackets: extension phase)	Status
Spain					
110	Mar de Trafalgar	Sogemar/EHN	n.b	994	planned
111	Banco de Trafalgar	NEK Umwelttechnik (Schweiz)	n.b	253	planned
112	Cabo de Trafalgar	Umweltkontor Espana	n.b	250	planned
113	Playa El Palmar	Capital Energy	n.b	250	planned
114	Delta de l'Ebro	Capital Energy	n.b	432	planned
115	Vinaròs - Benicarló	Capital Energy	n.b	384	planned
Source: BSH, BWEA, companies, Research journal 'Neue Energie', Date: November 2004					

Table 5: Offshore wind energy projects in Europe: the numbers correspond to those shown in Fig. 1 - Fig. 3. The red and orange coloured rows are representing completed projects as well as such under construction. The yellow and rose-colored rows are representing approved projects, whereas the white and blue coloured rows are representing planned projects. Based on [Ref 3]

3 Obstacles to Offshore Wind Energy Utilisation and Regulations

A variety of obstacles to the development of offshore wind farms exist: zoning issues and the legal assignment of areas for offshore wind power development; public acceptance; competing utilisation; administrative procedures; the requirements of environmental impact assessment; financing and insurances; institutional or legal framework conditions; long-term contract for power sales as well as power transmission; and power transmission, grid connection and grid integration.

In this chapter the obstacles presented by power transmission, grid connection and grid integration, by legal framework conditions on environmental impacts, and by financing are examined in more detail. Environmental and technical subjects discussed here, are presented in more detail in the subsequent chapters.

3.1 Obstacles relating to power transmission, grid connection and grid integration

Offshore wind power projects are planned by a range of parties, in most cases each with a separate application for an own cable route. The main obstacle to the development of most of these wind farms lies not in obtaining development approval, but in connecting to the onshore grid.

Technical problems relating to power transmission, grid connection and grid integration of offshore wind power lie in several areas.

There is a need to install electrical transmission systems with as large a capacity as possible, to limit the number of submarine cables needed. Classic HVDC systems based on thyristor technology are currently the only method of transmitting high capacities over large distances between sea and land. These systems have the disadvantage of requiring a large amount of reactive power at the offshore wind farms, which has to be provided either by diesel generator sets, phase shifters or a parallel AC cable. This increases investment and operational costs.

The alternative HVDC-IGBT systems do not have this disadvantage, as they can transmit energy in both directions and can provide capacitive as well as inductive reactive power. The disadvantage of these systems is their limited transmission capacity, which at present lies at 250–300MW. This is a result of their lower voltage, which currently lies at 145kV. The voltage may be increased in future systems. Developments in semiconductor technology may also help to overcome this limitation.

Further significant restrictions are caused by the onshore grid connection. Inevitably, offshore wind farms connect to the main onshore grid in coastal areas, often at a distance of around 100km from the main consumption areas. This is a particular problem in some regions of Europe – for example the parts of the Scottish coast best suited to the generation of wind energy, are mostly a long distance from main consumption areas. The same is true of large German projects.

To give an overview of the existing interconnected network, Fig. 4 depicts the high voltage grid around the North Sea, while Fig. 5 shows the grid around the Baltic Sea. The dots in the figures represent grid nodes, some of which may be possible connection points for large wind farms. As can be seen, a substantial number of nodes lie along the coastal areas around both seas. According to the rules of the Union for the Co-ordination of Transmission of Electricity (UCTE) the power generation capacity connected to each node should not exceed 3GW.

Fig. 4: Electrical transport network in the countries around the North Sea [Ref 49]. The red lines indicate 380kV grid. The small dots on the lines (open circles) indicate network nodes. The black and coloured squares and the larger coloured dots indicate power plants.

Fig. 5: Electrical transmission network in the countries around the Baltic Sea. The red lines indicate the 380kV grid, the blue lines the 300kV grid and the green lines the 220kV grid. The small black dots on the lines indicate grid nodes. The black and blue rectangles and the larger black dots indicate power plants [Ref 49].

The German case is a special one, as the grid near the coast already has to cope with a comparatively large proportion of onshore wind energy, and a large number of additional offshore projects are planned. Access to the nodes in coastal areas, and hence to the onshore grid, is planned by various project developers. Fig. 6 shows the transmission network, grid nodes and power plants in Northern Germany. The amount of additional wind power that can be incorporated into the grid in the coastal areas of the North Sea is estimated to be 3GW [Ref 8]. These 3GW will have to be divided between new offshore and onshore installations. Due to the fact that most of the suitable onshore sites close to the coast have already been used and only a few new sites will be approved onshore, it can be assumed that the larger share will be available for offshore wind energy.

Recently a study [Ref 51] was carried out on behalf of the German Energy Agency (DENA), in which the influence of a large proportion of wind power on the stability of the German grid was investigated by the main German grid operators. The German grid operators argue that the further implementation of wind energy would significantly raise the cost of balancing energy produced by conventional power plants. This ignores the fact that balancing energy is required to balance power output against fluctuating consumption. Power output is constantly determined by power consumption – more power cannot be produced than is consumed, and if less is produced, the supply system will fail.

Fig. 6: Electrical transport network in northern Germany [Ref 49]. The red lines indicate the 380kV grid, the green lines the 220kV grid. The small open circles indicate grid nodes. The black and coloured squares and the larger coloured dots indicate power plants.

Power generation can be divided fundamentally into controllable and non-controllable generation. Controllable generation is provided by conventional power plants (mainly gas and oil), designed for fast control, and also by large hydro power plants. The output of wind turbines and base-load providing plants such as large coal and nuclear power plants falls into the non-controllable category. In most European countries the energy market has no choice but to buy the power produced by nuclear power plants, and the system operator has to arrange the adaptation of this constant power production to the fluctuating power consumption by deployment of control power plants. Adjustment of the output of base-load power stations is far too slow to follow the fluctuations of power consumption. In this context wind energy is a fluctuating power source compared to the constant power generation of base-load power stations. How this fluctuating production matches fluctuating consumption has not been methodically analysed. It might well prove to be the case that fluctuations in renewable energy production correlate to some degree with power consumption, the stagnation of balancing energy in Germany during the past years during a steady growth of wind energy may give a first indication. Some basic research into this subject was done in the 1980s and 1990s, but there are no significant up-to-date publications.

It is difficult to assess the amount of wind power, which is hourly fed into the grid, as grid operators do not measure power output of wind farms – only energy output is counted and recorded integrally. With this in mind, the German utility E.on has installed an assessment method to gather the amount of wind power produced every 15 minutes by means of wind speed and power measurements on few selected wind farms and a simulation system. This system should allow operators to distinguish between fluctuating consumption and fluctuating wind power production within a selected network region. Even though it entails some uncertainties, this system should provide basic information on the temporal behaviour of wind power production and hence on the balance between wind, general renewable power production and consumption.

Refinement of databases and statistical procedures, together with the application of meso-scale wind prediction tools and a more flexible grid management and operation system, could serve to match these fluctuations even better, without negatively affecting grid stability, but actually enabling a decrease in the level of control power required. At present we can only go so far as to say that the amount of control power being required has decreased in Germany in recent years. Ref 48 shows that the level of available power required for control fell from 8.3GW in 2002 to 7.3GW in 2004, during which time an additional 6GW of wind power capacity were installed.

Furthermore, the use of wind prediction systems to forecast output for the coming hours could reduce the control power capacity required for wind power. If wind power output can be more reliably predicted, then the base-load level can be adapted to the expected wind power level. Various European system operators have already installed or are about to install wind prediction systems.

Further development and refinement of wind turbine technology towards turbines with grid supporting features will allow larger grid connection capacities. Until the second half of the 1990s German utilities required wind farm operators to switch off turbines automatically if the grid frequency fell below 49.5Hz or rose above 50.5Hz. This requirement led to an increasingly dangerous situation in terms of system stability: if a large power plant (e.g. 1.2GW) would drop out, the resulting short-term regional frequency shift would lead to a dropout of a further large capacity of wind power – perhaps another gigawatt. As this situation violated the UCTE rules, the German utilities decided to change the connection rules, allowing a larger shift in the grid frequency before turbines were required to be to cut off. This has led to increasing system stability, since wind turbines can now be used to support the grid in case of a dropout.

The issues concerning power transmission, grid connection and grid integration discussed above can be well summarised by the example of the German Bight:

More than 20GW of wind power capacity are planned to be installed in the German Bight. In most of the proposed wind farm areas, only a limited number of wind turbines are planned for the initial step. These initial projects total 3–4GW (see Fig. 7) and are planned with separate submarine cable connections. The capacities of these cables are often around 100 to 250 MW in average. For the total planned capacity this will lead to a large number of cable routes, meaning a serious impact on concurring utilisations as the national park Wadden Sea or shipping areas. To reduce the number of cable routes, it is recommended to concentrate the grid connection of several of the smaller projects with only limited power. This may be also useful for pilot project approaches.

Traffic routes and shipping areas and/or areas of the national park Wadden Sea have to be crossed, to connect these offshore wind farms to the on land grid. Although the representatives of the administration offices of both areas are positive towards offshore wind energy installations, both of them refuse the crossing of their respective area. To solve this problem a combined planning of cable routes is required, in order to reduce the number of cables and to allow a controlled development.

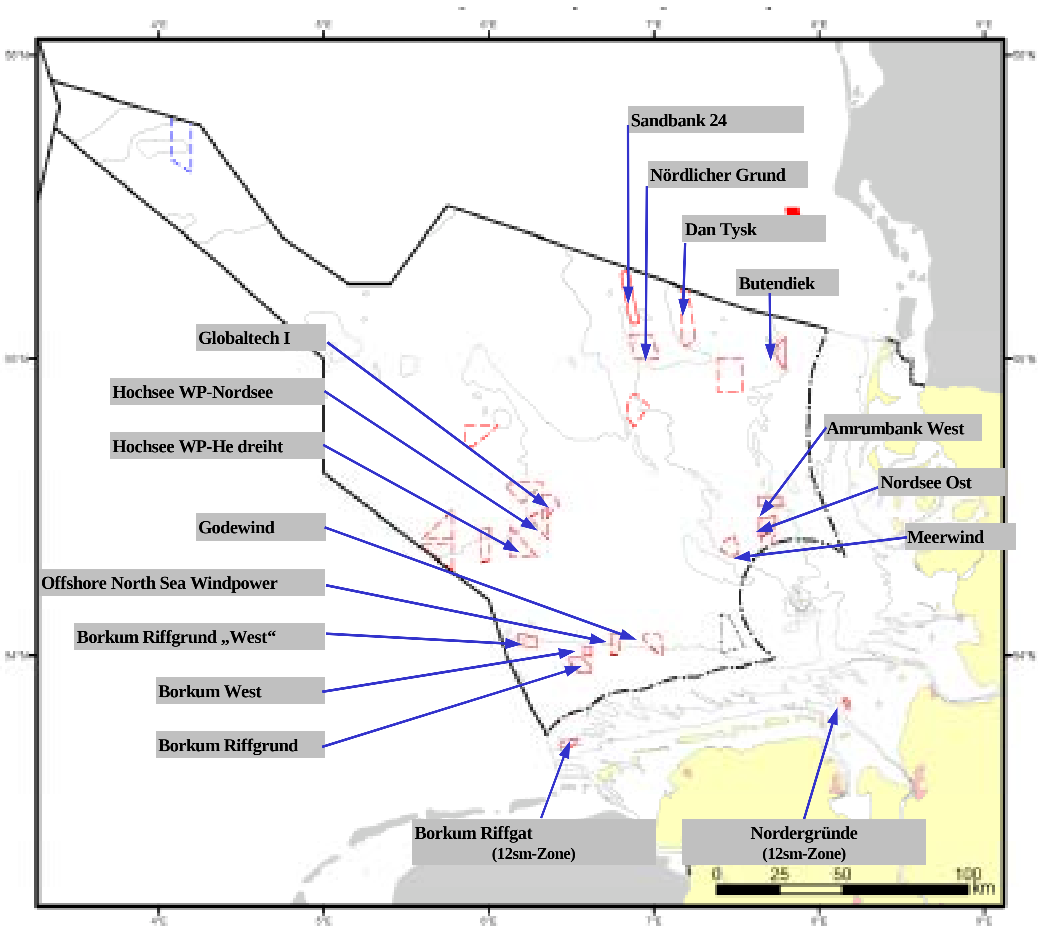


Fig. 7: Offshore wind projects currently in the approval phase in the German Bight. In the first (pilot) phase, the depicted areas will only partially be occupied by wind turbines, totalling a capacity of 3 – 4 GW. In a second phase a much larger number of turbines is planned, with a total capacity of more than 20 GW [Ref 8].

However, there are various problems restricting a combined planning of grid connection of several projects:

- There is no obvious reason for project developers to want to combine their planning. Their own planning may be slowed down, if agreements have to be reached and approvals obtained for combined cable routes. Furthermore, at present combined planning offers no economic benefit to the developers.
- For network operators, there is no certainty about the economic viability of single offshore grid connections, since at present it is simply not clear which of the projects (first and second phase) will become reality.

To overcome this situation political measures need to be taken to solve the problem of large-scale grid connection.

3.2 Legal framework conditions around environmental impact assessment

When looking at studies and research projects on the environmental effects of offshore wind energy use, different European and national regulations have to be addressed. Some of these European and national regulations deal with the requirements and guidelines for environmental impact assessments (EIAs) and strategic environmental assessments (SEAs) for national offshore wind energy projects, and some with the declaration of protected zones for animals, habitats and ecosystems. The EIA guidelines provide information on the types of surveying which are needed in order for specific projects to meet the requirements to obtain building approvals. Conversely, the EIAs that have either already been performed or are still going on have led to a considerable amount of knowledge and experience, which is in turn useful for research projects. For example, most studies on environmental impacts at the Danish wind farms Nysted/Rødsand and Horns Rev make use both of the EIAs on these sites, and of the monitoring programmes, which have been conducted since 1999.

On an international level there are treaties and conventions that need to be adhered to, relating most often to areas that are protected for the sake of sensitive and valuable biotopes and habitats. Examples of international agreements are the London Convention (relating to dredging where the sediment is dumped at another site), the OSPAR Convention (1992/1999), the Ramsar Convention (1971), the Bonn Convention (1979), ASCOBANS (1992), the Convention on Environmental Impact Assessment in a Transboundary Context (1991), the European Bird Directive 79/409/EEG (Special Protection Areas (SPAs), 1979), the European Habitat Directive 92/43/EEG (Special Areas of Conservation (SACs), 1992), the Treaty of Bern (1979), the Convention on Biological Diversity (1992 Rio de Janeiro) and the designation of Important Bird Areas (IBAs).

Another two important European Council Directives are 85/337/EEC and 97/11/EC (including amendments and in particular Appendix II). These are the main documents setting out the basis for rules on EIA for Member States of the European Union and they are of special importance for the Denmark, Germany and The Netherlands as being the three 'Wadden Sea States'.

The Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment, as amended by Council Directive 97/11/EC of 3 March 1997, "establishes a procedure to enable decision-makers to make appropriate decisions regarding the environmental impact of proposed projects in certain categories. The main objective is to introduce general principles for the assessment of environmental effects with a view to supplementing and co-ordinating development consent procedures governing public and private projects. In keeping with the principle of subsidiarity, each Member State decides on the particular policies and measures, which it needs adequately to implement the Directive. The Directive establishes the EIA procedure as an integral part of the development consent process. The EIA must be conducted on the basis of the (appropriate) information supplied by the developer. This information may be supplemented by the people who may be concerned by the project in question." [Ref 43]

The Directive includes four annexes:

1. Annex I contains a list of types of projects, which must be subjected to an assessment.

2. Annex II contains a list of types of projects, which may be subjected to an assessment, if their potential impact on the environment or other parameters laid down in Annex III requires it. The need for an assessment is determined by the concerned Member State, either on a case-by-case basis, or using established thresholds or criteria. The relevant selection criteria can be found in Annex III.

3. Annex III gives the specific selection criteria (characteristics, location and potential impacts of projects) to be used to decide whether an Annex II project must be subjected to an assessment.

4. Annex IV defines the basic criteria for the content of the EIA report or statement.

The screening process for Annex II projects implies, that before determining the type of approval procedure to be applied to an Annex II project (i.e. with or without EIA), certain parameters laid down in Annex III must be checked on the basis of existing information (maps, plans, etc.). If this check reveals possible incompatibilities with environmental protection goals (such as Natura 2000 areas), or the project is likely to have major effects (such as emissions, or interactions with existing projects), an EIA needs to be carried out.

Another relevant Council Directive is 2001/42/EC of 27 June 2001 – the Strategic Environmental Impact Assessment Directive. While the EIA Directive of 1985 (as amended by Directive 97/11/EC) covers EIA procedure at an individual project level, the Strategic Environmental Impact Assessment Directive states that an environmental assessment must be carried out for overall plans and programmes that are likely to have significant environmental effects.

As Member States do have a certain degree of freedom to implement Directives in their individual national legislation, the current legal framework and responsible authorities in a number of European countries are summarised below.

A good overview of legal aspects, relevant bodies and procedures in diverse European coastal states can be found in Ref 43: *Enabling Offshore Wind Developments; 3E – EWEA; Brussels 2002*.

Many passages used within this section were found in official documents, and taken over as a quote, especially market with quotation marks. The according references as well as presented information on the author and publisher represent the owner of the copyright.

United Kingdom:

Offshore Wind Farms: Guidance Note for Environmental Impact Assessment in Respect of FEPA and CPA Requirements [Ref 45]

Authors: Centre for Environment, Fisheries and Aquaculture Science (CEFAS)
Publisher / Date: Crown / Version 2 - June 2004

Guidance provided by this document refers only to those requirements necessary to enable the assessment of an application under the Food and Environmental Protection Act 1985 (**FEPA**) and Section 34 of the Coast Protection Act 1949 (**CPA**). Both Acts require assessment of a proposed project within the marine environment with regards to its potential for environmental impact.

The purpose of this guidance note is '"to assist the offshore wind farm industry and its consultants. Its primary aim is to provide scientific guidance to those involved with the gathering, interpretation and presentation of data within an EIA as part of the consents application process in England and Wales. The guidance is intended to supplement the Department of Trade and Industry (DTI)'s guidance '*Offshore Wind Farm Consents Process'*. It is not definitive and it is therefore recommended that it be read in conjunction with the legislation and the other sources to which it refers. It replaces the November 2001 document of the same name." [Ref 45] In addition the *Guidelines for the conduct of benthic studies at aggregate dredging sites* should be consulted, which has been done by CEFAS and DTLR in May 2002. The main competent authorities involved in the procedure for offshore wind developments are:

- The Crown Estate (Commissioners)
- Department of Trade and Industry (DTI), which is responsible for consenting environmental controls and licensing of energy facilities;
- The Department for Environment, Food and Rural Affairs (Defra);
- The Department for Transport (DfT);
- The National Assembly for Wales (NAW);
- The Scottish Executive (for Scotland); and
- The Marine Consents and Environment Unit (MCEU), a joint unit for regulating marine consents. It comprises representatives from DfT, the Welsh Assembly Government and Defra (which is responsible for consents in England, but also acts on behalf of the Welsh Assembly in this respect).

"The Crown Estate, as main landowner of the territorial seabed, is the primary authoritative body concerning sea areas, from which permission (via leasing/licensing) must be sought for the use of its sea property. The Crown Estate's Commissioners, under the provisions of the Crown Estate Act 1961, manage the Estate. Some competencies also lie with the relevant planning authority, whose competence to grant a planning permission extends to the mean low water line. […] The Crown Estate grants leases or licences on its estate. The largest leaseholders are local authorities, ports and harbours and conservation bodies such as English Nature, the National Trust and the Royal Society for the Protection of Birds. Some 570 kilometres (21%) of foreshore is leased specifically for conservation purposes and it is intended to extend this in consultation with English Nature. The activities licensed by the Commissioners of the Crown Estate are the extraction of marine sand and gravel, the laying of oil and gas pipelines and electricity and telecommunications cables, and the construction of maritime networks." [Ref 43]

DTI is the "lead government authority in the offshore wind farm consenting procedure by virtue of its Offshore Renewables Consents Unit, which has the co-ordinating role for offshore wind farm applications in the territorial waters around England and Wales. Furthermore, the amalgamation of Defra's Marine Environment Branch and DfT's Ports Division into the MCEU serves a central facility for the receipt of consent applications and for administrative co-ordination for relevant marine works (under the Food Environment and Protection Act, Coast Protection Act, Telecommunications Act, and other legislation). The MCEU performs these functions for Wales as well as England." [Ref 43]

The Crown Estate owns the total area of the territorial waters of the United Kingdom and hence any project developer for an offshore wind farm must follow the Crown Estate's procedure for granting leases. The latter is conditional upon the developer obtaining all the necessary licences or consents from the consenting authorities. The administrative procedure may be broken down as follows:

- The pre-exploitation;
- The exploitation phase; and
- The decommissioning phase

For England and Wales an EIA is likely to be needed for all applications under the Electricity Act as described in the Electricity Works regulations 2000 (SI 2000/1927). In contrast to England and Wales for proposals in territorial waters adjacent to Scotland, an EIA will be required to comply with the Electricity Works Regulations 2000. [Ref 43]

Denmark:

In 1998 the Danish Government instructed the electricity companies to erect five large-scale demonstration projects of a total of 750 MW on the basis of the recommendations in the 1997 *Havvindmølle-handlingsplan for de danske farvande* ("Offshore Wind Turbine Action Plan for Danish Waters"). Denmark has a 2030 target of 4 GW of offshore wind power capacity,[15] with the first milestone of 800 MW to be achieved by 2008.

An environmental programme for the demonstration projects before, during and after their establishment was recommended in *Havvindmøllehandlingsplanen* to ensure that the development of offshore wind farms gave due consideration to nature and environmental interests.

The Danish Energy Authority (DEA) made the implementation of an environmental programme an approval condition for the demonstration offshore wind farms.

The principles put forward were implemented in 2000 through a Government decree – *Bekendtgørelse om vurdering af virkninger på miljøet (VVM) af el-produktionsanlæg på havet* (Government decree 2000:815 of 28 August 2000. Translation: Government order on the Assessment of Environmental Impact from electricity production plants on the Sea) – which sets out the procedures for the EIA and conforms with EU maritime legislation. However, the decision on whether a VVM procedure is required is made by the DEA. [Ref 43]

[15] http://www.offshorewindenergy.org/ca-owee/indexpages/Activities_and_Prospects.php?file=actpros_p4.php at 10/02/2005

Besides the DEA there is a range of other authorities that supervise health, safety and the environment on and around offshore installations. However, the DEA is the most important body in terms of the national EIAs. The Danish State has all competence within the 12 Nautical Mile Zone (NMZ) and in the Danish exclusive economical zone (EEZ). Consents and approvals for offshore wind-power are handled by the DEA and the Ministry for Economic and Business Affairs in co-operation with the following authorities:

- Danish Forest and Nature Agency (Ministry of the Environment);
- Danish Maritime Authority (Ministry for Economic and Business Affairs);
- Ministry of Defence;
- Royal Danish Administration of Navigation and Hydrography (Ministry of Defence);
- Danish Civil Aviation Administration (Ministry of Transport);
- Danish Coastal Administration Agency (Ministry of Transport);
- National Working Environment Authority (Ministry of Employment);
- Counties; and
- Municipalities.

The Netherlands:

The Netherlands has expressed the ambition to install 6 GW of offshore wind power capacity within the North Sea area by 2020. The current status of this ambition is unclear. The permitting procedure always begins with an EIA followed by a permit application. There are four official consultation rounds for the public in the course of this procedure. The Ministry of Transport, Public Works and Water Management issues the permit. As in the UK, many other ministries are also involved, including the Ministries of Economic Affairs, Environment, Agriculture, Nature and Food Quality, as well as the National Coastguard as regards shipping safety. The “M.E.R.-richtlijn” (environmental effect report) is the directive, which concern the delivery of the EIA. The official name is “Richtlijn 85/337/EEG van de Raad van 27 juni 1985 betreffende de milieueffectbeoordeling van bepaalde openbare en particuliere projecten”. To build, operate or decommission offshore wind turbines a “Wbr-licence” (Wet Beheer Rijkswaterstaatwerken)) is necessary.

It is still not certain whether the strategic MER (SMER) will apply in future for offshore wind turbines. Some parties have been arguing in favour of the SMER, as this requires monitoring of any significant and cumulative effects (e.g. cumulative effects of several proposed offshore wind farms, or of offshore wind farms and other marine activities)[16].

The typical administrative procedure for an offshore wind development may generally be broken down into the following stages:

- The pre-exploitation;
- The exploitation phase; and
- The decommissioning phase

[16] http://www.noordzee.nl/ruimtelijkeordening/windmolensMER.html at 10/02/2005

However, the Netherlands makes an additional distinction between ‘near-shore’ wind farms (i.e. those located within the 12-mile zone) and ‘offshore’ wind farms (i.e. those located beyond the 12-mile zone). The border between these two types roughly coincides with the 20m depth line. At present the Dutch regulations prohibit the development of any further wind farms within the 12nm zone.

This may have different implications for the procedural phases to be followed, in particular in the pre-exploitation phase. The pre-exploitation phase is therefore described separately for the two types of wind farms. [Ref 43]

Ireland:

The relevant EU Directives (85/337/EEC and 97/11/EC) have been incorporated into Irish law. According to these directives, the preparation of an Environmental Impact Statement (EIS) is obligatory for wind energy installations of more than five turbines or having output greater than 5 MW. An EIS is required for all offshore wind farms, and as wind farms multiply will be required to address cumulative impacts, both visual and environmental. Consultation with interested parties (other users of the waters concerned, environmental groups, local authorities, coastguard, aviation authority, etc) is actively encouraged prior to preparation and publication of an EIS.

The relevant EU Directives (85/337/EEC and 97/11/EC) have been incorporated into Irish law. According to these directives, the preparation of an Environmental Impact Statement (EIS) is obligatory for wind energy installations of more than five turbines or having output greater than 5 MW. An EIS is required for all offshore wind farms. For several wind farms it will be required to address cumulative impacts, both visual and environmental. Consultation with interested parties (other users of the waters concerned, environmental groups, local authorities, coastguard, aviation authority, etc) is actively encouraged prior to preparation and publication of an EIS.

Details on the information to be included in the EIS are given within the policy document *‘Offshore electricity generating stations – Note for intending developers’* provides for a two-phase approach. The purpose of the EIS is to provide the competent authority – the Minister for Communications Marine and Natural Resources – with information to enable a decision on a particular project, in full knowledge of its likely environmental impact.

“The pre-exploitation phase therefore relates primarily to the acquisition of licences etc. for the use of the Irish Foreshore for the purpose of investigating the suitability of sites for the construction of an offshore wind farm. This is a two-stage process, involving applications for: Foreshore Licence and the Foreshore Lease.

Foreshore Legislation and the Foreshore Leases and Licences, which are required for “offshore electricity generating stations, fall under the competence of the Foreshore Section of the Department of Communications, Marine and Natural Resources.” Ref 43

The Foreshore Licence recognises the suitability of the site for the intended wind farm project. Licenses are granted for works (like laying of submarine pipelines and cables) and purposes (e.g. aquaculture). When a licence-holder is satisfied that the site is appropriate, then application may be made for a Foreshore Lease for the development. Application for a Foreshore Lease is contingent on the applicant having held a Foreshore Licence for investigation in good order, and on his making a valid Foreshore Lease application within 12 months of the Licence's expiry. A valid application must be accompanied (among other documents) by an EIS. The granting of the Lease allows construction and operation of the wind farm. [Ref 43]

The key underlying legal instruments thereby are as follows:

- Electricity Regulation Act 1999;
- Foreshore Act 1933;
- Foreshore (Amendment) Act 1992 (No. 17);
- Fisheries and Foreshore (Amendment) Act 1998 (No. 54);
- European Communities (EIA) Regulations 1989;
- Foreshore (EIA) Regulations 1990;
- European Communities (EIA)(Amendment) Regulations 1998; and
- European Communities (EIA) Regulations 1999.

Belgium:

The "Wet van 20 januari 1999 ter bescherming van het mariene milieu" (Law of 20 January 1999 on the Protection of the Marine Environment) is the relevant Belgian law and is based on the international framework mentioned at the beginning of this section. The law still has to be implemented and foresees the creation of five types of marine protected areas (state May 2004). The law will not allow areas to be excluded from wind farm development. [Ref 39]

Planning an offshore wind farm in Belgium requires the submission of a request to the Ministry of Social Affairs, Public Health and the Environment for exploration permission and subsequently for an authorisation to build the offshore wind farm. However, cable laying additionally requires permission for exploitation, an environmental evaluation and an authorisation to dredge or trench.

According to Article 25 of the law on the Protection of the Marine Environment, certain activities associated with offshore wind energy exploitation require environmental permits – that is licence or authorisation. This further entails a requirement for an Environmental Impact Statement (EIS) (milieu effectenrapport (MER)) to be provided by the developer. The two procedures are the 'domain concession' and 'licence and authorisation of environmental permits'. Conditions and procedure for the granting of domain concessions for the construction and exploitation of installations for the production of electricity from water, streams and winds in the areas at sea under Belgian jurisdiction, are laid down in the Royal Decree of December the 20th in 2000. The implementing legislation concerning the licensing/authorisation and EIA/EIS aspects of Law on the Protection of the Marine Environment with regard to offshore wind farm developments are the Royal Decree of 20th of December 2000 with regard to the rules applicable to the Environmental Impact Assessment (EIA Decree) and the Royal Decree of the 20th of December 2000 comprising the procedures for permission and authorisation of certain activities in Belgian territorial waters. According to the Decree an applicant for an offshore wind park will need two permits relating to environmental protection: a licence for the exploitation of the wind park, and an authorisation for the building of the wind park, both to be procured in the pre-exploitation phase. The application for licence/authorisation must be accompanied by an Environmental

Impact Statement (EIS), which, amongst other things, will form the basis of an Environmental Impact Assessment (EIA). "The EIA Decree describes the procedure for conducting the Environmental Impact Statement (EIS), which must be submitted by the developer with his application for licence/authorisation. The Decree refers to the Environmental Impact Assessment Directive (1985) of the European Council and to the Convention on EIA in a Transboundary Context (Espoo Convention). It makes a distinction between the EIA preliminary to the granting of a licence or authorisation (chapter II) and the EIA of the licensed or authorised activity (chapter III). The EIA must be therefore conducted before the granting of the licence or authorisation, and also after the acquisition of the licence or authorisation. Thus, after the granting of a licence or authorisation, the activities at sea will be submitted to a permanent evaluation by monitoring programs and permanent examinations." [Ref 43]

"The EIS of the developer outlines the potential environmental impact of the project and provides a basis, amongst other things, for the formulation of an Environmental Impact Assessment (EIA) or Environmental Impact Evaluation (Milieu-effectenbeoordeling). The competent administrative body for the formulation of the EIA is the Management Unit of the North Sea Mathematical Models (MUMM)". [Ref 43]

Germany:

In Germany the Federal Government has created a strategy for offshore wind power development. The strategy foresees the installation of 500 MW of offshore capacity by 2007 and 2 – 3 GW by 2010. In the long term 20 – 25 GW of installed offshore capacity may be achieved by 2030 [Ref 41].

The major part of the offshore wind farms are planned to be installed in the Exclusive Economic Zone (EEZ). The appropriate approving authority, the Bundesamt für Seeschifffahrt und Hydrographie (Federal Office for Maritime Traffic and Hydrography), set up a concept for EIA: "*For installations in the 12 nm zone an application for permission must be submitted to the responsible body of the respective federal state. This permission covers wind turbines, as well as cables needed to conduct electricity from the wind park to onshore connection points. The competent authorities for permits in the 12 nm zone are those responsible for the "Imissionsschutzrechtliche Genehmigungen" (Imission Control Regulation permit), in accordance with the Bundesimmissionsschutzgesetz (Federal Imission Control Act). Permission for the installation of rigid and floating structures in the exclusive economic zone has to be obtained from the Federal Maritime and Hydrographic Authority (BSH). For planned wind parks in the EEZ, two permit applications must be submitted to the Federal Maritime and Hydrographic Authority – one for the wind park, and a separate one for submarine cables. Completed applications are treated on a first-come-first-serve basis – that is, the application, which is the first to obtain all the necessary permissions (genehmigungsfähig) is the one, which gains priority over the site in question. At the same time, the application is weighted for its quality and focus towards the objective, so as to avoid situations in which applicants 'block' locations without serious interest in developing the wind park in the near future. Wind parks in the EEZ must also receive permission for the installation of submarine cables in the 12 nm zone. This permission must also be obtained from the respective federal state. The EU Directive on Environmental Impact Assessment 97/11/EG, 85/337/EWG has been implemented into German national law as of 3 August 2001. The Offshore Installations Ordinance states that the Federal Act on Environmental Impact Assessment will apply for offshore wind parks in the EEZ. The EIA must cover direct* *and indirect impacts on humans, flora and fauna, ground water, climate, landscape, cultural, and other assets. The law also requires a public participation.*" [Ref 43]

The relevant standard concerning EIA requirements[17] is worth to being considered in somewhat more detail, as it forms a very good and comprehensive example of a national set of EIA requirements, which must be fulfilled in order to gain a license for an offshore wind power development. Therefore a more complete extract of this standard may be found in Appendix E.

Standards for Environmental Impact Assessments Impacts of offshore wind turbines on the marine environment [Ref 44]

Authors: Issued by Bundesamt für Seeschifffahrt und Hydrographie (BSH) and others
Publisher / Date: Federal Maritime and Hydrographic Agency (BSH) / 2003-2-25

Any potential adverse impacts of the projected facilities on the marine environment have to be assessed within the framework of the approval procedure for offshore wind farms in the Exclusive Economic Zone (EEZ). In addition to following the amendment to the Seeanlagenverordnung (effective 5 April 2002), an EIA is now mandatory for most projects, according to Article 2a of the Seeanlagenverordnung. "*In the Standards for Environmental Impact Assessments, information is provided to applicants on the scope of investigations required by the approval authority, with all relevant details and explanations. The Standards for Environmental Impact Assessments constitute a framework of the thematic and technical minimum requirements for marine environmental surveys and monitoring in order to assess compliance with Article 3, Seeanlagenverordnung*."

The German EIA standard is divided into two parts: a set of general conditions (Part A), and a technical code of practice (Part B). The main features of this standard are represented below.

Part A contains the general conditions and therefore deals for example with possible adverse impacts of offshore wind farms on the marine environment. Various risks have been identified for the construction, operation and decommissioning phases. They can be summarised as risks concerning the construction phase, the operation phase and the removal phase. The objectives of investigating impacts on environmental features that should be protected (i.e. fish, benthos, birds, and mammals) can be summarised as follows: determination of spatial distribution and temporal variability in the baseline survey; monitoring the effects of construction, operation and removal; evaluating the monitoring results, with the baseline data serving as a basis for comparison; and conducting within the preliminary fish studies a quantitative determination of the near-bottom stationary fish species.

A distinction is made in terms of the degree of progress of a particular project. Thereby division is made into Pilot phase, Expansion phase and Removal phase.

"***Pilot phase:*** *Large-scale wind farm projects presently have to be preceded by a pilot phase to establish whether the authorisation requirements are met. Prior to and after the pilot phase, baseline surveys and monitoring have to be carried out following notification of the probable scope of the investigations based on the Standards for Environmental Impact Assessments. The scope of the monitoring will depend on the results of the baseline surveys, taking into account experience gained in the process.*

[17] http://www.bsh.de/en/Marine%20uses/Industry/Wind%20farms/standard_environmental.pdf at 24/03/2005

Expansion phase: *For every expansion step following the pilot phase, baseline surveys and monitoring in accordance with the Standards for Environmental Impact Assessments will be mandatory. Modifications required at individual sites will be laid down in the notification of the scope of monitoring.*

Removal phase: *The wind turbines including their foundations have to be removed completely, with subsequent onshore disposal. In principle, the monitoring requirements during this phase correspond to those in the construction phase, as specified in the Standards for Environmental Impact Assessments. Possible environmental impacts depend mainly on the dismantling techniques used. Dismantling techniques are expected to undergo major developments over the coming decades, as numerous oil and gas platforms are due for removal. Therefore, the scope of monitoring will be determined at a later date*."

Periods of assessment apply to all project phases (pilot phase, expansion phases) and are described as follows:

"*Baseline survey:* *Prior to the start of construction, in accordance with the Standards for Environmental Impact Assessments, a baseline survey has to be performed which covers the investigations made during two successive, uninterrupted complete seasonal cycles. One seasonal cycle comprises 12 calendar months including the month in which the survey begins. The baseline survey remains valid for two complete years. If construction work is not begun in the third year after completion of the baseline survey, the baseline survey should be updated with an additional seasonal cycle. Other details regarding the follow-up period will be dealt with on an individual case basis.*

Construction phase: *The construction phase covers the period from the start of construction work until completion of the construction project. Construction-phase monitoring has to be performed throughout this period. If essential components are put into operation prior to completion of the construction project, operation monitoring in the project section concerned may be started in co-ordination with the approval authority. However, it must be ensured that such continued construction activities do not have a significant impact on the results of operation monitoring. The precise time for stopping the construction monitoring will be determined by the approval authority in each individual case.*

Operation phase: *The Standards for Environmental Impact Assessments define the operation phase as the phase following the completion of construction work, when the wind turbines are put into operation. After the wind farm has become operational, operation monitoring has to be performed for a period of at least three years or, if required, up to five years in the entire project area. The end of operation monitoring will be determined by the approval authority in each individual case.*

Part B *outlines technical instructions concerning the environmental features to be protected. Technical details of the investigation and monitoring to be carried out in order to protect benthos, fish, birds, and mammals will be provided in the following. The scope and targets of the investigations, methods to be used, and the evaluation basis are described for each of the environmental features to be protected*."

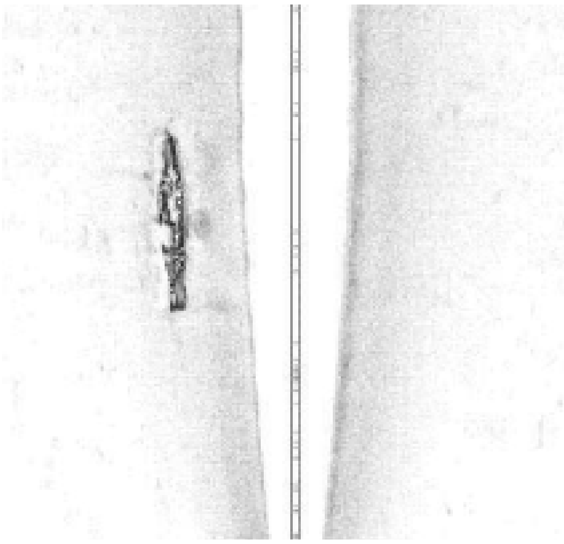


Fig. 8: Investigation of sediment through side scan sonar. The wreck of a ship is visible at the left-hand side.

3.3 Finance-related obstacles

The impediments related to financing issues can be resolved by the building in of more security within the planning processes. This can be achieved by several means. For instance, questions concerning cable routes, grid connection and grid integration need to be clarified so as to limit the number of offshore cables leading to land and to enhance planning security among project developers. Thereby a governmental surety would be a good means of overcoming a number of difficulties, especially within the initial phase of offshore wind power exploitation, but also for the longer term.

In some European countries, legal assignment of areas for offshore wind power utilisation is still necessary to increase planning security and hence reduce financial obstacles. Moreover, insurers must show a willingness to offer fair and realistic terms of coverage. Another important measure to increase the security during the planning processes is the certainty about power production certificates, which enable the operator of an offshore wind farm to sell the generated electricity to the mains during the project lifetime. There is a need for national Electricity Acts, containing stipulations to ensure that electricity supply companies or grid operators are obliged to purchase any electricity generated by offshore wind farms (as well as other renewable energy sources). A tariff-based system is best suited to promotion of this new market, as shown by onshore experiences in Denmark, Germany and Spain.

However, the crucial problem is the impact of the uncertainties mentioned above on the risk assessment of a project. For small and medium-sized companies (such as are often involved in offshore wind power development), these risks can make it difficult to attract outside finance, so that project financing becomes a major obstacle. Banks are still relatively inexperienced in dealing with the risks attached to the new technology and its offshore application, and so demand increased security before financing projects, rather than simply taking the project itself as collateral security. In order to decrease this financial uncertainty surrounding wind power projects and thus overcome the caution of institutional lenders, there is a need for projects to be guaranteed either by larger companies or by national governments. The reduction of risk by such means is especially important in the case of pioneering wind power projects, and will continue to be so while banks lack experience of project finance in the field.

3.4 Chapter Summary

Technical problems concerning the power transmission, grid connection and grid integration of offshore wind power cover several areas. Electrical transmission systems with the largest possible capacity must be installed, so as to limit the number of submarine cables. Classic HVDC systems based on thyristor technology are currently the only method for transmitting high capacities over large distances between wind farms and land; however, they have the disadvantage of requiring a large amount of reactive power at the wind farm. In contrast, HVDC-IGBT systems can provide capacitive as well as inductive reactive power, but currently have a limited transmission capacity of 250–300MW due to the lower voltage of about 145kV. Industrial developments in semiconductor technologies may help to overcome this limitation.

Competing uses such as marine protected areas and shipping lanes oblige project developers to reduce the overall number of cable routes. To facilitate this, it is recommended that the grid connections of a number of smaller projects with limited output be combined. This may also be a useful approach for pilot projects. Integrated planning of cable routes is therefore required to reduce the number of cables and to allow controlled development. However, project developers fear that their own planning may be impeded by the need to reach agreements and gain approvals for combined cable routes.

Furthermore, network operators lack sufficient assurances as to the economic viability of single offshore grid connections, since at present it is unclear which wind farm projects will actually be built. As long as no planning assurances are given for combined offshore networks to which several projects could connect, administrative and financial obstacles and delays will persist. To overcome this situation political measures must be taken in order to resolve the issue of large-scale grid connection.

Further restrictions are caused by onshore grid connection on land, as the connection points lie in coastal areas, often at a considerable distance from the main consumption areas. Moreover, according to the rules of the UCTE, the power generation connected to each onshore node should not exceed 3GW.

As wind energy is a fluctuating power source compared to the constant power generation of conventional base-load power stations, the question must be asked of how this fluctuating production matches fluctuations in consumption. This issue has not been methodically analysed. It might well prove to be the case that fluctuations in renewable energy production correlate to some degree with those in consumption. Refinement of databases and statistical procedures, as well as meso-scale wind prediction tools, could help to match these fluctuations and thereby decrease the amount of balancing energy needed. Further development and refinement of wind turbine technology towards turbines with grid supporting features will allow larger grid connection capacities, while increasing system stability by using wind power to supporting the grid in case of dropouts.

There are EU-wide and national rules concerning EIA requirements. Moreover, special attention must be paid to various international and EU treaties and conventions in the implementation of offshore wind farm projects.

The German EIA standards represent one of the most demanding approaches to meeting environmental requirements. As Germany plans to install 25GW of offshore wind power capacity by 2030, these standards are extremely relevant to the environmental impact of wind power development in Europe as a whole.

Within the EU, there are ambitious plans to install up to 10GW of offshore wind power capacity by 2010 and as much as 70GW by 2020. In order for this planned expansion to be achieved, there is a need to reduce uncertainties within the development planning processes, particularly in the early stages of offshore wind development. Insurers must show a willingness to offer fair and realistic conditions of coverage. Certainty also is required about guaranteed feed-in tariffs or power purchase agreements for long-term periods. Such measures will help to reduce the risks attached to offshore projects, which make it difficult for small and medium-sized companies to attract outside finance. However, the best means to reduce the risks to lenders would be for large companies or national governments to guarantee schemes.

4 Technological possibilities of power transmission and grid integration

4.1 Transmitting electricity over long distances

Compared to onshore, offshore wind farms will have large power installations in the size of conventional power plants. Modern transmission technologies operating at high and extra high voltage levels will be required in order to transmit high levels of power over long distances. Two main types of transmission system exist, based on either alternating or direct current (AC or DC):

- High voltage three-phase alternating current transmission (HVAC); and
- High voltage direct current transmission (HVDC).

Offshore wind farms will operate at medium tension levels, i.e. between 30 kV and 60 kV. The long distance interconnected network in Europe operates at extra high voltage levels of up to 380kV. The transmission system for an offshore wind farm has to connect these two voltage systems by means of a sea cable and a suitable conversion system.

The basic set-up of the transmission system is shown in Fig. 9: this is the same for both HVAC and HVDC systems. Power is collected from individual wind turbines by a medium voltage system and transmitted to a substation at sea. This substation has to convert the medium voltage into high or extra high voltage for onward transmission. In the case of AC systems the substation consists of a transformer, which transforms the medium AC voltage into high-tension AC. The transmission of the electricity to land then occurs via a three-phase high-tension cable. On land the power has to be transformed again from the AC voltage of the cable into the AC voltage of the onshore transmission network.

In case of DC systems the substation consists of a converter, which converts the power from the wind farm from medium AC voltage into high-tension DC. The power is transmitted to land by a two-pole high-tension DC cable. On land the power has to be converted from the DC voltage of the cable into the three-phase AC voltage of the onshore transport network.

The transmission capacity is defined by the capacity of the converter or transformer stations as well as by that of the sea cable. Both systems, HVAC and HVDC, may be based on high or extra high voltage for power transmission. A high transmission voltage reduces transmission losses in the cables.

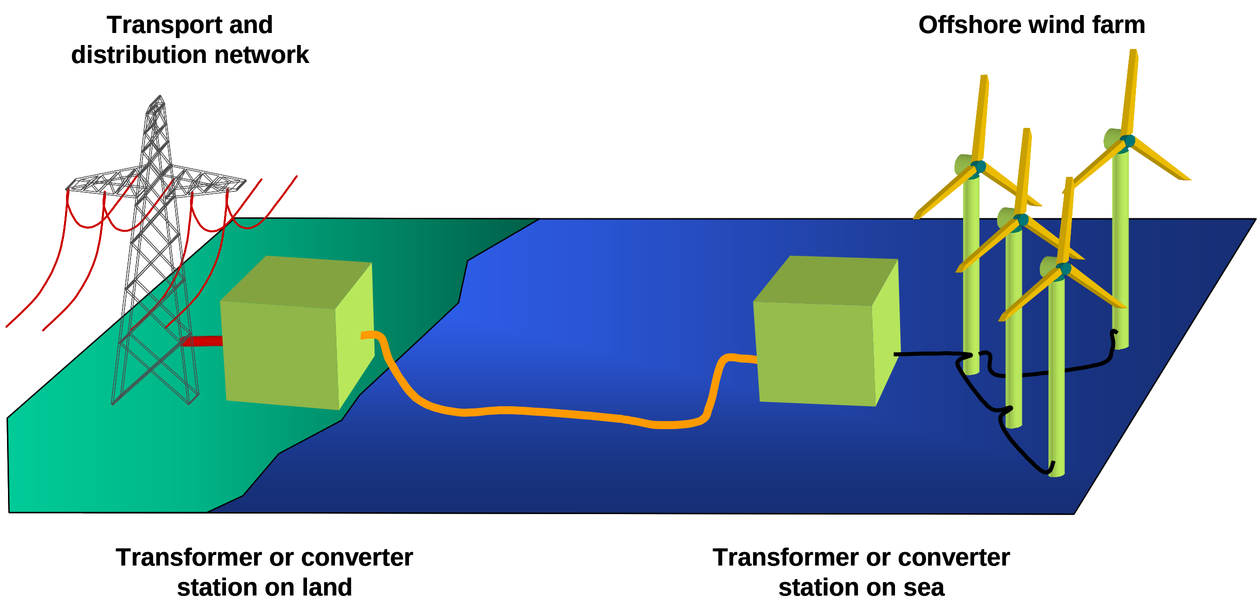


Fig. 9: Transmission scheme for offshore wind power.

	High Voltage Alternating Current	High Voltage Direct Current
Abbreviation	**HVAC**	**HVDC**
Voltage form of transport system	Three-phase alternating voltage	Direct voltage, two pole
Voltage range	Up to extra high voltage (< 420kV)	Up to extra high voltage (< 800kV)
Required cable	Either three single cables or one three-conductor cable	Two single cables or one two-conductor cable
Required station at sea	Transformer from medium to extra high voltage (e.g. 30kV to 400kV)	Converter from medium AC voltage to extra high DC voltage (e.g. 30kV AC to 400kV DC)
Required station on land	Transformer from extra high voltage to main land grid voltage (e.g. 400kV to 380kV)	Converter from extra high DC voltage to main land AC grid voltage (e.g. 400kV DC to 380kV AC)

Table 6: Overview on the basic differences between HVAC and HVDC systems.

4.1.1 HVAC

Three-phase AC transmission is the typical system for energy distribution and transmission on land. This system can also be used to connect offshore wind farms to the main onshore grid. The set-up of an HVAC system is shown in Fig. 10.

The power of the individual wind turbines is collected by a cabling system at a medium voltage level. The switchgear and bus bar are located on a central offshore platform within the wind farm, where the transformer station is also located. The transformer increases the three-phase medium voltage to high tension and then the power is transmitted by a sea cable to land. The transfer voltage very much depends on the characteristics of the sea cable. Theoretically the voltage of HVAC systems can reach up to 800kV, which is the highest voltage level of conventional network technology for switchgears and overhead transmission lines. For offshore installations this extra high voltage level is not realistic, since the enormous insulation required for the sea cables would be mechanically unfeasible. Available sea cable technology is therefore a limiting parameter for the voltage of the offshore transmission system.

On land a further transformer station is required to adapt the voltage level to that of the onshore interconnected network grid.

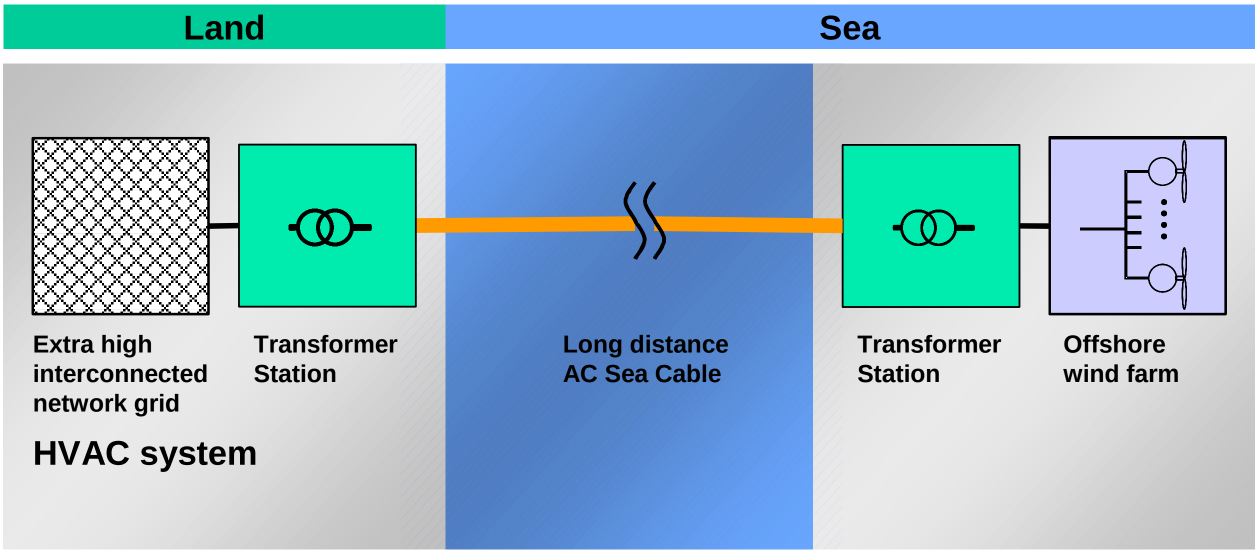


Fig. 10: Schematic diagram of the HVAC grid connection.

4.1.1.1 AC sea cable

A sea cable is very different from the typical cables used for low voltage distribution in households or industry. Sea cables are designed especially for the specific purposes of a project. The electrical characteristics of cables for AC and DC are fundamentally different – cables are designed for either one or the other voltage type. Common to all cable types however is the basic structure of insulation and metal and plastic sheaths. The metal sheaths serve two purposes, as a cover against corrosion and as armour to bear the mechanical forces. The need for corrosion protection is often met by a lead jacket, which prevents seawater from diffusing through the insulation. The need for armour is met by a wire mesh, it absorbs the forces acting on the cable during installation, as generally the cable is lowered from a ship to the sea floor and therefore hanging down through the entire water depth. The outer jacket of the cable is usually plastic.

For three-phase AC two main types of cables exist, the three-conductor cable and the single-conductor cable. In a three-conductor cable all three conductors of the three-phase system are kept within one cable. Each conductor is insulated separately, with the metal shield and outer insulation covering all three conductors in one. The great advantage of this type of cable is that the electromagnetic field of the three conductors is almost neutralised at the surface of the cable, since the sum of the voltages and currents of the three phases is zero at any one time. To ensure mechanical stabilisation, three-conductor cables require a substance to fill the hollow space between the conductors. In the past oil was used for this purpose, however modern cables use plastic.

The single-conductor cable is a cable with a single conductor for a single phase. Hence for a three-phase system three single-conductor cables are required. The main advantage of this type of cable is its high transmission capacity.

The limiting parameters for sea cables are weight and flexibility. During installation a cable is lowered from the cable-laying ship to the seabed: the stress on the cable is determined by the dead weight of the hanging cable, which in turn depends on the water depth; the deeper the water, the heavier the hanging cable. Consequently, very heavy cables cannot be laid in deep waters. In addition, large forces may act on the cable when the seabed underneath the cable is washed away, leaving it free-hanging for perhaps several tens of meters. These forces have to be absorbed by the cable and in particular by the metal armour, the heavier the cable, the more likely it is to be damaged in such circumstances.

The flexibility of the sea cable is also an important factor in the installation process. A stiff cable means high bending radii, requiring a large cargo area on board the cable-laying ships. Moreover, low flexibility results in a greater length of free-hanging cable during the laying procedure, and thus increases the stresses on the cable.

The power transmission capacity of a cable is determined by the current and voltage it is designed for. The current capacity depends on the diameter of the metal conductor, and the maximum voltage depends on the thickness of the insulation, both of which influence the weight and stiffness of the cable. Thus mechanical parameters determine the limits for the transmission capacity of sea cables.

The three-conductor cable is the optimum design for a three-phase system, except that the mechanical parameters mentioned above limit its transmission capacity to comparatively low values. The advantages of an almost completely neutralised electromagnetic field and of the need to lay only one cable route must be considered against the maximum transmission capacity of 200 MVA – see Table 7.

Cable type	Maximum tension	Maximum transferable power
Three-conductor cable	170 kV in future 245 kV	200 MVA in future 250 MVA
One-conductor cable	420 kV	1’200 MVA

Table 7: Maximum voltage and transfer capacities of actual AC sea cables.

For the same reasons the transmission capacity of the single-conductor cable is much higher. The single cables can bear higher currents and at the same time far higher tensions. As shown in Table 7, the voltage of 420kV allows a power transmission of 1200 MVA. A disadvantage of this cable type, however, is its higher power losses. The current in the conductor induces a voltage in the metal wire mesh of the cable. As this metal armour is grounded to earth at the connection point, a comparatively high current is flowing to earth, resulting in both power losses and a thermal load on the cable.

If the three-phase AC system is used for long-distance transmission, another disadvantage becomes apparent. The three parallel cables or conductors act as a capacitor to the AC voltage, and generate reactive power as a result. With increasing length of the cable, higher losses are generated due to the growing reactive power. To reduce these losses, reactive power compensation units are necessary along the cables. As this is not a feasible option at sea, the compensation can only take place at either end of the cables. Hence reactive power generation drastically reduces the ability to transmit power through a very long AC cable run. As a result of these losses, the maximum length of a three-phase AC sea cable run is limited to approximately 120 km.

The sea cable is the most restrictive factor on power transmission capacity. The power of converter or transformer stations, on land or offshore, may be increased by adding parallel units. This is also possible for cables, but additional cables mean additional cable routes.

4.1.2 HVDC

For long distance electricity transmission HVDC is the preferable technology. However, around the world only a limited number of large HVAC systems exist, mainly for marine power transmission. These systems are of the classical type with thyristor technology. But in principle two different systems are available:

- Thyristor HVDC transmission and
- Insulated-gate bipolar transistor HVDC transmission (HVDC-IGBT, also known as VSC-HVDC (VSC = Voltage Source Converter) or product names like HVDC Light (ABB) and HVDCplus (Siemens))

Both systems have the same fundamental set-up, as depicted in Fig. 11. At sea the medium voltage of the wind farm busbar is transformed into high AC voltage and then rectified into high DC voltage. The power is then transmitted to land at this high voltage level by a DC sea cable. On land an inverter system converts the DC voltage back into a 50Hz AC high voltage and it is then adapted by a transformer to the level of the extra high voltage of the onshore interconnected network. The thyristor transmission system is the classic HVDC technology, up to now no IGBT system with large transmission capacities exist.

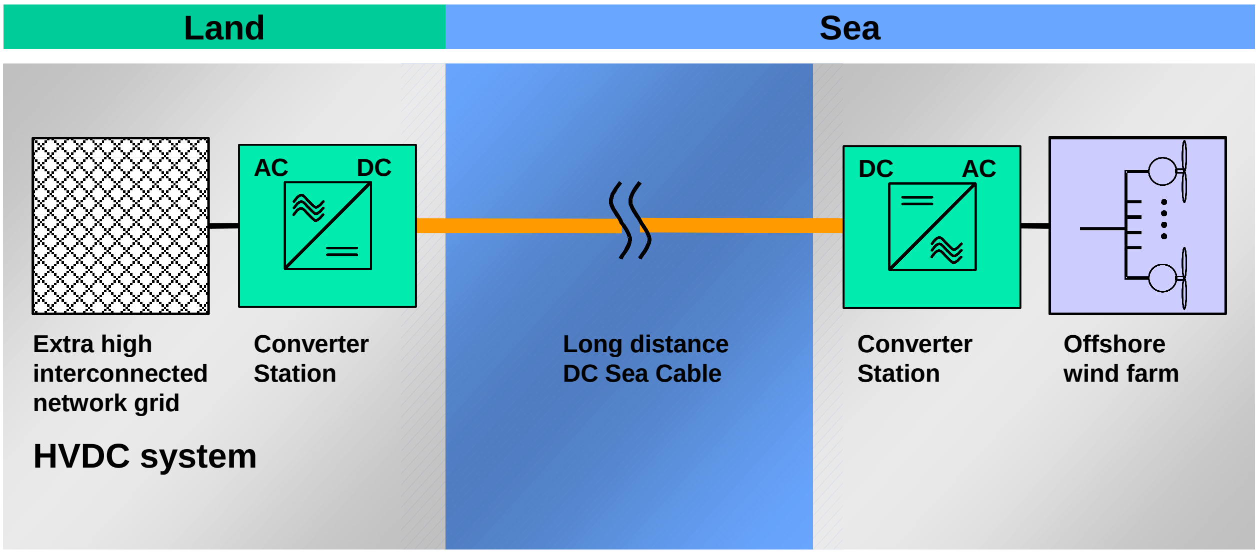


Fig. 11: Schematic diagram of the HVDC grid connection.

4.1.2.1 Classic thyristor-based HVDC

In the classic thyristor-based HVDC system, the AC voltage to be transmitted is converted into DC by a rectifier. At the other end of the system, the DC current is converted back into AC by a thyristor bridge that switches the DC poles alternatively to the three phases of the

AC system. This classic HVDC converter requires an existing AC grid for operation and it draws reactive power from it. The resulting AC current has staircase form and requires extensive filter units. Because of the additional need for rectifiers and inverters, HVDC systems are far more expensive than HVAC.

A schematic representation of the thyristor-based HVDC set-up is shown Fig. 12. HVDC systems are usually designed to be bipolar, which means that two converters are working symmetrically to ground level, with matching positive and negative output levels. This allows a higher transmission voltage at a lower insulation level. The voltage level across each of the two conductors is exactly half the total operating voltage. As both converters are working fully symmetrically, no current is flowing to ground level.

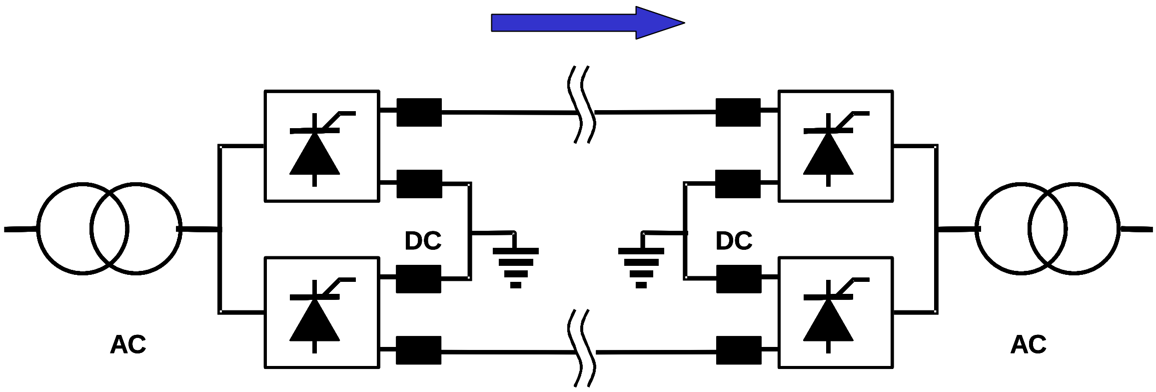


Fig. 12: HVDC-thyristor technology for energy transport by rectifier and inverter in one direction.

A major advantage of classic thyristor-based HVDC is the high transmission tension. Thyristors have a very high electrical strength, allowing operations up to 800kV. Modern thyristor-based HVDC technology is thus able to transmit 800 to 1000MW with a bipolar, two-conductor cable. One disadvantage of classic HVDC, however, is that it cannot generate its own grid voltage and frequency at the offshore wind farm. To provide AC voltage offshore – which is necessary to start up the wind turbines – a separate diesel generator has to be installed, which provides voltage and frequency as well as reactive power for wind turbines with induction generators. Another option is the installation of an AC cable, in parallel with the DC sea cable, to provide voltage to the turbines. The disadvantage of this solution is that it increases the number of cables to land, though it could be a viable option for offshore projects, which involve a pilot phase. Pilot projects usually have a low power rating between a few ten and a hundred megawatts, for which a DC transmission system would be unnecessarily expensive. The AC cable, which would therefore be used for transmission during the pilot phase, could subsequently be used as the auxiliary cable for the extended wind farm with HVDC transmission.

4.1.2.2 Transistor-based HVDC

Modern insulated-gate bipolar transistors (IGBTs) are the basis for HVDC-IGBT systems. Compared to normal transistors, IGBTs have a relatively high voltage and current strength, making them suited to use in high-voltage and high-current applications, though they do not match the electric strength values of thyristors. In contrast to thyristors, IGBTs can be switched within half an AC sine-wave. Inverters based on IGBTs with pulse-width modulation (PWM) technology can thus generate sinusoidal AC voltages in four-quadrant operation (see Fig. 13), which means that energy transfer is possible in both directions as well as in inductive and capacitive region. In offshore wind farms this feature makes it possible to provide voltage and frequency to the turbines without an additional AC connection or diesel generator and to deliver reactive power if desired.

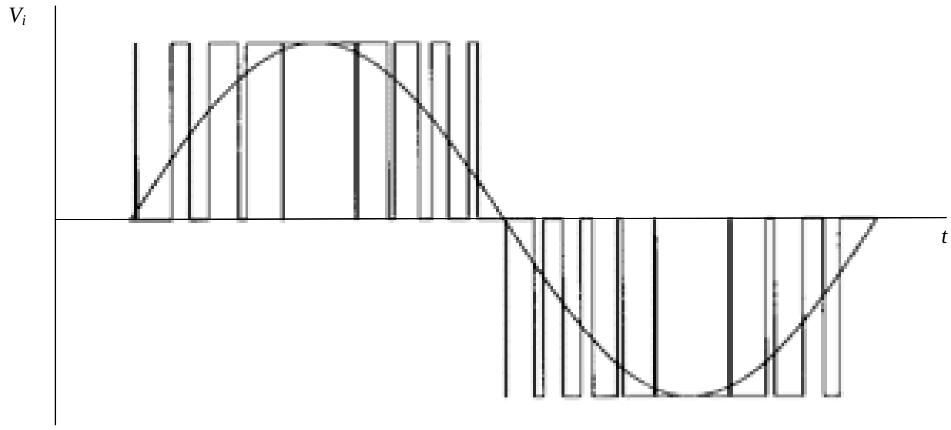


Fig. 13: Pulse width modulation inverter output voltage

4.1.2.3 DC sea cable

Although the electrical characteristics are different, the physical configuration of DC sea cables is similar to the AC design. The conductor is encased by an high-voltage insulation, an armour jacket, an anticorrosion layer and a watertight bitumen or plastic sheath, as shown in Fig. 14. In an AC cable the current, alternating at 50Hz, induces a voltage in the metal jackets of the cable. A DC cable has no induced voltages and currents and thus no power losses through the metal jackets. As long as the current remains constant, a single-conductor DC cable causes a static electromagnetic field, the strength of which depends on the current intensity. This electromagnetic field could potentially have a harmful impact on marine animals (for example on cetacean navigation) as well as on maritime navigation. To overcome this problem, the two poles of a DC system, the forward and the return conductor, have to be installed parallel and close to each other, so that the electromagnetic fields will neutralise each other. This is known as the bipolar system of power transmission, in contrast to the monopolar system, in which only one conductor connects the two converter stations while the sea and the seabed act as the return conductor. The undersea electrodes used in the monopolar system for the return current produce electrolysis. These impacts mean that the monopolar systems are not planned for offshore wind farm use.

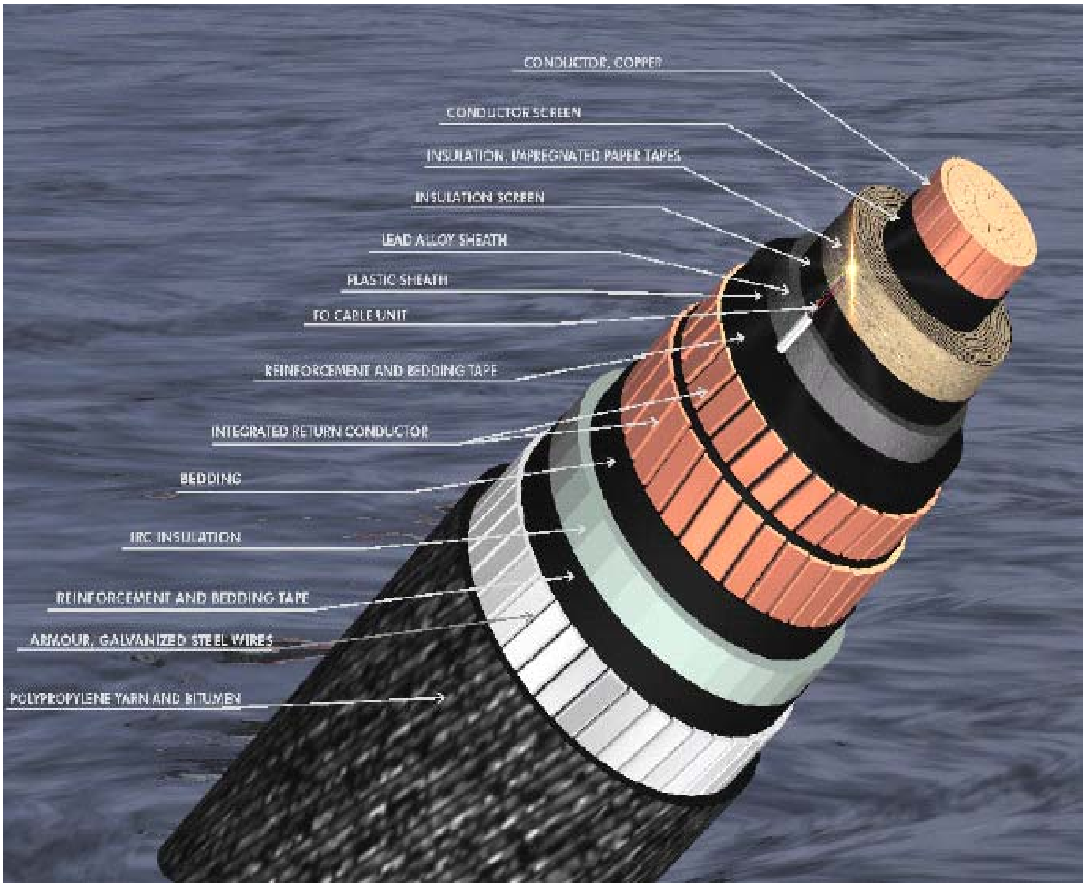


Fig. 14: Example of a HVDC cable (source: Nexans).

For bipolar transmission three options are available: two separate cables, a bipolar two-conductor cable or a concentric cable. When using two separate cables, they must be buried in the seabed parallel to and at a short distance from each other. The distance between the cables is determined by the capacity of the cable-laying ship to position the cables accurately, which depends mainly on the velocity of the ship, sea conditions, water depth and the mechanical characteristics of the cable. Distances achieved vary from 1m to over 10m.

A bipolar cable is a single cable including both conductors for forward and return current. One type is the flat cable, where the two conductors lie side by side within a common shield. Formerly the hollow spaces of this type of cable were filled with oil, but this has been replaced by a plastic filling, to prevent environmental pollution in case of accidents. The distance between the two conductors is negligible, only determined by the thickness of the insulation material between them. Maximum neutralisation of the electromagnetic field is achieved by a concentric cable, in which an outer hollow conductor encases an inner conductor, separated from it by high-voltage insulation. The outer conductor is also encased in both insulation and metal shields. The coincidence of the radial magnetic lines of force results in the absolute neutralisation of the forward and return fields.

As previously explained, HVDC converters are bipolar, so that forward and return conductors operate at only half of the transmission voltage level. Thus for a system of 800kV operating voltage a two-cable transmission would mean a voltage of just 400kV over each cable, thus reducing the thickness of the insulation required by half compared to a concentric cable, in which the insulation between inner and outer conductor has to cover the full voltage of 800kV, in addition to outer insulation sufficient for 400kV. Therefore, as the diameter of sea cables is limited by weight, the power transmission capacity of a bipolar two-cable system is far higher than for a bipolar concentric cable, as shown in Table 8.

Cable type	Maximum tension	Maximum transmission capacity
Bipolar or concentric	±400 kV	800 MW
Two separate cables	±600 kV	800 MW to 1 GW, future development 2.5 GW

Table 8: Transmission capacity of an HVDC system with a bipolar concentric cable and with two separate cables.

4.1.3 Comparison of transport technologies

The different transmission systems described in the previous sections present no clear favourite system. Systems should be selected for particular projects according to required transmission distance and capacity and their specific advantages and disadvantages. An overview of the characteristics of the different systems is given in Table 9.

For inshore wind farms the HVAC system offers the best solution, as it provides the simplest, least expensive, most tried and tested technology for grid connection, and is similar to the transmission network used on land. However, as transmission distances increase the losses from the HVAC system increase significantly. To avoid ineffective operation AC cable length should be limited to a length of approximately 120km (see Fig. 15).

For offshore wind farms further from the land and with higher capacities, HVDC is the more economical system, even though the technology is more expensive. At present, HVDC systems for large capacities are of the classic thyristor type. The high transmission capacities of such a system keep the number of cables required to a minimum. Modern HVDC-IGBT systems, however, offer clear technological advantages, though their transmission capacity is still too small to connect large amounts of offshore wind power capacity to the grid.

Further advantages of the HVDC systems are the avoidance of reactive power in the sea cable and the capability to control reactive power in the wind farm. The disadvantage of these systems against HVAC are the smaller contribution of short circuit power to the interconnected network and the larger demand for space at sea, as the converter systems require large platform.

	HVAC	HVDC	
		Thyristor technology	**IGB-Transistor-technology**
Transmission losses	High, increasing with distance	Low	Low
Supply of grid voltage and frequency	Possible	Impossible	Possible
Supply of reactive power	Yes	No, instead a source of reactive power is needed offshore	Yes, by inverter
Control of active and reactive power	Impossible by transmission system	Possible by transmission system	Possible by transmission system
Transmission direction	Bi-directional	In one direction only	Bi-directional
Required space	Low with gas-insulated switchgear	Very high due to air-insulated thyristors and use of extensive harmonic filters	High due to air-insulated semiconductor
Advantages	Comparatively simple technology Proved in numerous applications onshore	Very high transmission capacities	Bi-directional transmission Supply of reactive power to induction generators
Disadvantages	High losses, increasing with cable length	No provision of reactive power No generation of a grid voltage	Limited transmission capacity Only few applications up to now

Table 9: Comparison of the technical characteristics of the different transmission systems.

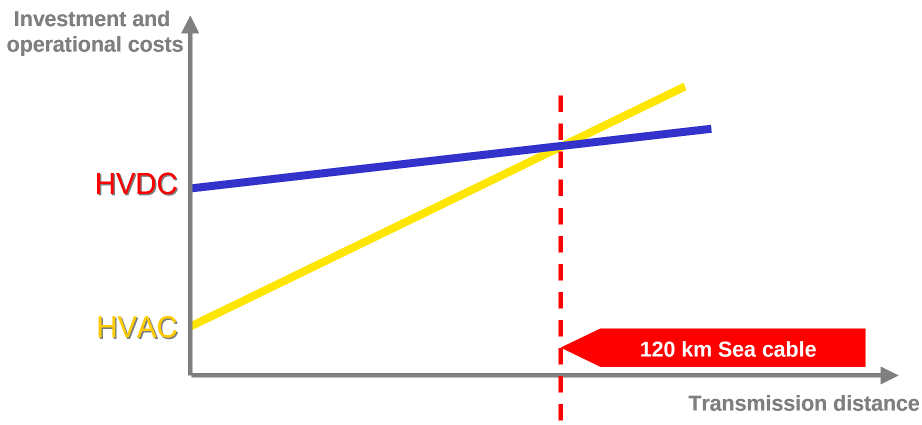


Fig. 15: Trade-off between operational costs of HVDC and HVAC cables as function of the transmission distance [Ref 9].

4.1.4 Transmission onshore

The first offshore wind farms are planned to be connected to mainland grids at points not far from the coast. However, as cable routes in coastal waters need to avoid major conflicts with shipping and nature, the cable route chosen may lead to longer distances both offshore and onshore. To avoid land conflicts and long planning times, the onshore lines to the connection points are usually planned as underground cable.

For the second generation of large offshore wind farms it may be necessary to transmit the electricity generated directly to the main consumption areas. One way of doing this would be to reinforce existing lines, by replacing lower voltage lines with the highest onshore voltage level of 380kV. Another option would be to build additional high voltage overhead lines. The latter would face considerable public resistance and would involve longer planning times of ten years or more.

A third option would be to continue the offshore transmission system on land. The majority of large offshore wind farms will probably use the HVDC system for transmission to land. This transmission system could be extended to connect directly with the in main consumption areas. In this case the on-land DC/AC-converter stations would be situated directly at the connection points, instead of in the coastal areas, large amounts of energy would be transmitted with high efficiency from the sea directly to the main consumer areas.

The further solution, to transport the energy by AC underground cables to the consumption areas has some disadvantages against the DC solution. High voltage AC power can be transported via overhead lines with a high efficiency, but with far lower efficiency by AC cables. Due to the so-called natural load, the characteristic wave impedance of an electric line, an AC overhead line is capable of transporting six times more power at the same conductor diameter as an AC underground cable. This makes AC underground cables unsuitable for long-distance transmission. DC cables do not share this disadvantage and are therefore far more suitable for long-distance transmission.

A recent study on grid reinforcement cost [Ref 7] presents figures comparing costs of underground cable to costs of overhead lines. The costs vary with voltage level, the higher the voltage, the higher the cost relationship. For voltage levels of 110kV and 220kV the costs for cable lie between 1.3 and 3.1 times higher than for overhead lines. For 380kV cable the relationship varies between 2.2 and 4.5.

4.2 Technologies of submarine cable laying

The parameter for laying sea cables for offshore wind farms are determined by environmental, safety and economic aspects. The main variables are the depth to which the cable trench is dug and the course of the cable route. The cable route is determined mainly by environmental, economic and safety considerations, but the fine alignment depends on the laying technology and speed.

As already mentioned, one design objective for sea cables is to limit the number of cables needed by maximising transmission capacities. However, large offshore wind farms will still necessitate several cables being laid.

The issues to be considered fall into two separate categories: cable-laying issues and operational issues.

During cable laying the following issues should be considered:

- The impact on environment and nature during cable laying should be limited to a minimum
- The work should be performed in minimum time
- The influences of the laying work should vanish as soon as possible
- In coastal waters the distance between different cables should be as small as possible to minimize the extension of the total cable corridor
- In maritime traffic zones the cable laying method should allow deeper trenching depth
- The cable route should be as short as possible to minimise costs
- The meteorological conditions should be favourable.

Operational issues include the following:

- A minimum distance between cable should be kept to allow for possible maintenance and repair later on
- The trenching depth should be chosen in order to minimise possible accidents and to avoid a significant temperature raise at the sea floor above the cable.

4.2.1 Trenching depth

The depth of the cable trench is determined by environmental, safety and economic factors as well as by seabed type.

Environmental: Sea cables produce heat in proportion to the power transmitted. Due to the immense heat capacity and conductivity of seawater, local heat production along the cable is not really a problem. For an HVDC cable it can be assumed that a significant temperature rise at the sea floor above the cable can be avoided if the trench has a depth of at least 1 m.

Safety: Sea cables may be fouled by bottom trawl nets or dropped anchors, or hit by falling ship cargo (e.g. containers). To avoid fouling by dragged bottom nets it is necessary to bury the cable, but only a small depth is required. No truly effective measure can be taken against anchors dropped from large ships, as modern anchors can dig deep into the seabed. The depth of trench to completely avoid a probable incident would be economically unviable. However, the accident by hitting a cable has no severe environmental and only a limited safety impact. Should the cable be torn, the resulting electrical short-cut will lead to an equipment overload and the shut-down of converter or transformer stations. Due to the high electrical conductivity of seawater, resulting in a complete earthing of the damaged cable, the ship involved will suffer no electrical shock. The economic damage, however, may be considerable, as the repair of broken cables is especially cost-intensive.

Economy: The cost implications of sea cable trenching depth involve three factors: maintenance costs, downtime costs and cable-laying costs. The deeper the trench, the more potential economic damage from dropped anchors or falling sea cargo is prevented (see Fig. 16). Thus a deeper trench reduces costs both of downtime and of maintenance and repair. At the same time, the actual cost of cable laying increases with deeper trenches. The total cost curve resulting from the three cost factors therefore shows an optimum, where the sum of operational and installation costs is minimal.

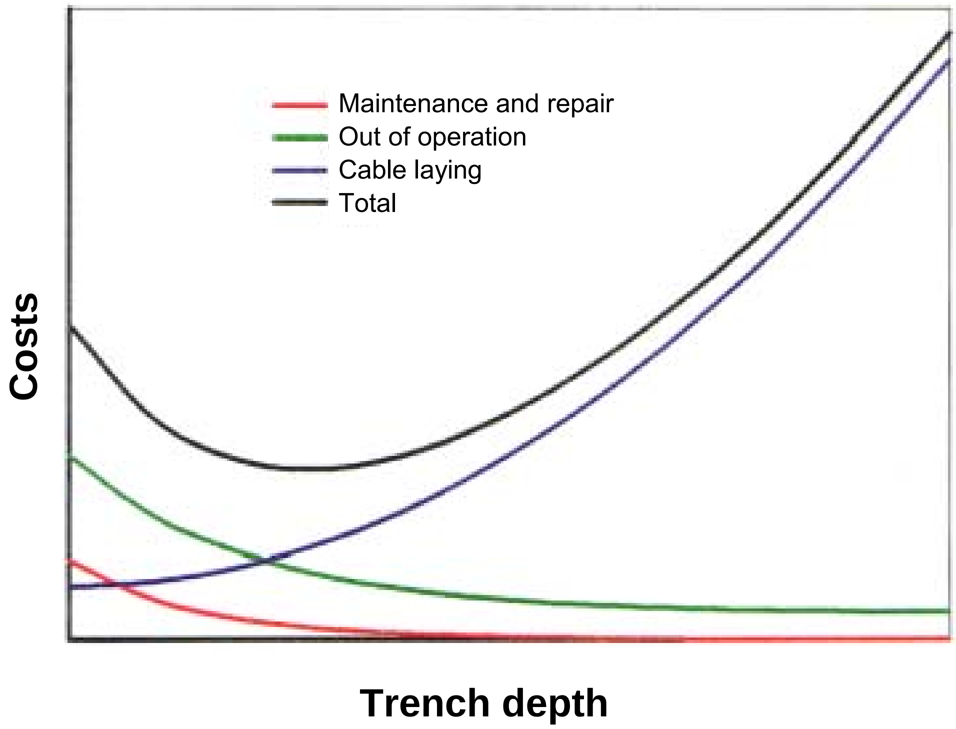


Fig. 16: Costs of laying sea cables depending on trench depth.

Seabed type: The type of seabed also affects trenching depth. In soft sediments (sand or mud) it will be easy to achieve the planned cable depths by trenching. In heavy sediments the speed of trenching will slow down and the planned depth may not be achieved. For extremely heavy or compact sediments a cutter dredger may be required, while for rock chainsaws may be necessary. In those areas of the North and Baltic Seas where offshore wind farms are currently planned, it can be assumed that soft sediments are predominant in coastal areas.

4.2.2 Digging methods

Basically, there are two different methods for burying sea cables, dredging and trenching. Dredging involves excavating a trench and depositing the excavated material either alongside the trench or in a different area of the seabed, the trench is filled back by the natural movement of the seabed. The cable is laid after the dredging process. In the trenching process the cable is laid either before or during trenching. The sediment is washed away underneath the cable, thus causing the cable to sink into the trench. More information is given in the following sections.

	Dredging	Trenching
Digging method	Removing sediment by suction and pumping it into the ship	Dissolving the sediment in the trench by a water jet or by ploughing
Deposition of removed sediment	Transport and dumping of sediment in a different sea area or alongside the trench	Dissolved sediment sinks down beside or back into the trench, no transport necessary
Cable laying	In a separate process after the excavation	During excavation or in a separate process before excavation
Typical width of trench	Approx. 15m plus 10m width per 1m depth, very gradually sloping sides	Approx. 1m, steeply sloping sides

Table 10: Comparison of the two main trench digging methods.

4.2.2.1 Dredging

Dredgers are either suction or flow dredgers. Suction dredgers excavate the sediment and pump it into barges or into the loading bay of the ship, see Fig. 17 (ships constructed as suction dredgers with a loading bay are called hopper). The sediment is then deposited in a different sea area. The hopper is suitable for dredging in soft sediments. The so-called cutter in addition is a suction dredger equipped with a cutting head and is thus suitable to dig also in heavy or hard sea beds. As both types deposit the removed material in the sea, they cause a temporary increase in water turbidity in the disposal area. As the cable is laid after the dredging is completed, the trench has to have a large width and gently sloping sides to prevent it silting up due to lateral movement of sediment. The trench bottom also has to have a minimum width to make sure that the cable hits the trench during laying. For example, a 1.5m deep trench has to have a width of 30m including sides, with a bottom width of 15m.

A flow dredger washes the sediment away by pumping water through a jet pipe against the sea floor, rather than sucking it away. The sediment settles on both sides of the trench. The water temporarily becomes rather muddy and the cable has to be laid immediately after the dredging to prevent sediment filling up the trench again.

Fig. 17: A large suction hopper dredger, excavating sediment at different sea depths. The excavated sediment is pumped into the ship’s cargo bay and is later deposited in a different sea area.

4.2.2.2 Trenching

In contrast to dredging, in trenching the submarine cable is laid before or during the excavation process. There are two trenching methods, plough trenching and jet trenching. Both methods use pumps and jet pipes to dissolve sediments in a narrow trench, so that the cable can be placed or left to sink to the bottom. The trench produced is far narrower (e.g. 1m at the bottom) than that produced by dredging, and is steep-sided.

The jet trenching method involves the cable being laid down on the sea floor first and then washed into the ground by a strong water jet from a trenching device, which blasts aside the sediment from underneath the cable – a process known as mass flow excavation, see (Fig. 18). Jet trenching may be carried out by either a ship with jet pipes, a sledge or a remote vehicle. Latter is either dragged or controlled by a ship. The trenching ship with jet pipes has a pipe or jet tube, which it guides along the cable during the burial process. One advantage of this method is that it can also be applied to existing submarine cables, either to bury them to a greater depth or to rebury them in the case that they have been exposed by shifting of sediments.

Fig. 18: Jet trenching with mass flow excavation

The second means of jet trenching involves pulling a sledge equipped with a jet sword over the sea floor along the previously laid cable. The sledge is pulled by a ship and guided by the cable itself.

The Remote Operated Vehicle (ROV) is similar in operation to the sledge. It is a wheeled vehicle, which powers itself over the sea floor (see Fig. 19). Again, a jet sword is used to bury the cable. The ROV is guided along the cable route by means of a control line linking it to the trenching ship. It should be noted, that the submarine cables for offshore wind farm grid connection will be much more thick and heavy as the telecommunications cables, for which the ROV is mainly used at present.

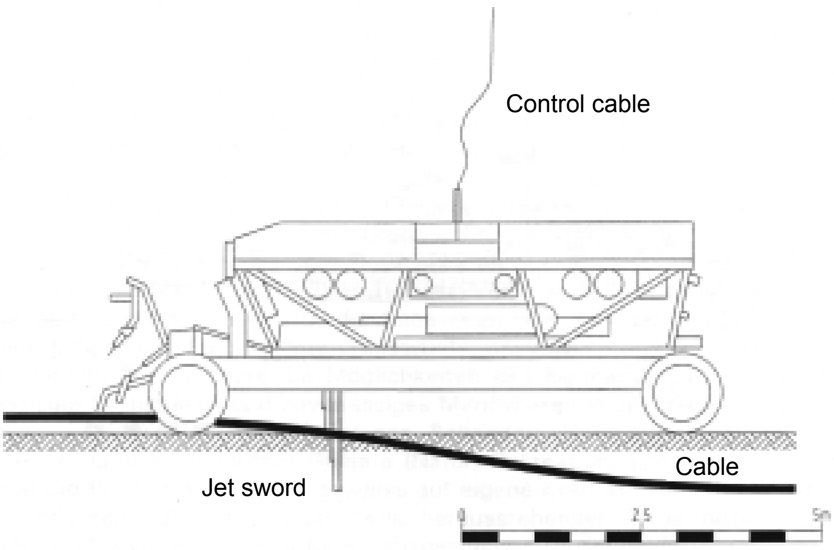


Fig. 19: A remote operated vehicle to burry the submarine cable by jet trenching.

The second trenching method, plough trenching, again uses a sledge to bury the submarine cable. Cable laying and trenching are performed simultaneously. The burial sledge has two runners, on which it is pulled over the sea floor by the cable-laying ship, see Fig. 20. The cable is guided into the plough via a cable inlet, and emerges behind the ploughshare. The ploughshare itself is adjustable in depth and will be lowered to the laying depth of the cable. It is equipped with jets, which beam seawater against the sea floor to blast away the sediment allowing the ploughshare to sink deep into the ground and to lower the cable. The water is fed to the jets by large pumps mounted on the sledge. The depth the cable is laid at depends on the sediment characteristics, being greater in soft sediment than in heavy sediment. In ideal conditions, the burial sledge allows a laying depth of up to 5m.

Fig. 20: Burial sledge for submarine cables (a: cable inlet; b: pumps; c: sword with nozzles, able to be lowered to different depth; d: sledge runners).

The plough trenching burial sledge, in a smaller and lighter version, can also be used to lay submarine cable in areas exposed at low tide, such as the mud flats around the Wadden Sea, see Fig. 21. In this case it is pulled, i.e. by a winch onshore, across the mud flats, burying the cable in a small trench.

The great advantage of trenching as opposed to dredging is its low impact on the marine environment. The trench itself is kept very narrow, which also limits the movement of sediment. The removed material is not deposited elsewhere: the suspended sediment starts settling directly after the cable is buried.

Fig. 21: Burial sledge for laying cable in shallow water and mud flats.

4.2.2.3 Cable laying

Specialised ships, storing the cable in large compartments, lay the submarine cables by paying them out over the stern. The positioning of the cables is performed with the help of a high-accuracy Differential Global Positioning System. This navigation system allows the ship to lay the cable within an accuracy of as little as 1m. However, the accuracy of cable laying depends on the one hand on water depth and the effects of any extreme currents, and on the other hand on the speed of the cable-laying ship. Where the current is extreme, or in deep-sea areas, the deviation from the planned route may therefore be somewhat greater.

A detailed route survey precedes the cable laying operation, examining water depths, surface slopes, sediment types and any obstacles on the sea floor. Existing cables, pipes and shipwrecks may all present obstacles. The crossing of existing cables or pipelines that are laid at only a shallow depth can be expensive, as they may be lowered to greater depth or the new cable has to be laid below the existing ones. Shipwrecks can be avoided only by going around them.

The laying ship presents an almost immobile obstacle to other sea traffic, having only very restricted manoeuvrability, as it is fixed to its position by the sea cable. As such, measures must be taken to avoid collisions with the ship or the hanging submarine cable. Where possible other sea traffic is requested to keep at a safe distance (e.g. one nautical mile) and in traffic zones the work has to be carefully supervised. At night and in fog, warning ships have to be positioned up- and downstream in the traffic route to alerting approaching vessels.

Bad weather and heavy seas can render cable laying difficult or impossible. Cable laying can be stopped in bad weather and the cable may have to be cut in extreme situations.

5 Ecological aspects

Due to the current limited experience of offshore wind power generation, the ecological impacts warrant close consideration. Non-sustainable and undesirable conditions and long-term side effects of offshore wind power must be prevented. Section 5.1 begins by giving an overview of research projects and studies, which have focused on the potential effects of offshore wind energy utilisation on the marine environment. Summaries of relevant research projects and study reports can be found in Appendices A–C, corresponding to sections 5.1.1 to 5.1.3 respectively.

In section 5.2, specific aspects of the electromagnetic impacts of different cable types and of the acoustical impacts of wind farm construction and operation on marine life are addressed.

5.1 Subjects covered in research projects - overview

Increasing consciousness of the lack of knowledge about the environmental impacts of offshore wind power has led over the past few years to an enormous number of research studies. Many of these studies have proved invaluable as background information during the licensing process for offshore wind farms. Recently, in particular, there has been a great deal of study activity within the EU, in connection both with the Environmental Impact Assessment (EIA) guidelines and directives and with the perceived need to increase knowledge in areas where it was seen to be lacking. In addition more understanding has been gained from the construction and operation of the first pilot offshore wind farms.

Studies have been classified into the following types:

1. EIA reports (final or interim) and documentation of studies and research projects referring directly to impacts of offshore wind power installations on the marine environment. These are dealt with in section 5.1.1 and especially in the corresponding Appendix A.
2. Earlier studies and fundamental research that is relevant to basic knowledge and understanding. These are mentioned in section 5.1.2, while a list of all the literature considered for this section can be found in Appendix B.
3. Section 5.1.3 and Appendix C give further documentation of studies and research projects with direct links to:
   - The environmental impacts on birds of onshore and/or inshore wind energy projects; and
   - Further probable environmental impacts of offshore wind energy projects, however without having evaluated these reports for the time being.

In certain cases no evaluation of the study was carried out or summary produced, mainly because (final) reports of research projects were not accessible – either because projects were still ongoing or because reports were confidential. Note also that only those research reports published in English, Dutch and German have been considered here, and that not all research projects were accessible to the authors of the present report. It can therefore be assumed that a considerable amount of research exists which was not considered for this report.

Many studies have already been carried out in the fields of offshore engineering, the effects of (coastal) onshore wind turbines on birds, marine ecology and animal physiology. However, further research is recommended in the following areas, in order to increase knowledge of potential environmental impacts of offshore wind energy projects:

- Development and propagation of noise and vibration under water;
- Orientation and acoustic communication of fishes and marine mammals in the context of electromagnetism and noise;
- Influence of offshore construction works and boat travel on the marine environment;
- Risks and prevention of collision of vessels with offshore structures;
- Effects of offshore oil platforms on the distribution of marine species; and
- Onshore bird response to wind farms, including collisions, compared with response to other high structures including transmission lines.

More effort should be made to apply the results of investigations in these specific fields to EIA requirements and the practice of offshore wind engineering. Application of such knowledge in the context of offshore projects could increase general understanding and the effectiveness of the EIA process. Most of the information in the appendices originates directly – sometimes as a quote – from the corresponding reports. Hence copyrights for the most part belong to the author(s) and/or publisher listed.

5.1.1 Reports on offshore environmental impact assessments and studies

Within EIA an initial baseline study is conducted before any impacts can occur. Subsequent monitoring is necessary to record any changes within the marine environment, which may have been caused by anthropogenic factors. The monitoring phase may go on for several years, and evaluations and conclusions are updated annually to assess changes over time. The same procedure is applied to an untouched reference site, in order to act as a control to assess the significance of any changes in measured factors. Fig. 22 shows an example of the management of site investigation for the EIA of an offshore wind farm. The yellow area represents the planned site of the wind farm. The green area represents the adjacent area, which will need to be investigated in addition to the planning site itself. The blue area represents the reference area. The thick line shows the route of a surveying transect.

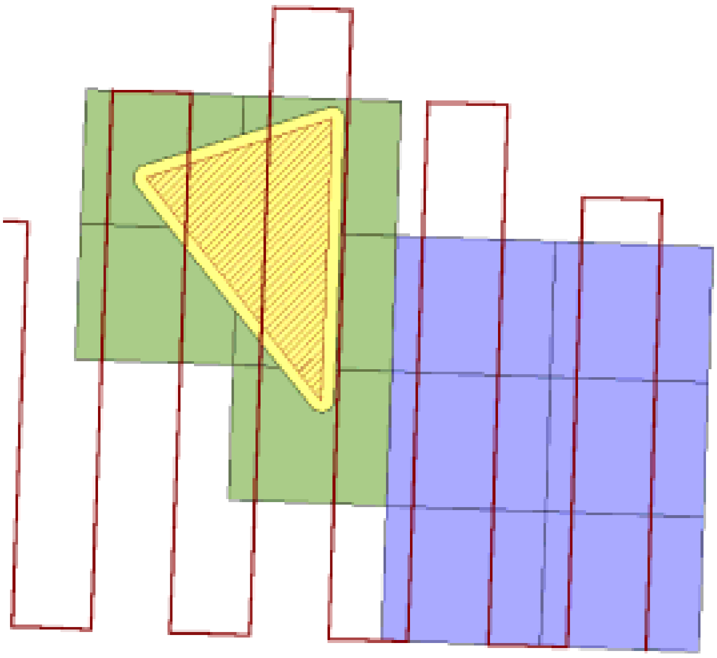


Fig. 22: Example of offshore wind farm site under development (yellow), the actual baseline and wind farm relevant EIA area (green, incl. yellow) as well as the EIA-reference site (blue). Transect route shown in brown.

For the most relevant studies in this context, see Appendix A.

5.1.2 Earlier studies with relevance of marine environmental impacts

In most European coastal states national regulations have been established covering the procedures required to obtain building permits for offshore wind farms and their components. The project developing body has to assess in qualitative and quantitative terms the expected environmental impacts on the marine environment. These procedures ensure that projects comply with international and EU law, conventions and regulations regarding habitat and wildlife conservation. Many study projects were conducted to establish the basic principles and knowledge, which form the basis of the current EIA recommendations, guidelines and directives. These pioneering studies and fundamental research projects form a substantial and important body of information, encompassing the results of both desk studies and field investigations. Appendix B provides an overview of this literature.

5.1.3 Further documentation of studies

There exists an additional pool of information that warrants consideration in relation to the environmental effects of offshore wind power developments. Many studies have been carried out in other disciplines, such as oil and gas exploitation; marine ecosystems and physiology; and the interactions of onshore wind power installations with birds or bats. The evaluation of the findings of these reports and, where possible, their application in the context of offshore wind energy, could lead to new hypotheses, better understanding and new approaches to EIAs. Studies in this category have not been reviewed in detail by the authors of the present report. Nonetheless most of these could form a potential pool of significant background information, and the topics concerned are recommended as a basis for further research projects by the relevant parties. This is particularly the case with the first two reports mentioned below, the most recent and perhaps most remarkable studies concerning the impact of onshore and near-shore wind power installations on birds (Appendix C no. 82 and 83).

5.1.4 Summary of existing and ongoing studies

Table 11 summarises the treatment of a range of topics in the reports listed in appendices A–C, and is divided into three colour-coded parts. The first part shows reports listed in Appendix A. Next are listed those given in Appendix B, which are often of a more general and comprehensive character. Reports listened in

Appendix C are given in the lowest part of the table.

Many studies have been conducted into wide-ranging aspects of the offshore wind power industry and its potential impacts on the marine environment. Not all impacts are necessarily detrimental. However, the detrimental impacts that exist need to be addressed seriously to develop a sustainable industry. To ensure this, there are many research projects ongoing or in a planning phase. The specialised and detailed long term EIA surveys and analyses considered here were conducted on existing wind farms, in particular Horns Rev (Denmark), Utgrunden (Sweden), and Nysted/Rødsand (Denmark). In addition, strong research activity is ongoing in the UK and Germany. In large part due to the uncertainties and risks concerning the environmental impacts of large-scale offshore wind energy use, developers, backers and industry have held back for a long time. The currently ongoing research activities contribute to greater confidence and security during the planning and operational phases.

Table 11 below summarises the previously introduced reports and their key subjects.

Subject	Accidents/ pollution	Barrier effects (fauna)	Ben-thos/ seabed life /reefs	Birds	Collision risks (ship)	SEA/ Natu-ra2000 /Guidelines	EM-fields/ cables/ grid	Fish	Hydro-graphy	Mam mals	Noise/ vibra-tion	Sediment/ soil
Frequency dealt with:	**6**	**23**	**26**	**44**	**5**	**10**	**14**	**16**	**10**	**19**	**14**	**15**
Report-No:												
01							X	X				
02											X	
03			X				X	X		X	X	
04		X		X								
05				X								
06											X	
07		X		X								
08			X	X			X					
09				X						X	X	
10			X					X				
11										X		
12										X		
13								X				
14								X				
15			X									
16										X		
17		X		X								
18		X										

Subject	Accidents/ pollution	Barrier effects (fauna)	Ben-thos/ seabed life /reefs	Birds	Collision risks (ship)	SEA/ Natura2000 /Guidelines	EM-fields/ cables/ grid	Fish	Hydro-graphy	Mam mals	Noise/ vibra-tion	Sediment/ soil
19			X									
20		X								X	X	
21										X	X	
22		X		X								
23				X								
24				X								
25		X		X								
26			X									
27		X		X								
28			X	X								
29		X	X	X				X		X	X	X
30			X				X	X			X	X
31									X			X
32		X								X		
33			X						X			X
34	X								X			X
35			X									X
36			X									
37			X									
38		X		X								
39										X		
40		X	X	X	X							X
41				X								
42	X				X							
43	X		X	X	X					X		
44				X								
45							X	X				
46			X									
47				X						X		
48		X		X								
49		X				X						
50			X									X
51									X			X
52												X
53							X	X				
54		X								X		
55				X								
56											X	
57			X									
58									X			X
59									X			X
60												
61							X					
62											X	
63							X					
64				X								
65											X	
66		X	X	X			X	X	X	X		

Subject	Accidents/ pollution	Barrier effects (fauna)	Ben-thos/ seabed life /reefs	Birds	Collision risks (ship)	SEA/ Natu-ra2000 /Guidelines	EM-fields/ cables/ grid	Fish	Hydro-graphy	Mam mals	Noise/ vibra-tion	Sediment/ soil
67						X						
68				X		X						
69	X	X	X	X	X	X		X	X	X		
70	X				X							
71						X						
72			X						X			X
73		X	X	X		X		X		X		
74	X	X	X	X		X	X	X	X	X		X
75				X								
76		X		X								
77		X		X		X				X	X	
78						X	X					
79											X	
80												
81												
82				X								
83				X								
84				X								
85		X		X		X						
86				X								
87			X				X	X				
88			X				X	X		X		
89			X				X					
90				X								
91				X								
92				X								
93				X								
94								X				
95				X								
96				X								
97				X								
98				X								
99				X								

Table 11: Summary on research topics, frequency and applicatory genre. The background colours indicate the relation to the different chapters, 5.1.1 (yellow), 5.1.2 (blue) and 5.1.3 (green) and their corresponding Appendices A, B and C.

5.2 Focus on specific subjects

This section gives an overview of the impacts of electromagnetic fields and noise/vibration.

5.2.1 Electromagnetic fields

An electric current passing through a conductor causes an electromagnetic field around it. This field usually surrounds the conductor concentrically, and its strength is proportional to the current flowing through the conductor. Due to the high currents used in power transmission from offshore wind farms, sea cables generate strong electromagnetic fields. Systems using a monopolar cable, where the return conductor is missing (the current is flowing back via seawater and the sea bottom), have an especially powerful magnetic field, which may have a strong impact on marine animals and on shipping. Some whale species, for example, navigate by sensing the earth's magnetic field and the electromagnetic field from a monopolar cable could impair their ability to do so. It could have a similar effect on the compass navigation of ships. For this reason monopolar cable systems are not considered suitable for power transmission from offshore wind farms. The design of offshore wind farm power transmission is instead based either on three-conductor cable systems for AC applications, or on two-conductor cable systems for bipolar DC applications.

In a bipolar DC system with two parallel conductors, the magnetic fields of the currents in the forward and return conductors are counter-rotating, see Fig. 23. The two fields are superimposed on one another, and if the distance between the two conductors is small, then they will cancel one another out and the resulting magnetic field will be zero at a certain distance from the cable if the forward and return current are equal. For the concentric cable the superposition of the magnetic fields is optimum, the resulting magnetic field around the cable surface will be zero, see Fig. 24.

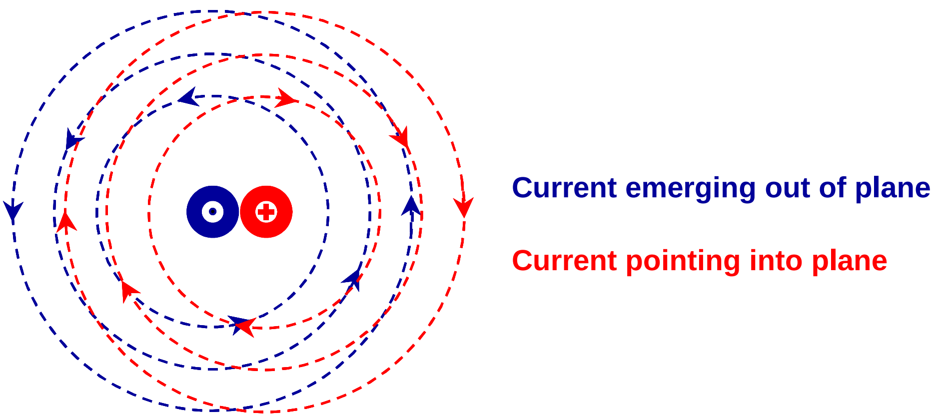


Fig. 23: Magnetic field around a parallel bipolar cable, with currents in opposite directions. At a certain distance the resulting magnetic field is zero, due to the superposition of the two counter-rotating magnetic fields.

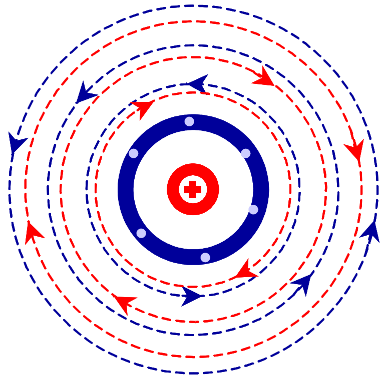


Fig. 24: Magnetic field around a concentric cable, with opposite currents in the inner and outer conductors. The resulting magnetic field is zero, due to the superposition of the two counter-rotating magnetic fields.

In three-phase AC systems, the magnetic field around the cable is also zero, as the sum of the currents in the three phases is zero at all times.

Since the magnetic fields of both types of cable, bipolar and concentric, are either small or zero, it may be concluded in the context of the studies listed in the Appendices and Table 16 that the electromagnetic fields of submarine cables for offshore wind power will not have any significant effects on the marine environment.

5.2.2 Acoustical impact on marine life based on actual research programmes

As outlined earlier, there have been several studies conducted on the noise and vibration produced both during the construction of offshore structures in general and by the operation of offshore wind turbines, and the disruptive effects of that noise on the marine environment and particularly on mammals and birds.

As the acoustical impacts on marine life are considered a major environmental factor, this issue is now considered more closely. The available literature has been reviewed and a general summary of the acoustical impacts on marine life is given before consideration of specific impacts on particular groups of organisms, including birds, mammals, fish and the benthos.

Finally, a list of further literature on acoustics is included as Appendix D. These references are potentially useful both for their background understanding of marine environmental impacts, gained in the context of other industries, and for aspects of animal physiology which may be relevant to an offshore wind context. However, it should be emphasised that not all the studies listed have been evaluated by the authors of the present report.

Generally speaking, the noise output of wind turbines can be subdivided into mechanical noise and aerodynamic noise. The components emitting the highest sound level (dB) are the generator, the yaw drive (motor and gear ring), the gearbox and the blades. Some of the noise generated by these components is regular and some of it irregular, but all of it (except, that generated by the yaw mechanism) is present only while the turbine is actually in operational mode. Even then, compared to road traffic, trains, construction activities and many other sources of industrial noise, the noise generated by wind turbines in operation is comparatively low [Ref 15].

However, it is not only the operational phase that needs to be considered. During construction and decommissioning certain offshore engineering activities such as ramming and explosions take place. Ramming of monopiles may lead to sound pressure levels of as much as 250 dB [Ref 20], though they are often much lower, depending on substrate of the sea bed. In the Rødsand (DK) wind farm area, the ramming of the monopile foundations caused noise levels of no more than 150 dB, with 91 dB in a part of an EU Special Protection Area and 71 dB in a part of a nature reserve (a seal sanctuary) [Ref 23]. The noise level during the construction phase is expected to be even lower if the caisson foundation type is used.

During operations, the noise from the wind turbines and the transformer is emitted to both, air and water (via the tower and foundations). Measurements of noise from wind turbines show that the airborne noise makes a negligible contribution to the underwater noise level. Therefore the noise measured underwater is transmitted almost entirely through the tower and foundations. During operation, the underwater noise emitted in the frequency range above approximately 1 kHz is no higher than the ambient noise level. In the frequency range below approximately 1 kHz, the underwater noise emitted is higher than the ambient noise level. During operation, the turbines also transmit noise to the surroundings, which could have an impact on the benthic fauna, fish and marine mammals in the vicinity of the foundations. So far, this impact has not been investigated thoroughly and knowledge of the subject is very limited [Ref 24].

Fig. 25 shows the sound pressure levels of a range of underwater noise sources as a function of frequency [Ref 20].

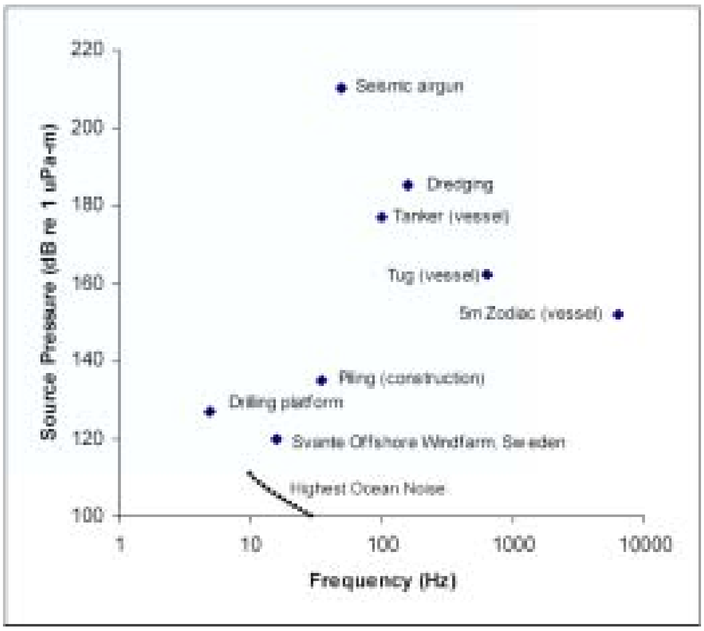


Fig. 25: A comparison of peak intensities in the frequency spectrum of noise for selected anthropogenic, underwater noise sources. The sound pressure level is depicted versus the frequency of the emitted noise.

The effects of anthropogenic noise can be broadly categorised into behavioural and physiological effects. Behavioural impacts include attraction or avoidance behaviour, panic and increases in the intensity of vocal communication. Such behavioural changes can in turn affect populations of sensitive species in an area. Physiological effects are less well documented. However, studies have shown that long-term exposure to noise can cause damage to the inner ear animals, even if for example many cetaceans appear to readily habituate to anthropogenic noise [Ref 20].

Studies of the impact of anthropogenic noise on fish, invertebrates and planktonic species have focused almost exclusively on the effects of geophysical surveying, and in particular the 'airguns' used in seismic surveys. These devices have been shown to produce a range of impacts on fish, from avoidance behaviour to physiological impacts. Studies have also shown that noise in general, such as that associated with shipping, causes avoidance or attraction behaviour in fish. Former can lead to avoidance of migration routes and feeding and spawning areas. Reports describing the impacts of noise on invertebrates and planktonic organisms are much fewer in number. However, the general consensus is that there are very few effects, behavioural or physiological, unless the organisms are very close to a powerful noise source [Ref 20].

A recent UK survey [Ref 35] investigated the levels of background noise at typical offshore wind farm sites, including source and impulse levels during piling at North Hoyle and Scroby Sands and source levels during cable trenching at North Hoyle, as well as rock socket drilling components and harmonics. This study is a valuable addition to knowledge of acoustical impacts of offshore wind farms on marine species. The main objectives of the study were:

- To characterise the noise spectrum and the level of underwater noise created during the construction, operation and decommissioning of wind farms;
- To identify which marine mammal species and other marine organisms use the coastal areas in the vicinity of the wind farms, and to determine their sensitivity to noise; and
- To determine the effects that noise may have on these species, and the duration of such effects.

Based on previous works of Yelverton et al. [Ref 36], Table 12 was compiled, to summarise the effects of impulses on mammals diving beneath the water surface. The effects of given noise levels should not however be overestimated on the basis of this table, as it records effects on terrestrial mammals (sheep, dogs, monkeys) rather than marine mammals, which are adapted to the pressure changes of diving and have increased body wall thickness.

Impulse (dB re 1 μPa.s)	Impulse (Pa.s)	Impulse (bar.msec)	Likely effects
169	276	2.76	No mortality. High incidence of moderately severe blast injuries, including eardrum rupture. Animals should recover on their own.
163	138	1.38	High incidence of slight blast injuries, including eardrum rupture. Animals should recover on their own.
157	69	0.69	Low incidence of trivial blast injuries. No eardrum ruptures.
151	34	0.34	Safe level. No injuries.

Table 12: Summary of effects of different impulses on terrestrial mammals diving beneath the water surface.

In summary, the unweighted North Hoyle pile hammering measurements showed that:

1. the effective source level of the piling noise measured at 5m depth was 260dB re 1 μPa @ 1m, and at 10m depth was 262dB re 1 μPa @ 1m. The corresponding transmission loss is given by 22 log (R), where R is the range; and

2. the level of noise fell evenly with range in all directions, i.e. there were no preferential directions for propagation of noise.

Furthermore, pile-hammering measurements in dBht units within a range of up to 10km from the piling site show that:

3. About 75% of the measurements were in excess of a value of 90dB$_{ht}$, indicating that significant avoidance reaction by a range of species would be likely. Hence behavioural effects (avoidance behaviour) of both marine mammals and fish could occur at several kilometres from the piling.

The ranges at which significant avoidance reaction would be expected (based on a criterion of 90 dBht) have been calculated and are tabulated in Table 13 below. [Ref 35]

Species	Calculated range for significant avoidance reaction
Salmon	1400 m
Cod	5500 m
Dab	1600 m
Bottlenose Dolphin	4600 m
Harbour Porpoise	7400 m
Harbour Seal	2000 m

Table 13: Calculated ranges for significant avoidance reaction by various species.

Following [Ref 35] Yelverton et al. [Ref 36] moreover noted that 163 dB (re 1 µPa·s) was the threshold for a high incidence of moderately severe blast injuries to marine mammals, including eardrum rupture. The use of this effect threshold in conjunction with the results above implies that injury might occur within ranges of 77 m at 5 m water depth, and 60 m at 10 m water depth. The severity of the injury would be expected to increase for marine mammals at lesser ranges.

The trenching noise at North Hoyle was found to be a mixture of broadband noise, tonal machinery noise and transients, which were probably associated with rock breaking. It was noted at the time of the survey that the noise was highly variable depending on the physical properties of the particular area of seabed that was being cut at the time. Furthermore it may be noted that, with one exception, all of the measurements were below 70 dB$_{ht}$, and hence below the level at which a behavioural reaction would be expected. [Ref 35]

The report also outlines measures to mitigate any environmental impacts, distinguishing between engineering methods (appropriate engineering, pile diameter, bubble curtains, vibropiling) and non-engineering methods (marine mammal observers, active or passive acoustic monitoring, acoustic harassment devices, scheduling, soft start). [Ref 35]

Simmonds and Dolman [Ref 21] provide a comprehensive list of the possible impacts of noise on marine mammals in general. Behavioural impacts listed include the gross interruption or modification of normal behaviour, displacement from an area, masking of communication with individuals of the same species, masking of other biologically important noises, and interference with the ability to interpret the environment acoustically. Physical impacts include temporal or permanent hearing threshold shifts and gross physical damage to hearing apparatus and body tissues. Other impacts of noise can result in decreased viability of individuals, increased vulnerability to disease and increased potential for impacts from cumulative effects, such as chemical pollution combined with noise-induced stress. In this context also habituation to noise impacts may exacerbate other effects [Ref 20].

In general Ref 20 is a valuable source of information concerning acoustic impacts on marine life, especially as much information is presented on audiograms, thresholds, hearing sensitivity and underwater vocalisation for several species present in the UK territory waters.

Another research programme at Utgrunden provided some valuable insights into several physical and technical aspects of underwater noise [Ref 32]. Some of the programme's key questions are listed below:

- **What is the character of sound from a single power station?**
  - The turbines radiate sound mainly at a few dominant frequencies from 30Hz up to 800Hz. At frequencies below 3Hz no contribution from the turbines can be detected due to the high background level from the waves and the low tower vibration level.
- **What mechanisms in the turbine generate the sound?**
  - Gearbox mesh frequency vibrations that are transmitted via the tower structure and radiated out to the water generate most of the sound. Airborne blade sound is effectively dampened in the transition from air to water.
- **How does the sound attenuate with increasing distance at different frequencies?**
  - The average attenuation per doubling of distance for frequencies between 31Hz and 722Hz is approximately 4dB in the measured positions. No clear variation in attenuation according to frequency could be found.
- **How does the sound pressure level vary with increasing wind speed?**
  - With increasing wind speed, the sound pressure level increases and the dominating frequencies move upward due to increasing turbine rotational speed.
- **How does sound from different power stations interfere with each other and influence the over all sound image?**
  - No clear tendencies of interference could be observed in this study. This could be because of small variations in turbine speed and the possibility that the hydrophone positions needed to be less dominated by a single turbine.
- **How do passing vessels influence the sound level in the wind farm?**
  - The passage of ships dominates the sound in the wind farm for frequencies higher than approximately 63Hz, though this varies greatly according to type of ship, distance, etc.

Several other research projects have included measurements and investigations to assess the propagation of vibrations and noise through water, air and the seabed. An overview of additional studies related to noise or vibrations can be found in Table 11 of section 5.1.4.

In the following section a brief overview of acoustical impacts on various types of marine life, collected from actual research programmes, is given.

5.2.2.1 Birds

Compared to what exists for other marine animals, there is a substantial amount of information available on the impacts of offshore wind power installations on birds, though this is still considerably less than the information available from onshore investigations on the same topic. Wind farm layout (and its effect on bird flyways), collision detection systems, bird counting, bird alimentary behaviour, bird flight behaviour and avoidance behaviour have been seriously addressed, and research activities are undertaken not only by project planners, but also by pressure groups and conservation organisations.

However, while it is generally difficult to isolate any impact of wind turbine acoustical noise, this is especially true in the case of impacts on birds. One reason for this is that noise emissions only occur when the turbine is operational, and as the spinning of the rotor may have an impact on the birds' vision, it is difficult to distinguish between this influence and any impact of the noise.

One study [Ref 22] indicated that birds passing close to the wind turbines of a near-shore wind farm did collide significantly more often with wind turbines at night than during the day. It also points out that birds react more frequently with evasive movements if headwind prevails than during downwind. This difference in reaction could therefore be linked to a difference in acoustic sensitivity as well as to variation in the ability to manoeuvre at different speeds, which in turn are the consequences of tailwind and headwind situations respectively.

Further study of the flight patterns, traces and evasive reactions of birds (e.g. flying just above the water surface while heading upwind and higher when heading downwind), in combination with investigation of the frequency distribution of wind direction at specific seasons, could provide us with new insights and recommendations for the placement and constellation of offshore wind farms in areas with high levels of bird movement and/or vulnerable species.

A comprehensive assessment of noise effects as part of the EIA for Øresund led to the supposition that the noise caused by ramming did not have a detectable impact on the breeding birds in the study area (e.g. gulls, terns and waders). At Øresund moulting Greylag Geese, a species very sensitive to disturbance, showed a high degree of habituation to the constant and frequent banging construction noises. On the other hand the noise caused by ramming is expected to disturb Long-tailed Ducks, especially at first. However, the only effect expected from this disturbance is, that the species may leave the area earlier as usual [Ref 23]. A study at Tunø Knob [Ref 30] also concluded that neither the rotor noise and movement (established through on-off experiments), nor the standing towers had a negative effect on the abundance and the distribution of eiders. However, it was observed that eiders avoided flying and landing within 100m of the wind farm, which should decrease any risk of collision with towers (in good weather conditions) [Ref 34].

5.2.2.2 Marine mammals

Marine mammals spend most or all of their lives at sea, and spend the majority of that time submerged. Light is absorbed quickly in salt water and in many marine habitats visibility is thus limited to a few metres. Sound, however, propagates efficiently through water and marine mammals use sound for a variety of purposes, such as finding prey, detecting predators, communication (often over long distance ranges) and probably also navigation. Any noise pollution in the water can therefore have a range of impacts on mammals in particular, and this topic accordingly requires detailed investigation.

Marine mammals in general, and cetaceans in particular, are vulnerable to interference from underwater noise, as they rely on sound to communicate, sense food and understand their local environment. Water-borne noise and vibration transmitted from the moving blades, through the tower and into the water, has the potential to cause significant disturbance or harm to marine mammals, as introduced previously in Table 13. When assessing whether water-borne noise from a specific wind farm is likely to be problematic, a number of issues need to be addressed:

- Whether there are cetaceans and/or other marine mammals in the area – if there are none, the effects of noise on marine mammals will not be an issue;
- The sensitivity to noise of any receiving marine mammals;
- Details of the noise emitted by the noise source;
- The attenuation rate along the propagation path; and
- Ambient noise levels near the marine mammals.

Regarding the third point, the information currently available indicates that noise generated by offshore wind turbines lies in the same range of frequencies as the noise generated by sources such as shipping, fishing vessels, wind and waves [Ref 14]. However, the crucial difference is that the noise caused by passing ships is temporary, whereas an operating wind farm is expected to run continuously, and hence the emitted noise will be of continuous character. As such the long-term effects of exposure to such noise need to be investigated in more detail.

There is a large volume of data available regarding the second bullet point – see [Ref 16]. Also Ref 17 refers to audiograms, characteristic frequencies of vocalisations and hearing sensitivity of marine mammals such as harbour seal, grey seal, baleen whales and toothed whales. In addition, exposure to loud sounds can lead to temporary or permanent threshold shifts as well as potentially fatal non-auditory tissue damage. Experiments to induce threshold shifts have been conducted and are described in Ref 17.

The behavioural and physiological effects of noise on a particular species depend on its intensity, frequency bandwidth and duration [Ref 19]. Seals are known to be sensitive to low frequencies (mainly <1kHz), whereas small (toothed) cetaceans are relatively insensitive to low frequencies [Ref 17].

The behaviour of cetaceans in response to offshore wind farms is as yet totally unknown. However, what is known of the impacts on common and grey seals seem to indicate that they are not significantly disturbed by the presence of offshore wind turbines. Investigations near to the shore have shown no negative effects of wind turbines on common and grey seals and in the vicinity of the Tunø Knob wind farm, for instance, a group of 10 seals regularly haul themselves out [Ref 18]. The EIA for the offshore wind farm at Horns Rev showed that the strongest effects were observed in connection with the pile-driving operations during the construction of foundations. Harbour porpoises left the construction area when pile-driving began, but returned again a few hours after the end of each pile-driving operation. Safety protocols were employed to reduce the sound exposure to porpoises and seals in the area during pile-driving operations: these involved either a gradual ramping up of impact energy or the underwater deployment of acoustic pingers and seal-scarers. Nevertheless, the effects were not restricted to the wind farm area – pronounced effects were also observed in the control areas. Fewer animals were observed foraging close to the construction site (up to a few kilometres away) on days when there were pile-driving operations [Ref 25].

Another survey of seals at Horns Rev found that some animals spent periods in the reef area, presumably foraging, both before and during construction. There seems no reason to believe that construction – even the highly noisy ramming of monopiles into the seabed – had any large-scale influence on the seals in the area. The reef seems to be a central corridor for movements between foraging areas and haul-out banks, but in itself is less important as a foraging area than had previously been expected. The limited extent of the wind farm there in comparison to the entire reef makes it unlikely that it will function as a barrier to movement. However, in the case of future extensions of the Horns Rev wind farm or other constructions in the area, the possibility of barrier effects would have to be considered [Ref 33]. The latter also highlights the need to focus further research activities on the enlargement of existing offshore wind farms, as well as on the selection of new areas.

An annual status report on the effects on harbour porpoises at Horns Reef [Ref 25] states the following:

> Data from acoustic data loggers (T-PODs) and visual surveys conducted from ships confirmed the presence of harbour porpoises inside the wind farm area during all periods investigated. Comparison with baseline data from 1999–2001 and with control areas outside the wind farm did not show a statistical significant change in sighting rates inside the wind farm area in the first year following construction relative to baseline. T-POD data showed a pronounced effect of the construction of the wind farm on the indicators encounter duration (number of minutes between two silent periods longer than 10 minutes) and waiting time (number of minutes in a silent period lasting more than 10 minutes). Both parameters seem to indicate higher levels of porpoise activity during construction. Encounter duration went up from baseline to construction and fell again to post construction phase, whereas waiting time went down during construction and up again during post construction. A partial return to baseline levels was seen for these two indicators in 2003 (wind farm was constructed in 2002 and opened in December 2002). Both changes are consistent with a relative increased porpoise activity inside the wind farm area during construction. This is contrary to what was anticipated in the EIA [Ref 29] and also the low number of animals observed inside the wind farm area on surveys conducted during construction period [Ref 28]. It was expected that echolocation activity would decline during the construction period and then increase to an intermediate level during the post construction period. This apparent increase in porpoise activity during construction can be explained by an increase in porpoise abundance caused by a genuine attraction of animals to the wind farm area caused by the construction. Alternatively, it can be explained by changes in one or more unknown biotic or abiotic (like salinity) factors controlling the overall distribution of porpoises in the entire reef area [Ref 25].

Calculations and field experiments indicate that harbour porpoises may be able to hear individual turbines at distances of up to a few hundred metres [Ref 26 and that short-term behavioural changes (avoidance) can be expected at distances closer than 180 metres [Ref 27 Little is known about long-term effects and what level of habituation to the noise can be expected. Harbour porpoises seem to use a variety of signals with frequencies spanning around 47Hz to above 130kHz and their highest sensitivity has been found to be between 8kHz and 30kHz (below 50 dB re 1 μPa) [Ref 37]. Wind turbines, in contrast, are expected to generate noise above ambient levels only at frequencies below 1–2kHz [Ref 38].

Another crucial impact concerns pregnant common porpoises, which need shallow and calm water to bear their offspring. During this time they are more strictly dependent on certain biotic and abiotic circumstances and hence they are not able to move away from any disrupting source of noise. The dams are rather sensitive during this period and hence it is necessary, if considering offshore activities in the vicinity of common porpoises, to ensure that the porpoises are single rather than comprising a dam-calf-group [Ref 19].

5.2.2.3 Fish

Operational effects may occur for 20 years or more and can be seen as long-term. This could result in fish moving from an area permanently, which could have a major impact on larval survival, for example. Moreover, most planned offshore wind farms will eventually consist of a few hundred turbines each, according to current plans. Assuming that the turbines have to be checked at least once a year for regular maintenance and that extra visits will be necessary to deal with technical management, there could be more or less daily transport activities within the wind farm area. Access activities associated with the maintenance and technical management of the turbines may thus create more disruption than the operating turbines themselves [Ref 14].

If noise is generated at low frequency, as is likely according to the information available, it may be audible to many fish species. The navigation and behaviour of the fish could as a result be affected. The extent to which fish are affected will be highly dependent upon the frequency, intensity and duration of the noise. Only a small amount of research has been conducted into the effect of noise on fish behaviour [Ref 14]. One study indicates that fish typically respond strongly to low-frequency hydrodynamic/acoustic fields (below ca. 50Hz). Significant noise emissions in this frequency range are expected to be confined to the immediate vicinity of the wind turbines, within a radius of no more than a few hundred metres. Moreover, fish will perceive them very differently to the low-frequency fields generated by other animals. A fish swimming through the hydrodynamic field created by another animal experiences a rapid change in water flow in terms of both strength and direction. The low-frequency fields generated by wind turbines are much larger than those of swimming animals, meaning that fish passing through them will not experience rapid current changes. Therefore, the ability of the fish to detect predators and prey and interpret the fields from other sources (i.e. wind turbines or animals) may exist. Furthermore, the continuous nature of wind turbine noise will probably mean that the fish become habituated to it.

In addition to the low-frequency fields, noise is also radiated in the frequency range 0.05–2 kHz with source levels up to 74 dB re 1 μPa. Fish respond only slightly to these frequencies, and the influence of wind turbines over this range compared to the level of marine anthropogenic noise in general is probably minor. Wind turbines produce no noise above 2kHz, and this frequency range is therefore of no concern. As a whole the effect of wind turbine noise is presumed to be negligible [Ref 37].

In spite of the expectation that noise and vibration might scare fish, the Bio-Wind study showed that the bridge pillars and monopiles actually attract fish, especially two-spotted goby. Common gobies are also found at the base of the pillars [Ref 24]. Research on the effects of noise transmitted through water on fish at Vindeby also showed that the fish appeared undisturbed by the noise and accumulated in the area [Ref 31].

5.2.2.4 Benthic (benthos)

There has been very little research to assess noise or vibration effects on benthic communities, even though any effects on benthic communities could have a knock-on effect on any species higher up the food chain and as such could be important. What is more, there are large differences between the vibrational behaviour of concrete and steel-monopile foundations, which make it difficult or even impossible to transfer knowledge. However, unless the turbine tower vibration causes changes in the physical composition of the seabed (e.g. liquefaction) little or no remarkable effect on benthic communities is expected [Ref 14].

At Horns Rev changes in the community structure of the benthic infauna and the sediment occurred both before and after the wind farm was established, and were observed both inside and outside the wind farm area. This indicates that the changes were the results of natural variation, rather than impacts due to the wind farm [Ref 46].

However, hard bottom substrate monitoring at Horns Rev [Ref 47] , detailed in the 2003 annual report, found that the faunal communities on the introduced hard substrates are completely different to the faunal community found in the wind farm area prior to the erection of the wind turbines and the establishment of the scour protection. At this time, no large hard structures existed in the area and the fauna inside the wind farm area consisted mainly of infaunal species typical of sandbanks in the North Sea. After construction of the wind farm, it was noticed that the introduced hard substrates began to be used as hatchery or nursery grounds for several species. The introduction of epifouling communities has increased the general biodiversity in the wind farm area. It is estimated that the availability of food for fish (mainly consisting of benthos) has increased by a factor of eight, after the introduction of the hard substratum, compared to the normal soft seabed fauna in the wind farm area. Thus, even if noise and vibration do prove to have an effect on the benthos, the benefits still seem to outweigh the disadvantages in terms of providing hard substrates, on which specific benthos species can settle.

5.2.2.5 Conclusion

There is a need for more experimental measurement of noise generated by offshore wind farms (frequency, sound power level and propagation) and its impacts on the marine environment would, as it should be noted that on some of the above mentioned areas insufficient information is available. Further study could even be conducted as part of the EIA process. However, reliable data on long-term impacts will only become available in the next five years, as more EIAs on operational and planned wind farms are completed.

Again, it is worth mentioning that some relevant information on noise may be found in research conducted in connection with other disciplines such as offshore oil and gas engineering. Many stages of the oil extraction process, for example, produce potentially disturbing or even damaging sound pressure levels. Exploration entails seismic surveys, which produce intense low-frequency impulse noise; extraction involves drilling, increased vessel traffic, pipeline laying and further seismic site surveys as well as decommissioning of structures by means of explosive [Ref 17].

A list is given in Appendix D of reports or papers, which, although not evaluated here, may contain further relevant information on the potential impacts of noise on the marine environment.

Wherever possible, the findings of these reports mentioned above should be applied to specific situations within the field of offshore wind energy engineering. The development of synergies by this means could reduce the need to perform new studies.

Fig. 26 illustrates the key interactions influencing the effects of offshore wind farms on marine wildlife and indicates where the uncertainties and gaps in knowledge lie. The top row of the table contains those factors expected to have a direct impact on marine wildlife, while the left hand column contains those physical characteristics, which may determine the nature/extent of these key factors. The extent of the interaction (major interaction, minor interaction, no direct interaction or uncertain interaction) is shown by the symbol in the lower left of each cell. For example, turbine size has a major interaction with vibration, noise production and noise transmission. The right hand column contains different components of the marine wildlife: colonising organisms, benthos, plankton, fish, etc. The interaction of the key factors on each component of marine wildlife is represented by the symbol in the upper right of each cell. For example, noise transmission from wind farms is expected to have a minor interaction with plankton and an uncertain interaction with local fish populations.

Physical Characteristics	Key Factors Influencing Impacts on Marine Wildlife						Marine Wildlife
	Vibration	Noise production	Noise transmission	Surface area for colonisation	Shelter/ attraction	Seabed disturbance	
Coastal morphology	○ ?	○ ?	● □	○ ■	• ■	○ □	Colonising organisms
Seabed type/ sediments	• ▪	○ □	● ▪	○ □	• ▪	● ■	Subtidal bethos/ epi-benthos (seabed)
Distance offshore	○ ▪	○ □	● ▪	○ □	● ▪	• ▪	Intertidal benthos
depth	• □	○ □	● ▪	● □	● □	○ ▪	Plankton
Turbine size	● □	● ?	● ?	• □	• ■	• ▪	Local fish populations
Number/arrangement of turbines	● □	● ?	● ?	● □	● ▪	● □	Fish migration
Foundation type	• □	• ?	● ?	● □	● ■	● □	Odontocete/pinniped communication/behaviour
Foundation Reinforcements	• □	• ?	● ?	● □	● □	● □	Mysticete communication/ behaviour
Installation methods	•	•	•	○	○	●	
Decommissioning	•	•	•	●	●	●	

KEY: ■ ● *Major interaction* ▪ • *Minor interaction* □ ○ *No direct interaction* *? Uncertain interaction*

Fig. 26: Vibration, noise and other key interactions influencing the effects of offshore wind farms on marine wildlife.

6 Strategies to develop the offshore wind energy sector

6.1 Measures relating to power transmission, grid connection and grid integration

For environmental, technical and economic reasons the combining of the cable systems of single wind farm projects to a common grid connection is desirable. This solution would require a high-capacity cable, leading from land to a central point between several offshore wind farm projects. This cable should be an HVDC system with the maximum available capacity, and a common converter system. The connection between the offshore wind farms and the offshore grid connection point could be a medium- or high-voltage AC system.

In an area such as the German Bight, where numerous offshore wind farms are planned (see chapter 3.1) this strategy could be extended to the construction of several of these central connection points. If this approach were pursued to its logical conclusion, the interconnection of these network extensions at sea could lead to a genuine extension of the onshore interconnected network into an offshore interconnected network. An even more challenging vision is presented in [Ref 50], which presents an outline of a trans-European network, connecting wind farms from the Atlantic Ocean to the Baltic Sea with the main areas in Europe (see Fig. 27). The likelihood of realising this vision is unclear, as it would be enormously costly. On the other hand wind energy is one of the very few energy sources whose cost is likely to remain stable or decrease in the future. As it is very likely that the costs of fossil-fuel and nuclear energy will increase significantly in the future, the opportunities to achieve a larger proportion of renewable energy in Europe, including offshore wind energy, will also increase. If project developers are unable to develop a common approach to grid connection or an offshore grid, than government intervention may be the best means to realise these goals.

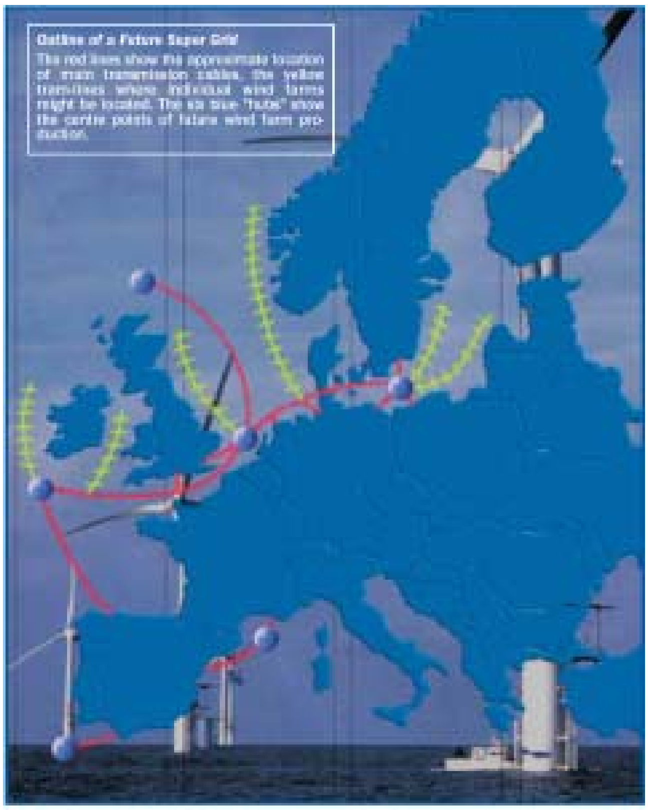


Fig. 27: Vision of a new high voltage 'super grid' to transmit wind power through Europe. See [Ref 50].

The development of renewable energies has to be seen in the context of the rising cost of all conventional energy sources. The price for crude oil as the major world wide energy source influences the price of all other energy sources that are traded. During 2004, consumers in European countries experienced a sharp increase in gas prices as a consequence of the rising price of crude oil. The uncertain political and security situation in the main oil-producing region in the world, the Middle East, increases uncertainty over the price of oil.

Besides the obvious increase in petrol prices, the price of electricity has risen steadily over the last few years (for example, in Germany in 2004 the price of natural gas rose for the domestic consumer by 8% on average, while the price of electricity rose by 4.4% for domestic consumers and 4% for industry). By contrast, the price of wind energy is not determined by external factors such as political instability in producing regions or rising energy demands elsewhere in the world. This is the background against which the likelihood of increased economical viability of renewable energy sources must be seen. While the price of fossil-fuel energy will very likely continue to rise in the future, the costs of wind energy will decrease. This prediction has actually been enshrined in law in the country, which currently has the highest installed wind energy capacity in the world, Germany. The purchase price for produced energy set by the German Renewable Energy Law, which is a tariff compensation system rather than a quota system, decreases each year for new wind farms. For existing wind farms, the price will not rise in parallel with the conventional energy market; rather it is fixed for the operational period of the wind farm at two levels: between five and 20 years after installation the price will drop from the initial level by approximately 30–40% for the remaining operating period, depending on the specific wind conditions of the site. Moreover, the price does not rise with inflation, so in real terms it will continue to fall.

6.2 Political measures

The main existing obstacles to the implementation of offshore wind farms lie in the area of grid connection. The submarine cables will have to cross shipping routes and possibly marine protected areas. If the parties involved cannot agree on cable routes, the offshore grid connection will need to be secured by political measures. In the German Bight, for example, approvals will soon be given for the installation of a small number of submarine cable routes, having capacities of 150 – 250 MW. On the one hand these approvals are required to promote the installation of the first offshore wind farms in this area of the North Sea. On the other hand there is a danger latent in the approval of a number of small-capacity cables – namely that the parties involved in the approval process, such as shipping and nature preserve authorities, may obstruct further installations so as to prevent too large a number of cables from being laid.

The solution to this problem could be a development plan either for installation of a combined offshore interconnected network to which different wind farms could connect, or for the approval of large-capacity cable routes, around which proposed wind farms would have to be concentrated.

A related problem is that the installation of large-capacity offshore cable routes requires planning security. Often wind farm development companies are not in a position to give this planning security, as they are too small to insure against potential losses on large investments. A potential investor for large-capacity offshore transmissions will need the security, that all wind farms that are proposed to connect to his system will be build and operated. As long as this is not guaranteed, the planning situation is too insecure to attract possible investors in submarine cable projects.

One solution to this situation would be a state guarantee to enable the installation of an offshore grid extension without the need for wind farm projects to have finalised approvals and finance. With the certainty that an offshore grid connection point would be provided, project development companies would have a secure basis on which to construct their wind farms. For example a number of smaller wind farms, each of 100–200MW, could focus on a common connection to a 0.8GW or 1GW cable system.

6.3 Programmes, networks and incentives

Programmes, co-operative networks and initiatives are increasingly developing on a European level, comprising bodies from several European countries and representing a range of specialist disciplines. These activities offer important opportunities to share knowledge, to discuss problems and generate solutions, besides forming a basis for lobbying and pressure groups, which can represent a common point of view. In most cases useful synergies can be achieved. Such activities are of special importance in terms of increasing public acceptance by communicating the facts about offshore wind energy. Some examples of recent activities are given below:

Pushing Offshore Wind Energy Regions (POWER), an EU Project in Interreg III B Programme – North Sea Region (2004–07)[18]

By establishing a common platform for discussion, exchange and transnational initiatives, POWER aims at helping the North Sea regions to develop offshore wind energy‘s economic and technological potentials. For example, the work package ‘Planning and Participation’ will "*cover improved integration of the different planning systems of the Member States bordering the North Sea. Its aim is to harmonise planning and information strategies for offshore wind farms in compliance with existing government legislation, in particular environment and nature protection legislation.*

The second work package aims to encourage the offshore wind industry to establish and develop the offshore wind supply chain. A network of centres of excellence in the sector will be created. Experiences in the offshore oil and gas industry, as well as the onshore wind energy sector in the North Sea region, will be useful.

The third work package will cover the needs of the offshore wind sector as regards qualification and further training of specialised personnel and skilled workers within the complete supply chain. The work package will develop employment opportunities in the offshore wind industry and its suppliers in structurally weak regions.

The fourth work package aims to support the exchange of best practice examples and the transfer of know-how both between project partners and with other actors in the North Sea region. Brochures, a website and a travelling exhibition will inform the general public."

Concerted Action for Offshore Wind Energy Deployment (COD) (2003–05)[19]

"*The objective of the COD initiative is to speed up the implementation of offshore wind energy in the EU by early identification and possible removal of non-technical barriers involving legal, administrative, policy, environmental and electrical infrastructure issues. COD*

[18] http://www.kopenmunt.nl/documents/kopenmunt/news/bis-windpowerflyer.pdf at 10/02/2005
[19] http://www.offshorewindenergy.org/ at 10/02/2005

aims to provide a harmonised European process for EIA, permission procedures, deployment and grid integration of offshore wind energy farms.

COD is steered by a Ministerial Committee, with members from the Energy Ministries of the United Kingdom, Ireland, Sweden, Denmark, Germany, Poland, and the Netherlands. The Chairman is Michel Verhagen (Netherlands Ministry of Economic Affairs).

COD work is carried out by a Working Group that is co-ordinated by Ruud de Bruijne (Netherlands Agency for Energy and the Environment). Assistance is provided both to the Ministerial Committee and to the Working Group by an Advisory Board consisting of representatives from industry and NGOs.

The COD Working Group gathers all available information on environmental impacts, legal issues and conflicts of interests with other sea users. This information is made accessible via the Internet. Throughout 2004 and 2005, the Working Group is analysing this information and using it for benchmarking and to produce guidelines."

COD began on 1 January 2003 and will end in 2005. The COD database may be downloaded from www.offshorewindenergy.org/ (10/02/2005).

Structural and Economic Optimisation of Bottom-Mounted Offshore Wind Energy Converters (Opti-OWECS) (granted 1996–97)[20]

"*The Wind Energy Section of the Faculty of Civil Engineering at Delft University of Technology, the leading institution of higher technical education in the Netherlands, co-ordinated the Opti-OWECS programme. Two groups co-operate closely in the field of offshore wind energy: the Wind Energy Section (SWE, formerly Institute for Wind Energy) and the Offshore Technology Workgroup (WOT). The extent of the collaboration has grown and the two groups have worked closely together within the JOULE III project "Opti-OWECS JOR3-CT95-0087". Within the proposed project both groups will act as one contractor, denoted Delft University of Technology, under the lead of the SWE. The SWE has been involved in wind energy research and education since 1976 and has experimental facilities in an open jet wind tunnel as well as an open-air test facility. The theoretical research is focused on integrated offshore wind farm design, aerofoil and rotor aerodynamics, turbulent wind field description and structural dynamics.*

Since 1992, offshore wind energy has been an increasingly important research subject for the SWE, leading to the development of a design tool for offshore wind turbines: DUWECS. Recently, the application of this code to actual offshore wind turbines has been demonstrated in the first Dutch offshore wind farm at Lely. Moreover, previous and ongoing research covers operation and maintenance as well as structural and economic optimisation of offshore wind turbines. The SWE has ample experience in both theoretical and experimental research and project coordination gained through a number of European R&D projects within the framework of JOULE, including the Opti-OWECS (co-ordinator), OWTES (principal contractor), OWEE (co-ordinator) and NewGust (co-ordinator) projects."

Concerted Action on Offshore Wind Energy in Europe (CA-OWEE) (1999–2001)[21]

[20] http://www.offshorewindenergy.org/txt2html.php?textfile=ca-owee/indexpages/info/Project_Partners.txt - 1 at 10/02/2005
[21] http://www.offshorewindenergy.org/ at 10/02/2005

"*The objectives of this project were to define the current state of the art of offshore wind energy in Europe through gathering and evaluation of information from across the continent, and to disseminate the resulting knowledge to all interested, in order to help stimulate the development of the industry. The project was funded by the European Commission and was completed at the end of 2001*." The knowledge gathered is freely available on the Internet at www.offshorewindenergy.org/.

The project divided offshore wind energy into five subject clusters:

1) Technology of wind turbines and support structures

2) Grid integration, energy supply and financing

3) Resources and economics

4) Activities and prospects

5) Social acceptance, environmental impact and politics.

Conclusions from these surveys were used to develop recommendations for the RTD strategy for Europe.

The project's 17 partners came from 13 countries active in offshore wind energy, thus covering the majority of the European Community's coastline. The partners covered a wide range of expertise and included developers, utilities, consultants, research institutes and universities.

Wind Energië op Zee / Wind Energy at Sea (We@Sea) (2004–08)[22]

The consortium We@Sea has planned and proposed a research and development programme, 'Large-scale wind power generation offshore: towards an innovative and sustainable business', within the framework of the Dutch subsidy programme Bsik (Besluit subsidies investeringen kennisinfrastructuur). The main objective of the consortium is to increase knowledge and to improve and accelerate large-scale development of offshore wind energy in the North Sea, thereby contributing to the Dutch Government's ambitious target to install 6GW of wind power capacity offshore by 2020.

"*The research and development programme consists of seven parts:*

1. *Integration and scenarios*
2. *Offshore wind energy technology*
3. *Layout planning and environmental aspects*
4. *Energy transport and distribution*
5. *Energy market and finance*
6. *Construction, use, maintenance and teardown*
7. *Education, training and passing through knowledge*

Concrete outputs of the knowledge programme are:

[22] http://www.we-at-sea.org/ at 10/02/2005

- *Cost-effective scenario(s) for installation, and for operation and maintenance*
- *A site atlas containing all relevant, site-specific information*
- *Cost models and models for decision support during daily operation*
- *A decision support tool for site selection*
- *Validated design tools and design tool benchmarks*
- *Recommendations for the application of standards and guidelines*
- *Specifications of new, potentially better concepts*
- *Tools for optimal wind power station design and control*
- *Concepts for an optimal interconnection electricity grid offshore to onshore and insight in transient behaviour*
- *A concept describing the required port capabilities and facilities, including costs and a plan of action*
- *Life cycle analysis of wind power plants*
- *Environmental impact assessment*."

Wind Energy R&D Network (December 2001 – May 2005)[23]

"*The Wind Energy R&D Network is a European Commission funded project, coordinated by the European Wind Energy Association (EWEA), with the overall aim of ensuring that EU-funded wind energy RD&D meets the needs of the European wind industry to maintain and increase its competitiveness in EU and external markets.*

The Wind Energy R&D Network comprises strategy discussion groups, which meet on a regular basis for workshops. Further discussion and dissemination of information is carried out on the network's dedicated website. Crucially, these discussions enable direct exchange of information and views among actors from across the industry. Participants may choose to join one of the four groups: End Users and Utilities; Financiers and Insurers; Turbine and Component Manufactures: and Research and Testing Centres.

At present the wind energy R&D community has no detailed common strategy. International co-operation among research institutes, manufacturing industry, financial institutions and end users – through the Wind Energy Network – identifies the key barriers facing wind energy development, and specifies R&D actions to overcome these.

Further R&D is required to achieve the levels of wind penetration outlined in EWEA's Windforce 12 – A Blueprint to Achieve 12% of the World's Electricity by 2020. Continued European dominance of the global market can only be achieved with increased R&D into new technology, policy support options, and markets.

The objectives of the Wind Energy R&D Network are as follows:

1. *To optimise EU-funded industry research, to formulate requirements for European policy and to formulate innovation in the European policy.*
2. *Facilitate exchange of information between the European Commission and the wind industry.*

[23] http://www.ewea.org/06projects_events/proj_WE_RD.htm at 01/03/2005

3. Formulate a cross-industry strategy, to minimise redundancy through replicated efforts.

4. Reduce the costs of onshore and offshore generation."

In the following appendices information is provided by title, author, publisher and publication date wherever possible. In most cases, key words and objectives are given. Though, depending on accessibility some of these information may not be provided at present. Most of the following information originates directly – sometimes as a quote – from the corresponding report, even if not especially marked as such. Hence copyrights for the most part belong to the author(s) and/or publisher listed.

Appendix A

- Reports on EIA and documentation referring directly to impacts of offshore wind energy matters onto the marine environment -

1 The potential effects of EM fields generated by cabling between offshore wind turbines upon *Elasmobranch*

Authors: Gill, A.B., Taylor, H.
Publisher / Date: Countryside Council for Wales CCW / 2001-09-00
Keyword(s): fish, EMF, *Elasmobranch*

This report assesses the potential effects of electromagnetic fields generated by cabling between offshore wind turbines upon *Elasmobranch* fishes. The report contains four main sections:

1. A review of the literature relating to electro-reception in *Elasmobranchs* and relevant literature on offshore wind farm developments.

2. A review of the current situation regarding offshore wind developments focussing on their environmental impacts with particular implications for British elasmobranches.

3. A summary of the current status and extent of relevant biological knowledge of British *Elasmobranchs*.

4. A pilot study which experimentally demonstrates the response of the benthic *Elasmobranch*, the dogfish *scyliorhinus Canicula*, to two electric fields, one simulating prey and the other the maximum potential output from unburied undersea cables.

Finally, the report provides recommendations for future research considerations.

2 Utgrunden offshore wind farm - measurements of underwater noise

Author(s): Lidell, H.
Publisher / Date: Ingemansson Technology AB / 2003-06-17
Keywords: noise, vibration

This project was initiated in order to achieve a better understanding on how offshore based wind farms affect the underwater noise. The main reason is to gain knowledge on how marine wildlife could be affected by this kind of installation. The measurements were performed at Utgrunden wind farm that is situated at the reef Utgrunden on the Swedish southeast coast. The farm consists of seven 1.5 MW turbines. Three hydrophones registered the underwater sound and four accelerometers the tower vibrations. The measurement campaign was conducted during a period from November 2002 to February 2003.

The objectives within this project were to answer the following issues:

1. What is the character of sound from a single power station?
2. What are the sound generating mechanisms in the turbine?
3. How does the sound attenuate with increasing distance at different frequencies?
4. How does the sound pressure level vary with increasing wind speed?
5. How does sound from different power stations interfere with each other and influence the over all sound image?
6. How is a passing ship influencing the sound level in the farm?

Suggestions were provided for further activities. Activities mentioned regard to:

- Particle acceleration measurements/calculation
- Interference measurements
- Noise reduction measures

The represented picture origins from the report itself.

3 The effects of marine wind farms on the distribution of fish, shellfish and marine mammals in the Horns Rev area

Author(s): Hoffmann, E., Astrup, J., Larsen, F., Munch-Petersen, S., Strottrup, J.
Publisher / Date: Institute for Fisheries Research / 2000-00-00
Keywords: fish, shellfish, marine mammals

In relation to the proposed establishment of an experimental marine wind turbine park at Horns Rev, ELSAMPROJEKT conducted an Environmental Impact Assessment. As a contribution to this EIA, the Danish Institute for Fisheries Research (DIFRES) has been contracted by ELSAMPROJEKT to provide a quantitative description of the fish and shellfish fauna in the area and to evaluate the effects of the wind turbine park on fish, shellfish and marine mammals.

The purpose of the report is:

- to give a quantitative description of the abundance of the fish and shellfish in the area surrounding the wind turbine area and to evaluate the effects of the physically presence of the wind turbines on the abundance of fish and shellfish in the area
- to evaluate the artificial reef effect in the wind turbine area
- to evaluate the effects of noise and electromagnetic fields on the abundance of fish and marine mammals

The description of the fish fauna in the Horns Rev area is based on eleven years trawl surveys. The most common species are dab, plaice, hooknose, whiting, dragonet and grey gurnard. A total of 42 different fish species are listed. The relative abundance of the ten most common species is given for three different areas within and outside the wind turbine area. These mean figures indicate some systematic differences among the three areas for species like plaice, hooknose, whiting and gobies. However, there have been large fluctuations from year to year in the abundance of the species.

The effects on fish, shellfish and marine mammals are within the report divided into:

- Effects of the physically presence of the wind turbines
- Artificial reef effects
- Effects of noise
- Effects of magnetic fields

Each of these topics is divided into sub-chapters, closing with concluding remarks each.

4 Assessment of the effects of offshore wind farms on birds

Authors: Percival, S.M.
Publisher / Date: Ecology Consulting - DTI / 2001-00-00
Keywords: bird collision risks, barrier effects

This report seeks to review current knowledge of the effects that offshore wind farms have on birds and to identify sensitive offshore locations where bird conservation interests and wind energy development may conflict. It seeks to provide information for all stakeholders in the development of offshore wind farms. The specific objectives of the project were to

(i) produce a review of all available reports, data and information relating to the effects of offshore wind farms on birds,

(ii) establish the locations of offshore sites and areas that hold important birds populations,

(iii) identify the bird migratory routes that may encroach upon prime offshore wind energy development areas,

(iv) identify gaps and uncertainties in the existing knowledge and recommended further studies that are needed to address these,

(v) provide an inventory of planned and ongoing studies,

thereby focusing in specific on the national situation within the UK.

5 Offshore Wind Energy and Noise Monitoring

Authors: Verhoef, J.P., Westra, C.A., Nijdam. R.J., Korterink, H., Eecen, P. J.
Publisher / Date: ECN - research Centre of the Netherlands / 2003-04-00
Keyword(s): bird collision risks

This report focuses on demonstrating the appropriate and target oriented operation of the automatic bird collision registration system (WT-BIRD) that has been developed by ECN. This is an important investigation, as an inventory on bird's detection systems and methods shows a lack of appropriate methodologies to study bird victims caused by wind turbines. The system must be relatively inexpensive, robust and applicable for offshore conditions. The system identifies bird impacts by noise measurements and a camera identifies the specific species. The system can also distinguish between turbine specific sounds and a collision of a bird against tower, nacelle and rotor. The ECN bird collision registration system is proven to be a very promising way to detect and record bird collisions against wind turbines. The first experimental results are good. This way of detecting the collisions of birds can be very useful for the future implementation of offshore wind farms. An inventory on bird's detection systems and methods shows a lack of appropriate methodologies to study bird victims caused by wind turbines [Ref 6]. That's one of the reasons why ECN started the development of an automatic bird collision detecting system called WT-Bird [Ref 7]. [Ref 8]

The photo origins from the report itself.

6 Assessment of the effects of noise and vibration from offshore windfarms on marine wildlife

Author(s): Velly, G., Rushforth, I., Mason, E., Hough, A., England, R., Styles, P., Holt, T., Thorne, P.
Publisher / Date: Department of Trade and Industry –DTI / 2001-00-00
Keywords: noise, vibration

Key focus of this study was to assess the effect of noise and vibration from offshore wind farms on marine wildlife. The key aims being to review relevant studies, reports and other available information, identify any gaps and uncertainties in the current data and make recommendations, while outlining methodologies, to address these gaps.

To determine and investigate the environmental effects of offshore wind farm development, a range of generic impacts on marine wildlife are addressed in this report, which are:

- Characterisation of noise and vibration generated by offshore turbine operation and construction activities
- Propagation and attenuation of noise and vibration above and below the surface
- Prediction of noise levels at the shoreline and impacts on marine wildlife
- Likely range of background noise above and below the surface
- Identification of the range of noise sensitive marine species most at risk to noise and vibration impacts related to UK offshore wind farms
- The effects of noise and vibration on marine species
- The extend to which offshore wind turbines may provide physical protection and new habitat opportunities

The conclusion and recommendations can be outlines as follows:

On the basis of the available data, pinniüeds (seals) and odontocetes (toothed whales) are likely to show initial avoidance to wind farms, followed by habituation and possibly attraction to wind farms as feeding grounds. The reaction of mysticetes (baleen whales) is unknown in the absence of data regarding their audible sensitivity. However, it is possible that they will show a behavioural response to the low frequency sound wind farms are likely to produce. The significance of this response will depend upon the proximity of wind farms to whale migratory routes.

From the information available for operating offshore wind farms and other noisy offshore structures such as oil and gas platforms, it is expected that effects on fish population dynamics will be determined by immigration/attraction of fish to wind farms following constructions. No adverse impacts on marine invertebrates are expected by the noise and vibration generated by turbines.

However, the full effects of offshore wind farms on marine wildlife, particularly mammal, fish and migratory fish behaviour and ecology can only be useful determined through further monitoring. Additional studies into the effects of offshore wind farms on marine species are therefore recommended.

7 Visual and radar observations of birds in relation to collision risk at the Horns Rev offshore wind farm

Authors: Christensen, T.K., Clausager, I., Petersen, I.K. Hounisen, J. P.
Publisher / Date: NERI / 2004-00-00
Keyword(s): Birds, IEA

The aim of the project is to assess the collision risk between birds and wind turbines at the Horns Rev wind farm. In 2003 the studies focused on describing bird movements in relation to the wind farm and to identify the species-specific behavioural responses towards the wind turbines shown by migrating and staging species. The Horns Rev area lies in a region known to be important for substantial water bird migration as well as holding internationally important numbers of several wintering and staging water bird species. Theoretically, birds approaching the wind farm may:

- pass through the wind farm
- increase flying altitude and pass above the wind farm
- change direction and pass around the wind farm

The present study is restricted to the period after the construction of the wind farm. For practical reasons, data from the pre-construction period was not collected. Consequently, no base-line studies of bird movements in the area prior to establishment of the wind farm are available to which the present data can be compared.

8 Ökologische Begleitforschung zur Windenergienutzung im Offshore-Bereich auf Forschungsplattformen in der Nord- und Ostsee - BEOFINO

Authors: Dr. Knust, R., Dr. Heuers, J.
Publisher / expected Date: Alfred-Wegener-Institut, Bremerhaven / expected 2005
Keyword(s): birds, collision, benthic community, emf, electro-magnetic

The main focus of the project is to investigate possible impacts of future offshore windturbines on the marine environment and to develop methods and criteria for the evaluation of such impacts. The following compartments will be taken into account:

- Impact of the wind turbines on birds migration and collision risk of birds with the turbines
- Impact of the wind turbines on the benthic community near the piles
- Impact of electro-magnetic fields on marine organisms

9 MINOS - Marine Warmblüter in Nord- und Ostsee: Grundlagen zur Bewertung von Windkraftanlagen im Offshore-Bereich – Marine mammals in the North and Baltic Sea: Fundamentals for evaluation of wind energy converters in offshore applications

Authors: Eskildsen, K:, Adelung, D., Benke, H., Dehnhardt, G., Garthe, S. Kellermann, A., Lucke, K., Scheidat, M., Siebert, U., Verfuß, U., Wilson, R.
Publisher / Date: Landesamt für den Nationalpark Schleswig-Holsteinisches Wattenmeer / 2004-00-00
Keyword(s): birds, mammals, Harbour Porpoise *Phocoena phocoena*, Common Seal *Phoca vitulina*, Grey Seal *Halichoerus grypus*

The erection of high power wind turbines in the offshore area will lead to additional impact on the marine ecosystem. The construction of offshore wind parks and the assessment of their effects on the environment are new territory for all concerned. The results of investigations from other countries can not always be applied to the conditions prevailing in German coastal waters. The basic information needed for a comprehensive evaluation of the impact of wind parks is not yet available. The most clearly formulated objection to offshore wind parks is the effects they might have on bird life and marine mammals. The Harbour Porpoise (Phocoena phocoena), Common Seal (Phoca vitulina), Grey Seal (Halichoerus grypus) and the birds roosting in the offshore area are thus at the center of the investigations in the interdisciplinary "MINOS" project. The project will supply information on the populations of birds and marine mammals in the offshore area including:

I. their population size

II. their temporal-spatial pattern of utilisation

III. their reactions to the effects of noise pollution.

The information gathered during the project will fill essential gaps in our knowledge and will form the basis for the evaluation of the impact of wind turbines on the marine environment in the offshore area.

Within the project there are several relevant sub projects being conducted. For each the subject of research and the project leader(s) shall be given below. In the most cases there does not exist a final report by the time being as the projects still are of an ongoing:

1. Effects of acoustical emissions of offshore wind turbines onto marine mammals in the German North Sea and East Sea
   - PD Dr. Guido Dehnhardt, Fakultät für Biologie, Allgemeine Zoologie und Neurobiologie, Ruhr-Universität Bochum
2. Assessment of the density and distribution of harbour porpoise (*Phocoena phocoena*) in the German North Sea and East Sea
   - Dr. Ursula Siebert, Forschungs- und Technologiezentrum der Christian-Albrechts-Universität Kiel
   - PD Dr. Karl-Hermann Kock, Bundesforschungsanstalt für Fischerei, Institut für Seefischerei
3. Investigation into the special distribution by harbour porpoise in the North Sea and East Sea by aid of acoustical methods (POD's)
   - Dr. Harald Benke, Deutsches Meeresmuseum Stralsund
4. Inter-calibration of different methods to assess the occurrence of harbour porpoise within the nature reservation area National Park of the Schleswig-Holstein Wadden Sea
   - Dr. Ursula Siebert, Forschungs- und Technologiezentrum der Christian-Albrechts-Universität Kiel
5. Offshore wind farm utilisation and the occurrence of migratory birds in German waters: Analysis of the conflict potential at the example of the Eastern German Bay (North Sea) and the Pommersche Bay (East Sea)
   - Dr. Stefan Garthe, Forschungs- und Technologiezentrum der Christian-Albrechts-Universität Kiel
6. Investigation into the special and tidal utilisation of the Schleswig-Holstein Wadden Sea and the bordering areas by common seals (*Phoca vitulina vitulina*) and grey seal *(Halocoerus grypus)*
   - Dr. Rory Wilson, Institut für Meereskunde

7. Coordination and combination of data
   - Dr. Adolf Kellermann, Landesamt für den Nationalpark Schleswig-Holsteinisches Wattenmeer

10 2nd Status for the project entitled: Investigations on the artificial reef effect on fish from marine wind turbine park at Horns Reef

Authors: Unknown
Publisher / Date: Danish Institute for Fisheries Research / 2002-01-00
Keyword(s): fish, plaice, whiting, sandeel

The objectives of this investigation are:

- to study fish attraction relative to single wind turbine structures and to the wind turbine park
- to study the potential fish production enhancement of single wind turbine structures and of the wind turbine park.

The first project year is the baseline study and will be based on data from 2 fishing surveys, an early spring and late summer survey.

11 Monitoring effects of offshore windfarms on harbour porpoises using PODs (porpoise detectors)

Authors: Teilmann, J., Damsgaard Henriksen, O., Carstensen, J., Skov H.
Publisher / Date: Ministry of Environment and Energy / 2002-02-00
Keyword(s): harbour porpoises, porpoises detection system, POD

The study was conducted with the aim of giving the best advise on usability, data collection, statistical methods and experimental design when using PODs

The aim of this report is to summarise the present experience with PODs under controlled conditions and in the wind farm areas. The data collected under controlled conditions will be used to evaluate variations in the sensitivity between and within PODs as well as documenting how selective T-PODs are in recording harbour porpoise sounds. The POD data collected in the field are compared with visual surveys to see if changing animal density is correlated with echolocation activity. The collected POD data is also used to select indicators and the most appropriate statistical model. Finally a design for a monitoring program is discussed as well as recommendations for future work with PODs.

Specific aims of the study are:

- to test the reliability of recorded T-POD-data in controlled conditions with and without captive animals
- to test the directionality and inter-differences between T-PODs using artificial and recorded harbour porpoise echolocation signals
- to compare visual observations with T-POD data to document whether echolocation activity reflects the density of animals
- to develop statistical methods for analysing POD data
- to develop a robust monitoring design for detecting effects of offshore wind farms on harbour porpoises

- to document the present knowledge of POD research during an international workshop

12 Use of the North Sea by Harbour Seal with special emphasis on the Horns Reef area

Authors: Tougaard,S., Tougaard, J.
Publisher / Date: Fisheries and Maritime Museum, Esbjerg / 2004-04-00
Keyword(s): harbour seal GPS, GSM
This report addresses the test of prototype GPS/GSM-transmitter on harbour seals in the Sealarium, Esbjerg. Therefore a combined GPS-receiver and GSM mobile phone transmitter designed for deployment on wild seals was tested on a captive harbour seal. The unit has been under development in recent years and consists of a GPS-unit for positioning and a GSM mobile phone unit for transmission of logged positions to land. The test took place in the Sealarium at the Fisheries and Maritime Museum, Esbjerg. The unit was glued onto the fur on the head of the seal, where it stayed on for 13 days. Only one position was acquired by the unit and it failed to connect to the GSM-net during the test. Technical information from the constructor of the unit is not available and it is thus not possible to conclude on the reasons why the unit did not function as intended. The behaviour of the seal can however, be ruled out, as close observation and registration of the seals dive behaviour during the first days of deployment showed that the unit was free of the water for sufficiently long periods for positions to be acquired.

13 Sandeels in the wind farm area at Horns Reef

Authors: Jensen,H., Kristensen, P. S., Hoffmann, E.
Publisher / Date: Danish Institute for Fisheries Research / 2004-08-00
Keyword(s): sandeels, *A. tobianus, H. lanceolatus, A. marinus*

This report summarises preliminary results from a survey carried out in the Horns Reef area in March 2004 and contrast these results to those from a previous survey carried out in February/March 2002. The surveys were designed to analyse the effect, if any, of the construction of a wind farm on sandeels in the area. The 2002 survey was done prior to construction of the wind turbines and the 2004 survey was done after the construction of the wind turbines. There are no indications that the construction of the wind farm has had any effect on the sediment composition in the impact area (the wind farm area). Especially there was no indication that the content of the finest particles, the Wentworth sediment classes silt/clay and very fine sand, has increased in the impact area from 2002 to 2004. In this respect the construction of the wind farm is not likely to have had any effect on sandeels in the area of the wind farm. The effect of the wind farm on sandeels was evaluated on the basis of changes in distribution and densities of all species of sandeels combined, as there is no information available to suggest that the possible effects, if any, on sandeels of the construction of a wind farm is dependent on the species.

14 Sandeels and clams (Spisula sp.) in the wind turbine park at Horns Reef

Authors: Jensen,H., Kristensen, P. S., Hoffmann, E.
Publisher / Date: Danish Institute for Fisheries Research / 2003-04-00
Keyword(s): sandeels, clams, *Spisula sp., A. tobianus, H. lanceolatus, A. marinus*

In order to investigate the impact, if any, of the construction of the wind turbine park on sandeels and shellfish in the area of the wind turbine park the following field programme has been suggested by DIFRES:

- a survey before the construction of the wind turbine park
- a survey 1 year after the construction of the wind turbine park
- a survey 2 and/or 3 years after the construction of the wind turbine park.

During the surveys the relative densities of sandeels in the seabed should be measured at fixed sample locations in the area of the wind turbine park and in a control area in the region of the wind turbine park outside the impact area. The sediment composition at the sample locations should be determined from analyses of sediment samples collected at the same locations as where sandeels and shellfish densities are measured.

The purpose of this report is to evaluate the results of the survey carried out in February and March 2002 before the wind turbine park was constructed and hence also may serves as

base line survey of the EIA.

15 Infauna Monitoring Horns Rev Offshore Wind Farm Annual Status Report 2003

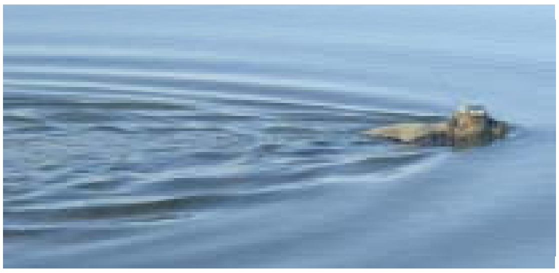
Authors: Bech, M., Leonhard, S.B., Pedersen, J.
Publisher / Date: Bio/Consult A/S / 2004-05-13
Keyword(s): benthic fauna, indicator organisms

The monitoring programme of the benthic fauna was carried out in September 2003 after the wind farm had become operational. Baseline surveys for the present monitoring programme were conducted in the wind farm area on three occasions prior to the construction of the offshore wind farm: spring 1999, spring 2001 and September 2001. In designated reference areas, surveys were conducted in spring 1999 and September 2001. The reference areas in 1999 and September 2001 were placed at two different geographical locations because the survey in September 2001 was planned to be a part of a fish-monitoring programme. Assessment of possible impacts of the establishment of the wind farm was mainly done by comparing results from September 2003 with the results from the baseline study conducted in September 2001. The survey in September 2003 included collection of bottom fauna at 6 turbine sites, a total of 18 stations in the wind farm, and at 6 stations in a designated reference area outside the wind farm area. The stations in the wind farm were situated respectively 5, 25 and 100 meters in a leeward direction from the scour protection of the wind turbine towers at each turbine site. Scuba divers collected the bottom samples. Additional samples were collected for sediment analysis.

In 2001, results revealed that the following species could be used as indicator organisms of environmental changes in the wind farm area due to relative uniformity in dominance relations: *Pisione remota*, *Goodallia triangularis*, *Goniadella bobretzkii, Ophelia borealis, Orbinia sertulata* and *Nephtys longosetosa*. The character species *Spisula solida*, although dominant in biomass, showed a more aggregated distribution in 2001. In September 2003, the surveyed areas were characterised by the presence of character species such as the bristle worm *Goniadella bobretzkii* and the mussels *Spisula solida* and *Goodallia triangularis*, because they were the most important species in respect of abundance or biomass. Other character and appointed indicator species such as *Ophelia borealis* and *Nephtys longosetosa* were less common or absent compared with previous surveys. The main difference between the survey in 2001 and in 2003 was the decline of the *Pisione remota* population and an increase in the population of *Goodallia triangularis.* Presence of new species to the infauna community at Horns Rev, the bristle worms *Euzonus flabelligerus* and *Polygordius appendiculatus*, typically associated with coarse sand, might be a result of changes in sediment characteristics towards coarser sediments.

16 Satellite tracking of Harbour Seals on Horns Reef - Use of the Horns Reef wind farm area and the North Sea

Authors: Tougaard,S., Ebbesen, I., Tougaard, J., Jensen, T., Teilmann, J.
Publisher / Date: Fisheries and Maritime Museum, Esbjerg / 2003-03-00
Keyword(s): harbour seal, *Phoca vitulina*, GPS, GSM



Background for the studies is the construction of the Worlds largest off shore wind farm on Horns Reef. Based on previous studies using VHF-transmitters, it was expected that the seals would spend considerable time on Horns Reef. The VHF-telemetry studies showed that the preferred direction for seals leaving the Danish Wadden Sea is NW from Grådyb tidal area outside Esbjerg, the direction directly towards the wind farm area. The previously used VHF-transmitters had a limited detection range and it was decided to equip a number of seals from the same area as before with satellite transmitters. This allows for positioning of the seals in the entire North Sea as well as providing dive summary information, as a transmitter with a depth transducer was chosen for the study.

The image origins from the discussed report itself.

17 Offshore-Windenergieanlagen und Vogelschutz

Authors: Exo, K. M., Hüppop, O., Garthe, S.
Publisher / Date: SEEVÖGEL, Zeitschrift Verein Jordsand, Hamburg Band 23, Heft 4 / 2002
Keyword(s): birds

There are two internationally important areas for seabirds and coastal birds off the German North Sea coast: the Eastern German Bight and the sea stretch seawards off the East Frisian Islands. Important areas along the Baltic coast comprise sea inlets in Mecklenburg–West Pomerania including the Szczecinski lagoon, Pomeranian Bay, as well as large parts of the Bight of Lübeck and Kiel Bay. Every year during migration, tens of millions of birds cross the North Sea and the Baltic Sea on their way from breeding grounds to wintering areas and back. Both seas are part of global flyway systems. The erection of wind facilities offshore can have the following adverse affects on birds: (1) risk of collision with wind turbines; (2) short-term habitat loss during construction; (3) long-term habitat loss due to disturbance by wind turbines including disturbances from sailing activities in connection with maintenance; (4) formation of barriers on migratory routes; and (5) disconnection of ecological units, such as roosting and feeding sites of local birds. To evaluate conflict potentials of individual parameters, we should know the distribution of birds at proposed wind plant locations and details of their behaviour, in particular flight altitudes above sea level, perceptibility of wind turbines and species-specific sensitivities. To analyse the latter, elaborate behavioural investigations should be carried out on pilot wind power facilities.

18 Bird numbers and distribution in the Horns Rev offshore wind farm area

Authors: Christensen, T.K., Clausager, I., Petersen, I.K.
Publisher / Date: NERI / 2004-00-00
Keyword(s): birds

Main focus of the report lies on the utilisation of the Horns Rev wind farm area and surroundings by birds, pre- and post construction of wind turbines. This report presents data from six aerial surveys of birds in the Horns Rev wind farm area in 2003. Including 16 surveys conducted before construction of the wind farm started and three during the construction phase, a total of 25 surveys have been performed in the area since August 1999. The operational phase of the wind farm commenced in 2002. Hence the six surveys from 2003 are all considered post-construction data sets. A preliminary evaluation of the potential impact of the wind turbines on bird distributions has been carried out by comparison of these data to those from the 16 pre-construction surveys.

The installation of wind turbines was finished in autumn 2002. Hence, the annual status reports for 2003 merely represent data from one year during the initial operational phase of the wind farms. Thus, natural variation between years, seasons, species and sites and the possible habituation effects during the operational phase could not be considered. Therefore, it must be emphasized that the tendencies, suggested by the results are to be considered as preliminary, and must await further compilation of data, before firm conclusions can be drawn with respect to impact on birds. The final environmental impact assessment is planned to be undertaken upon termination of the environmental monitoring programmes in 2006.

19 Hard Bottom Substrate Monitoring Horns Rev Offshore Wind Farm 2004

Authors: Frederiksen, R.
Publisher / Date: Bio/consult A/S / 2004-05-30
Keyword(s): Hard Bottom Substrate, *Jassa marmorata*, *Mytilus edulis*, *Telmatogeton japonicus*

In connection with the implementation of the monitoring programme concerning the ecological implication of the effect of the introduction of hard substrate related to the Horns Rev Wind Farm, the third survey was carried out in the period 24–31 March 2004. The survey covered collection of fauna and flora samples from the scour protection and at the wind turbine towers at six turbine sites. Video recordings were planned at different sites to provide documentation, but due to poor visibility the video recordings were postponed. On request from Elsam Engineering A/S video inspections on technical installations were made at turbine `84 and 95. This report covers a short description of the methodology, sampling activities and site description.

20 Harbour Porpoises on Horns Reef - Effects of the Horns Reef Wind Farm

Authors: Tougaard, J., Carstensen, J., Henriksen, O. D., Teilmann, J.
Publisher / Date: NERI Technical Report / 2004-06-00
Keyword(s): harbour porpoise, *Phocoena phocoena,* noise

Occurrence and distribution of harbour porpoises (Phocoena phocoena) in and around the off-shore wind farm on Horns Reef, Denmark, was investigated. This report describes data collected in 2003 as part of an ongoing monitoring program, covering a period before construction of the wind farm (baseline), the construction period in 2002 and one year following construction of the wind farm. Data from acoustic data loggers (T-PODs) and visual surveys conducted from ships confirmed the presence of harbour porpoises inside the wind farm area during all periods investigated. Comparison with baseline data from 1999-2001 and with control areas outside the wind farm did not show a statistical significant change in sighting rates inside the wind farm area in the first year following construction relative to baseline. T-POD data showed a pronounced effect of the construction of the wind farm on the indicators “encounter duration” (measure of how long porpoises remain close to the POD) and “waiting time” (measure of time interval between porpoise encounters. Both parameters seem to indicate higher levels of porpoise activity during construction (encounter duration went up, waiting time went down) compared to baseline. A partial return to baseline levels was seen for these two indicators in 2003. Effects expected especially by wind farm operation were

- changes in habitat
- noise from wind turbines
- noise from maintenance activities

Hence within the study a closed look was laid onto these topics.

21 Short-term effects of the construction of wind turbines on harbour porpoises at Horns Reef

Authors: Tougaard, J., Carstensen, J., Henriksen, O.D., Skov, H. and Teilmann, J.
Publisher / Date: Hedeselskabet, Roskilde / 2003-04-00
Keyword(s): harbour porpoise, *Phocoena phocoena,* noise

Ship based visual surveys and long-term deployment of acoustic dataloggers (PODs) were used to assess short term effects of construction on behaviour and abundance of harbour porpoises (Phocoena phocoena). Most focus was put on mounting of steel mono-pile foundations for the turbines, as they were rammed into the seabed. This type of operation is known to generate very loud underwater sound levels. Combined evidence from animal densities obtained from visual surveys, behavioural observations during surveys and acoustic activity data in and outside the construction area demonstrated effects on the behaviour and abundance of animals on both short-term (hours) and long term (entire construction period) scales. Acoustic activity by the porpoises decreased dramatically on the entire Horns Reef at the onset of ramming operations and returned to higher levels a few hours after each ramming operation was completed. A reduction in abundance close to ramming operations was anticipated, as deterring devices (pingers and seal scarers) were deployed prior to each ramming operation to deter marine mammals from the area and thus protect them from exposure to the loud sound levels generated by the ramming procedure. The changes in abundance and behaviour over large distances are unlikely to be explained by the deterring sounds, which have comparably lower intensities than the ramming sounds and these effects must be attributed to the ramming.

A general effect on the behaviour of animals was seen during the construction period and at distances of up to 10-15 kilometres from the construction site. Compared to observations before and after construction there was a decrease in non-directional swimming, a behaviour assumed to correlate with feeding activity. Animal density estimates indicates that there were fewer animals present on the entire Horns Reef during the construction period compared to observations before and after the construction phase. Whether these changes are attributable to the construction activities or are related to overall temporal variation cannot be determined without further observations in the post-construction period.

22 Environmental impact assessment of an offshore wind park at Rødsand: Technical report on birds

Authors: Kahlert, J., Desholm, M., Clausager, I., Krag Petersen I.
& Ib Krag Petersen
Publisher / Date: National Environmental Research Institute (NERI) / 2000-00-00
Keyword(s): EIA, birds

This report presents the technical background to the ornithological environmental impact assessment for the construction of an offshore wind park at Rødsand ca 10 km southwest of Gedser. Denmark is centrally placed on the East Atlantic flyway and is annually passed by large numbers of migrating birds. Furthermore, Danish waters hold very high concentrations of staging, moulting and wintering waterfowl. In total at least 5-7 million birds of more than 30 species of waterfowl winter in Danish waters and even more individuals stage for shorter or longer periods during migration. As a consequence, Denmark has obligations under both the Ramsar and the Bonn Conventions, and the EU Birds Directive, to protect and maintain these populations. For this reason, it is pointed out in the environmental impact assessment should give special attention to bird life. Possible effects on birds of the wind park may relate to the following three categories, which is dealt with within the report:

- Collision risk
- Physical changes of the habitat
- Disturbance effects

23 Base-line investigations of birds in relation to an offshore wind farm at Rødsand: results and conclusions, 2000

Authors: Kahlert, J., Desholm, M., Clausager, I., Krag Petersen I.
& Ib Krag Petersen
Publisher / Date: National Environmental Research Institute (NERI) / 2001-00-00
Keyword(s): EIA, birds, base line study

This report presents data from the initial phase of the base-line investigations of birds in relation to the proposed construction of an offshore wind farm at Rødsand. The study area at Rødsand is important for birds migrating between their breeding and wintering localities.

24 Base-line investigations of birds in relation to an offshore wind farm at Rødsand: Results and conclusions, 2001

Authors: Kahlert, J., Desholm, M., Clausager, I., Krag Petersen I.
& Ib Krag Petersen
Publisher / Date: National Environmental Research Institute (NERI) / 2002-00-00
Keyword(s): EIA, birds, base line study

This report presents data from the base-line investigations of birds, which were carried out during 2001 in relation to the proposed construction of an offshore wind farm at Rødsand.

Mapping of migration routes was carried out by use of radar day and night. The mapping of migration routes was combined with identification during daytime of migrating bird species by use of telescope. Waterfowl, which included staging migrants, wintering or wing moulting birds in the study area at the wind farm area, were monitored by aerial surveys. On the basis of the mapping of migratory birds a GIS-database of migration tracks was created. Subsets of data were derived from the database to establish a base-line, which describes migration routes before wind turbines are erected. These base-line data will be used for comparisons with similar data obtained during a monitoring programme carried out in a period after start of operation of the wind farm. Three key variables are presented in this report:

1. the orientation of autumn migration routes for waterfowl and terrestrial bird species; the variable is used to measure future avoidance response to individual wind turbines,
2. the probability that waterfowl will pass through the wind farm area during autumn and spring; the variable is used to measure their response to the entire wind farm,
3. the migration intensity measured as the number of flocks, which passed the eastern and northern edge of the wind farm area; the variable is used to measure the effect of their avoidance responses to the volume of migration in the wind farm area.

25 Base-line investigation of Birds in relation to an offshore wind farm at Rødsand, 2002

Author(s): Desholm, Mark, Petersen, Ib Krag, Kahlert, Johhny and Ib Clausager
Publisher / Date: NERI, DK / 2003-09-00
Keywords: birds

This report presents data from the base-line investigations of birds, which were carried out during 2002 in relation to the Nysted/Rødsand offshore wind farm. Mapping of migration routes was carried out by use of radar day and night. The mapping of migration routes was combined with species identification during daytime by use of telescope. Waterfowl, which included staging migrants, wintering or wing moulting birds in the study area at the wind farm area, were monitored by aerial surveys.

The baseline study has shown the waterfowl tracks registered by radar pass the eastern border of the wind farm area during spring and autumn. All migration tracks were entered into a GIS (Geographical Information System) database; subsets of data were selected for description of migration routes before the wind turbines are erected. These base-line data will be used for comparisons with similar data obtained during a monitoring programme carried out in a period after the wind farm has started to operate. Three key-variables are presented in this report:

1. orientation of autumn migration routes for waterfowl and terrestrial bird species; the variable is to be used to measure potential avoidance response to individual wind turbines,
2. the probability that waterfowl will pass through the wind farm area during autumn and spring; the variable is to be used to measure the waterfowl response to the entire wind farm,
3. migration intensity measured as the number of bird flocks that pass the eastern and northern edge of the wind farm area; the variable is to be used to measure the effect of the avoidance responses to the volume of migration in the wind farm area.

Comparisons of key variables between individual base-line years were undertaken while controlling for various factors such as weather conditions, season and time of day, mainly by use of multi-factorial ANOVA or regression analyses.

The potential effects of the wind farm on birds were considered with aspect to three main headings:

5. disturbance effects (displacement, habitat loss),
6. physical changes due to construction (bottom fauna changes and new resting facilities),
7. risk of collision (mortality).

Discussion of the results took place within the chapters:

- Patterns of migration
- Lateral change in migration routes
- Probability of passing the wind farm area
- Migration intensity in the wind farm area
- Staging, moulting and wintering birds

26 Offshore Aquaculture Project

Authors: Buck, B., Spahic, S., Smetacek, V.
Publisher / Date: Alfred-Wegener-Institut für Polar- und Meeresforschung / 0000-00-00
Keyword(s): mussel, oysters, plankton

In cooperation with the Research Center Terramare (FTZ Wilhelmshaven), all marine areas, where wind farms were planned, were equipped with mooring systems to test the settlement and/or growth of candidate species in January 2003. These mooring systems were equipped with two culture testing facilities, so called "LAM"-frames, in a depth of 4-6 m below the water surface. The top frame had a holding unit for the culture of *Laminaria saccharina* and oysters (*Ostrea edulis, Crassostrea gigas*); at the lower frame mussel larval collectors and juveniles of *Mytilus edulis* were installed. On monthly expeditions all these moorings are visited and samples are taken, such as plankton loads, growth parameters, oceanographic data, etc. The outcomes of this project will provide an expertise for the feasibility of offshore wind farm areas for the extensive culture of bivalves and seaweed.

27 Impact assessment of an off-shore wind park on sea ducks

Authors: Guillemette, M., Kyed Larsen, J., Clausager, I.
Publisher / Date: Ministry of Environment and Energy National Environmental Research Insitute (Neri) / 1998-03-00
Keyword(s): birds, sea ducks, offshore wind park, impact assessment, BACI

As part of the plan of the Danish government to expand off-shore wind energy production, The Ministry od Environment and Energy, in collaboration with ELSAM (an energy consortium), initiated a three-year study of the potential conflict between the Tuno Knob off-shore wind park and aquatic birds in 1994-1997. Danish costal waters support very large, internationally important concentrations of moulting, migrating and wintering sea ducks, which depend on shallow water areas as major feeding habitats.

Two general approaches were adopted for the investigation:

- the before-after-control-impact (BACI) and
- *after* studies conducted around the wind park

The aim of the BACI studies was to compare bird abundance and distribution before and after the construction of the wind park and between the area presumably affected by the development and a control area. This was carried out on three spatial scales.

The *after* experiments were conducted around the wind park with the aim of controlling the confounding effect of food supply and to establish

1. the short-term possible effects of noise and rotor movements generated by the turbines on the distribution and abundance of sea ducks and

the long-term scaring effect of the wind park (the impact of revolving rotors and the presence of the standing towers)

28 Assessing the impact of the Tunø Knob wind park on sea ducks: the influence of food resources

Authors: Guillemette, M., Kyed Larsen, J., Clausager, I.
Publisher / Date: Ministry of Environment and Energy National Environmental Research Insitute (Neri) / 1999-02-00
Keyword(s): birds, seaducks, offshore wind park, EIA, BACI, food resources, *Melanitta nigra, Somateria mollissima*

This study deals with the influence of benthos abundance when assessing the potential impact of a small wind park on wintering sea ducks. Using the Before-After-Control-Impact design, it was suggested in a elated study that the wind park provoked a decline in the abundance and a change in the distribution of common eiders *Somateria mollissima* and common scoters *Melanitta nigra*. However, the observed decline in sea duck abundance occurred concomitantly with a decline of benthic food supplies. It was measured concomitant food and common eider abundance for a fourth year at Tunø Knob to test the hypothesis that, if food abundance increases again, also an increase in duck abundance should be observed.

29 Forschungsplattformen in Nord- und Ostsee (FINO)

Authors: Rakebrandt-Gräßner, P. Germanischer Lloyd WindEnergie GmbH
Publisher / Date: Bundesministerium für Wirtschaft und Technologie / -
Keyword(s): marine mammals, noise, birds, vibrations, seabed

The Germanischer Lloyd WindEnergie (GL-Wind) has been contracted by the German Ministry for Economy and Technology to co-ordinate the design, construction, installation and operation of research platforms. Basic technical, biological and ecological data shall be gathered for the use in design, installation and operation of offshore wind farms. The platforms shall be installed adjacent to future wind farms and will be used for the determination of data for design, approval, erection, operation and environmental impact. Data will be collected before, during and after installation of wind farms. A mast up to 101 m above sea level is to be installed on the platforms. Furthermore, consoles for measurement sensors and equipment are to be installed on the platform structure. Measuring equipment, living/working space (emergency accommodation) and a diesel/generator set with batteries and radar equipment are to be housed in four containers. A crane will be used to take seabed samples. The platforms are to be operated without personnel and without supervision. The platforms will be monitored centrally from shore. As the platform will have a helicopter pad they are to be reached by ship or helicopter. The platforms will be built according to the rules for offshore installations of a certification company. The data collected will be transferred onshore by radio beams or via satellite and are available publicly after validation by the measuring institute.

30 Auswirkungen von Offshore-Windkraftanlagen auf die Fischfauna

Authors: Dr. Ehrich, S.
Publisher / Date: Bundesforschungsanstalt für Fischerei, Institut für Seefischerei / 2000-00-00
Keyword(s): fish, seabed; EMF, substrate, noise, warming of the sea bed near cables

Within the project was tried to demonstrate results concerning the investigation on impacts of offshore wind turbines on the fish fauna beyond the 12 sea miles. The following influencing variables onto the fish fauna were incorporated:

1. Changes in turbidity and sediment during the phase of wind turbine erection
2. Changes in biotope by seabed insertion through foundations
3. Increased noise level during the operation of the wind turbines
4. Magnetic and electric fields around the cables
5. Warming of the seabed and the circumfluent water in direct surrounding of the cable

Based on this results and long monitoring experiences in the North Sea the author dares to make an evaluation on probable impacts of these variables onto the fish fauna on meso- and macro-scale. Subsequently recommendations are given on which sorts fish are suitable as monitoring objects and how to representatively catch them in order to provide stochastically evidence on possible impacts of offshore wind farms on the fish fauna.

31 Untersuchung der Wirkung von Offshore-Windenergie-Parks auf die Meers-strömung

Authors: Mittendorf, K., Zielke, W.
Publisher / Date: Institut für Strömungsmechanik und Elektron, Universität Hannover / 2002
Keyword(s): sedimentation, seabed, ocean current

Within this report the question shall be investigated whether offshore wind farms do have an impact on the ocean currents and if so, how this can be quantified and assessed. Especially it focuses onto reduction of ocean current in a large area within and around the wind farm, resulting from a higher flow resistance of the wind farm.

32 EIA - Investigation of marine mammals in relation to the establishment of a marine wind farm on Horns Reef

Authors: FSM Esbjerg - Ornis Consult A/S - Copenhagen Zoological Museum
Publisher / Date: Fisheries and Maritime Museum, Esbjerg / 2000-02-00
Keyword(s): marine mammals, porpoise, *Phocoena phocoena,* seal, *Phoca vitulina*.

The environment impact assessment focuses on the evaluation of the possible effects on harbour porpoise and common seal. The investigation constitutes the first phase of a *before-after-control-impact* (BACI) analysis of the occurrence of harbour porpoise before, during and after the construction of the wind farm.

Especially concerning porpoises was targeted on the assessment of effects born by:

- Reaction on physical structure
- Reaction on boat and helicopter traffic
- Habitat loss
- Total effects
- Mitigation
- Monitoring needs

Concerning seals an assessment on their distribution and distance to the haul out sites on land has shown, that it is unlikely that the seals are getting disturbed or lose their habitat.

33 Horns Rev Wind Power Plant EIA of Hydrography

Authors: Edelvang, K., Møller, A.L., Steenberg, C.M., Zorn, R., Hansen, E.A., Mangor, K.
Publisher / Date: Danish Hydraulic Institute / 1999-12-22
Keyword(s): EIA, hydrography, geomorphology

Establishing a wind power plant at Horns Rev has a potential impact on the local hydrography and thus potentially on local and regional coastal morphology. In order to assess these options, investigations of the impact of the foundation on currents and waves has been carried out locally in the area where the wind power plant is to be erected as well as the nearby region. Furthermore, in connection with establishing the single foundations, sediment spill may influence the water quality in sensitive areas and spill simulations have thus been carried out. This investigation is to be part of an overall EIA of the setting up of the wind power plant at Horns Rev. The following aspects will be addressed in this document:

- Hydrography
- Costal morphology
- Sediment transport

34 Horns Rev Offshore Wind Power Farm Environmental Impact Assessment on Water Quality

Authors: Andersen, P.
Publisher / Date: Bio/Consult A/S **/** 2000-05-04
Keyword(s): EIA, water quality, primary production, plankton

Only local and minor changes are anticipated in connection with the currents, sediments and wave conditions during the production phase. These will occur in the immediate vicinity of the individual foundations. For these reasons, no changes are expected in the water quality. This also includes also the pelagic primary production and the occurrence of plankton in the area. Increased local copper contamination of phytoplankton and zooplankton may be expected during the production phase, as a result of the total annual discharge of 206 kg copper from the slip-rings in the wind turbines. The contamination will potentially result in a local reduction of the pelagic primary production and changes in the species composition of the plankton.

The wind turbines will be sandblasted and painted once during their lifetime, as part of the routine maintenance. The sandblasting and painting will lead to a temporary spill of paint, paint waste and sand. The impacts on water quality and plankton production are unknown. It is recommended that factors such as the toxicity of the paint be investigated, and that spills and the impact of waste be reduced as much as possible. The water quality and the plankton in the wind farm area and along the cable line's passage to shore through the international protected area will only be affected in a minor way during the construction phase. The impacts will be from sediment spill and re-suspension, caused by the construction of the wind-turbine foundations and water jetting the cable into the sediment. On the basis of the expected impact from the establishment of the wind farm, it is not deemed necessary to carry out special programmes during the construction phase for monitoring of the water quality and plankton. A monitoring and control programme is recommended during the production phase in order to follow the impact of increased copper concentration on the pelagic primary production and the qualitative and quantitative composition of the plankton. The alternative is to initiate recovery or elimination of the copper-laden waste.

35 Horns Rev Offshore Wind Farm EIA of Sea Bottom and Marine Biology

Authors: Leonhard, S. B.
Publisher **/** Date: Bio/Consult A/S **/** 2000-03-01
Keyword(s): EIA, *Ophelia borealis,* sediments, vegetation, benthic fauna

The study forms part of a total EIA of the planned offshore wind farm. This EIA study has been drawn up in accordance with the guidelines laid down by the Ministry of Environment and Energy in the publication, “Guidelines for preparation of EIA studies for offshore wind farms.”

The fauna in the wind farm area has similarities to fauna recorded on other sandbanks in the North Sea and is best characterised as an *Ophelia borealis* community, so-named after one of the characteristic and important marine bristle worms in the area. Such sand banks are characterised by a lower number of species and individuals, and a lower biomass than adjoining areas where the bottom is less unstable and has a higher content of fine sand and organic matter.

These studies and this report are part of a total EIA for the construction and production phases of the wind farm at Horns Rev. In accordance with the requirements the following subjects will be dealt with:

- Sediments
- Vegetation
- Benthic fauna

36 Horns Rev Offshore Wind Farm Introducing Hard Bottom Substrate Sea Bottom and Marine Biology - Status Report 2001 and Data Report 2001

Authors: Leonhard, S. B., Pedersen, J.
Publisher **/** Date: Bio/Consult A/S **/** 2002-08-00
Keyword(s): EIA, hard bottom substrate, base line study

A baseline description of the benthos was carried out in spring and autumn 2001 prior to the construction of an offshore wind farm at Horns Rev. The surveys have been conducted as part of an environmental monitoring programme for the introduction of hard bottom substrates in the North Sea. The establishment of a monitoring programme is required according to some environmental guidelines set up by the Danish Energy Agency for offshore wind farms. Because no environmental criteria existed for benthic communities in connection with the construction activities, no power analysis was made prior to the design of the monitoring programme. The monitoring programme established for the benthic infauna is thus somewhat limited and only major changes in the community structure are expected to be detectable. The baseline description for the benthic infauna can also be used for comparison of the stomach contents of fish in a comparative programme. A newly defined reference area may be introduced for the fish programme why sampling in this area was carried out in the autumn 2001. The data report 2001 presents the data of the baseline environmental survey of the seabed in the wind farm site and in the proposed reference site and a brief description of the weather conditions at the time of sampling.

37 Hard Bottom Substrate Monitoring Horns Rev Offshore Wind Farm Annual Status Report 2003

Authors: Leonhard, S. B., Pedersen, J.
Publisher / Date: Bio/Consult A/S / 2004-05-14
Keyword(s): EIA, hard bottom substrate, annual report 2003

This report describes the first year results of surveys on hard substrate after the completion of the offshore wind farm at Horns Rev. The expected impact of the wind farm will primarily be an alternation of habitats due to the introduction of hard bottom substrates as wind turbine towers and scour protections. A continuous development in the epifouling communities will be expected together with an introduction of new or alien species in the area. The indigenous benthic community in the area of Horns Rev can be characterised by infauna species belonging to the *Goniadella-Spisula* community. This community is typical of sandbanks in the North Sea area, although communities in such areas are very variable and site-specific. Character species used as indicators for environmental changes in the Horns Rev area are the bristle worms *Goniadella bobretzkii*, *Ophelia borealis*, *Psione remota* and *Orbinia sertulata* and the mussels *Goodallia triangularis* and *Spisula solida*. In connection with the implementation of the monitoring programme concerning the ecological impact of the introduction of hard substrate related to the Horns Rev Wind Farm, surveys on hard bottom substrate was conducted in March 2003 and in September 2003.

Surveys were performed at six turbine sites concerning the horizontal distribution of *epifouling* assemblages on scour protections, whereas the vertical distribution of *epifouling* assemblages was only performed at three turbine towers. *Epifouling* communities exposed to different current regimes were studied both on the turbine towers and at the scour protection. The diameter of the monopile foundation of the turbines is 4 m. The scour protection with a diameter of approximately 20 m consists of stones up to 40 cm in diameter. At the outer edge of the scour protections, zones of up to 4 m in diameter were observed, consisting of smaller stones 10 cm in diameter.

In March, additional observations on specific faunal assemblages revealed the existence of the giant midge *Telmatogeton japonicus*, not previously recorded in Denmark, inhabiting and feeding on the dense mats of filamentous green algae growth in the splash/wash zone at the turbine towers.

38 The effects of offshore windfarms on birds

Authors: Dirksen, S., Tulp, I., and Winden, van der J., Schekkerman, H.
Publisher / Date: Bureau Waardenburg, Culemborg, NL / 0000-00-00
Keyword(s): bird collision, barrier effects

This project deals with two studies aiming at filling some of the gaps in knowledge still existing concerning offshore wind energy impacts on the marine environment:

1. a study on flight behaviour of sea ducks approaching a semi-offshore windfarm
2. a study on flight behaviour of sea ducks at an offshore windfarm.

Based on these studies the report ends with recommendations for further research

39 Investigations of harbour porpoises at the planned site for wind turbines at Horns Reef

Authors: Skov, H., Carstensen, J., Teilmann, J. & Henriksen, O.D.
Publisher / Date: Ornis Consult A/S / 2002-07-00
Keyword(s): harbour porpoises, *Phocoena phocoena*

This report deals with the results of the investigations on harbour porpoises on Horns Reef during the period from January 2001 to December 2001. These investigations involve a range of new field and analysis techniques, which have never been applied in studies of the impact of human activities at sea on harbour porpoises. The successful implementation of the investigations has been possible by drawing on a broad range of experience from Ornis Consult, National Environmental Research Institute, The Danish Fisheries Research Institute, Centre for Sound Communication at the University of Southern Denmark, The Zoological Museum in Copenhagen and the Fisheries and Maritime Museum in Esbjerg. The work has been commissioned by Tech-wise A/S, the advisory branch of Elsam, and the main part of the field and analyses work has been carried out by Ornis Consult A/S and the National Environmental Research Institute.

During the report period the visual surveys were supplemented by new acoustic methods and hydrographic monitoring. Stationary acoustic data-loggers (so-called T-PODs, porpoise click detectors) were applied and the use of the T-POD as a means to collect acoustic survey data was also tested during the period. In order to increase the statistical power of harbour porpoise data collected by the stationary T-PODs two CTD-stations (measures salinity and temperature) were launched during 2001.

The embedded picture originates from the mentioned report.

40 Effects on birds of an offshore wind park at Horns Rev. Environmental impact assessment

Authors: Noer, H., Christensen, T.K., Clausager, I., Petersen, I.K.
Publisher / Date: NERI / 2000-00-00
Keyword(s): birds

This report presents the technical background to the ornithological environmental impact assessment for the construction of an offshore windpark at Horns Rev, 14 km west-south-west of Blåvandshuk, Denmark. Construction of the park is planned to commence in 2001. The park will consist of c. 80 wind turbines, each of at least 1.8 MW, and cover an area of 27.5 km2 (including the 200 m exclusion zone around the park). The inner Danish waters and the eastern part of the North Sea constitute major staging and wintering grounds for huge numbers of water- and seabirds. The present gross estimate, to be regarded as a minimum estimate, is that 5-7 million birds of more than 30 species winter in these areas, and that even larger numbers stage or pass through on migration.

Impacts on birds resulting from construction work are expected to be temporary and limited. The effect of laying the cable to land is also considered to be temporary and minimal in two proposed scenarios. Potential permanent impacts on seabirds resulting from the long-term operation of the wind park are identified under three main headings:

a) physical changes of the habitat
   i. the loss of the bottom area which supports the turbine foundations
   ii. the provision of new underwater substrate for the settlement of larvae of marine invertebrates
   iii. the provision of platforms for birds to sit or perch on

b) disturbance effects resulting from avoidance of the turbines, equivalent to the loss of potential to exploit the otherwise available habitat

c) collision risk

41 Base-line investigations of birds in relation to an offshore wind farm at Horns Rev, and results from the year of construction

Authors: Christensen, T.K., Clausager, I., Petersen
Publisher / Date: NERI / 2003-04-00
Keyword(s): Birds, IEA; base line investigation

The present report presents the base-line investigations of birds conducted during August 1999-April 2001 in relation to construction of an offshore wind farm at Horns Rev in the Danish North Sea. The report also presents data collected during the period September 2001-April 2002, when construction of the wind farm was in progress. Detailed distributions of birds in the area around and at Horns Rev were virtually unknown until initiation of this project. Previous bird counts in this area have been carried out almost exclusively from the coast and detailed knowledge exists concerning the numbers of roosting at and migrating birds from the westernmost point of Jutland, Blåvandshuk. To describe the numbers and distributions of birds staging and wintering in the Horns Rev area, bird investigations were initiated in 1999 by using standardised transect counts from aircraft. Up to April 2002, 18 aerial counts have been carried out over an area of c. 1’700 km² cantered on the Horns Rev project area.

42 Rechnerische Bewertung von Fundamenten von Offshore Windenergieanlage bei Kollisionen mit Schiffen - Simulation of ship collision with foundation types of wind energy constructions

Authors: *Prof. Lehmann, E., Biehl, F.*
Publisher / Date: Arbeitsbereiche Schiffbau der Technischen Universität Hamburg-Harburg / 2004-10-22
Keyword(s): collision, risk analysis, hazard analysis

This present paper gives a short introduction to the principle questions on calculation of collisions between ships and offshore wind energy converters. Numerical simulations, based on the non-linear finite element method for different situations, will be prepared.

Aim of the project is the investigation of collision incidents between ships and offshore wind turbines based on numerical conducted crash tests. Based on the achieved results procedures shall be developed to detect during the licensing procedure for offshore wind turbines the collision behaviour of offshore wind turbines with ships concerning prevention of lose of substances harmful to the marine environment. The assessment procedure within this project shall exemplary be applied onto three wind turbine constructions and certain ship types.

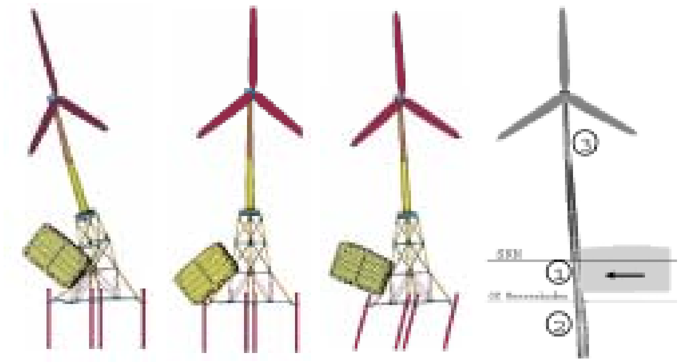


Fig. 28: Different dynamic responses due to different foundations and forces. Picture taken out of the report

43 Untersuchungen zur Vermeidung und Verminderung von Belastungen der Meeresumwelt durch Offshore-Windenergieanlagen im küstenfernen Bereich der Nord- und Ostsee (OffshoreWEA)

Authors: Dr. Knust, R., Dr. Heuers, J., Alfred-Wegener-Institut, Bremerhaven
Publisher / Date: Alfred-Wegener-Institut / Umweltbundesamt Texte / 2003-00-00
Keyword(s): biocoenosis, birds, mammals, ship collision, benthos

Possible impacts of offshore wind farms on the marine environment in the North Sea and the Baltic Sea are investigated by means of literature studies, the analysis of existing data, the interrogation of experts and some complementary field studies. Suggestions for prevention and reduction of possible impacts are made. The biotic compartments benthos and fish communities, marine mammals, resting and migrating birds as well as the collision risk of ships with offshore wind turbines are taken into account. The project therefore is divided into a number of sub-projects concerning:

- Reporting the degree of knowledge about possibly impacts on the marine environment by offshore wind turbines (erection, operation, decommissioning) under consideration of the benthos and fish biocoenosis, (migratory) birds as well as marine mammals
- Development of methodical basis for investigation and evaluation of potential stress onto the marine environment due to offshore wind energy converter
- Estimation of the risk potential concerning ship collision and possible consequences
- Formulation of methods for prevention and reduction of the strains of offshore wind turbines on the marine environment
- Appointing gaps on research and gaps in knowledge necessary to be closed, in order to support evaluation of the possible impacts on the marine environment

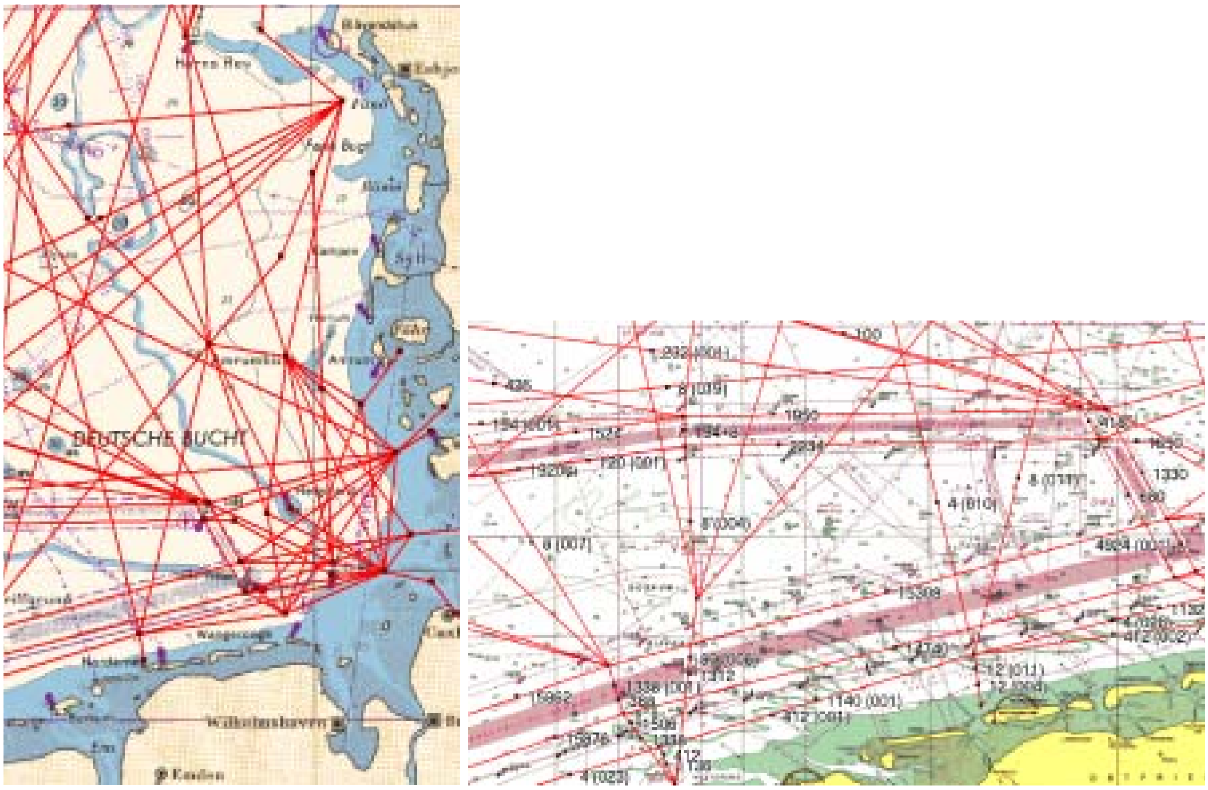


Fig. 29: Shipping traffic in the German Bay as important parameter during risk assessment and calculation

44 Status report of seabird surveys at Horns Rev, 2000-2001

Authors: Christensen, T.K., Clausager, I., Petersen, I.K.
Publisher / Date: NERI / 2002-00-00
Keyword(s): birds

The report presents the results of three bird surveys conducted in the Horns Rev area during the second half of 2001. The surveys are part of the *base-line investigations* of birds performed in relation to the proposed construction of an offshore wind farm at Horns Rev in the Danish part of the North Sea. Based on the distribution of the most abundant bird species recorded during 16 aerial surveys performed during August 1999 - January 2002, there were no indications that the wind farm area was of any particular importance to the birds' exploitation of the Horns Rev area.

Preference analyses of bird exploitation of the Horns Rev area showed that if the birds completely avoid the wind farm area after erection of the wind turbines, this will affect less than 1% of the various species, except divers where 1.58% will be affected. If the birds avoid the wind farm area and an adjacent 4 km zone (worst case scenario), it is estimated to affect 8-11% of the common scoter, 10% of the gannet, 7-9% of the divers, alcids and velvet scoter and 0-6% of the remaining species.

45 A Baseline Assessment of Electromagnetic Fields Generated by Offshore Windfarm Cables - *An Investigation of EMF Generated by Subsea Windfarm Power Cables*

Author(s): CEMACS at University of Liverpool & ECONNECT LTD
Publisher / Date: COWRIE / 2003-07-00
Keywords: EMF, offshore power cable, electro-sensitive fish species, *elasmobranchs*

The aims and objectives of this desk-based study were to calculate the strength, frequencies and wavelengths of the electromagnetic fields produced by both 33 kV (EPR) and 132 kV (XLPE) cables in association with offshore wind farms (both between turbines and the full length of cabling to the grid connection on land). The study also calculated the effects of burial and/or shielding (at various depths, strata, sediment type and thickness) on electromagnetic fields.

Moreover investigation was contracted to assess the following items:

- The likely EMF emitted from a sub-sea power cable,
- A suggested method to measure EMF in the field, which could be applied by wind farm developers or in future projects
- Guidance on mitigation measures to reduce EMF
- Consideration of the results for the next stage of investigation into the effects of EMF on electro-sensitive species

An assessment of existing publications and direct communications regarding EMF emitted by undersea power cables suggested that the current state of knowledge is too variable and inconclusive to make an informed assessment of any possible environmental impact of EMF in the range of values likely to be detected by organisms sensitive to electric and magnetic fields. Therefore modelling and direct measurement of the electric and magnetic field components of EMF was undertaken.

The results of the model simulations showed that a cable with perfect shielding i.e. where conductor sheathes are grounded, does not generate an electric field directly. However, a magnetic field is generated in the local environment by the alternating current in the cable. This in turn, generates an induced electric field close to the cable within the range detectable by electro-sensitive fish species.

In terms of the potential significance of the modelled results to electro-sensitive fish the following conclusions were made:

- EMF emitted by an industry standard three-core power cable will induce electric fields
- In the case modelled, this resulted in a predicted electric field of approximately 91ìV/m (=0.9 ìV/cm) in seawater above a cable buried to 1m. This level of electric field is on the boundary of electric field emissions that are expected to attract and those that repel *Elasmobranchs* (the most widespread electro-sensitive fish group of UK coastal waters).
- In addition, the induced electric fields calculated from the magnetic fields measured in situ were also within the lower range of detection by Elasmobranchs.
- The options for mitigation using either changes in permeability or conductivity indicate that the induced electric field can be effectively reduced. However, unless highly specialised materials and manufacturing process are used with high permeability values, the electric field will still remain within the lower range of detection of Elasmobranchs. Hence any reduction in electric field emission using existing materials could minimise the potential for an avoidance reaction by a fish if it encountered the field but may still result in an attraction response.

- Another important consideration is the relationship between the amount of cable, either buried or unburied, producing induced electric fields and the available habitat of an electro-sensitive species.
- There is also a need to determine if the power cable operating frequency (50Hz) and associated sub-harmonic frequencies have any effect on the EMFs that are detectable by UK electro sensitive fishes.

Subsequently recommendations concerning the need for further studies were given, divided into an electro-technical and a biological column.

46 Open Ocean Aquaculture and Offshore Windparks. Eine Machbarkeitsstudie über die multifunktionale Nutzung von Offshore-Windparks und Offshore-Marikultur im Raum Nordsee

Authors: Buck, B. H.
Publisher / Date: Alfred-Wegener-Institut / 0000-00-00
Keyword(s): Aquaculture, mussel (*Mytilus Edulis*), pacific oyster (*Crassoestrea gigas*), EEZ

The feasibility study deals, on theoretical basis, with the potential multifunctional use of planned offshore windfarms with commercial marine aquaculture (open ocean aquaculture) in the North Sea are. Exclusively, literature data from existing international experiences are reviewed here, as well as the output of several discussions with experts. The study closes with a final evaluation of all factors, which are critical for the development of a commercial offshore aquaculture in combination with the planned wind farms in the North Sea region.

For several European offshore wind energy research projects no report was assessable by the time being. Amongst other reasons one reason may be that the projects are of ongoing and/or confidential character, so that no (final) report has been published (yet). Projects of this type are represented in Table 14 below:

Project title	Contact	Specification of the project	Status / output
47 **MINOS plus:** Research on seabirds and marine mammals for evaluation of offshore wind turbines	National Park Office of the Schleswig-Holstein Wadden Sea	Proceeding of MINOS-project. Accompanying effect monitoring during construction and operation of planed wind farms in the German Exclusive Economic Zone.	Ongoing Project
48 **Specious related levels of impact to migrating birds for the area of the south west Baltic Sea and hazard to bird migration caused by offshore wind turbines**	Institute for Applied Ecology Ltd	Quantification of migration rates and calculation of a specious related collision risk. Modelling of the population dynamics of migratory bird in the Baltic sea. Determination of specious related levels of impact to migrating birds.	Project in preparation

49 **Consideration of effects on the marine environment within the licensing procedure of wind parks in the German EEZ:** Discussion of methods and practical advise for the drafting and quality assurance of EIA studies and Habitats Assessment studies	TU Berlin, Institute for Landscape Architecture and Environmental Planning	The project comprises two work packages: • Preparation of the present scientific results making them more usable for decision procedures and for required environmental planning instruments. • Development of advice for the good professional practice and quality assurance of the required EIA and Habitats Assessment studies.	Ongoing work (until May 2006)
50 **Development of Generic Guidance for Sediment Transport Monitoring Programmes in Response to Construction of Offshore Wind farms**	Paul Leonard: Defra (Department for Food and Rural Affairs, UK)	Sediment transport, sea bed.	In 2004, progress will be reported in the "State of the Seas Report"
51 **Assessment of the Significance of Changes to the Inshore Wave Regime as a Consequence of an Offshore Wind Array**	Paul Leonard: Defra (Department for Food and Rural Affairs, UK)	Hydrography.	In 2004, progress will be reported in the "State of the Seas Report"
52 **Environmental Monitoring at Scroby Sands Offshore Wind Farm Site** - Generic Coastal Process issues and how they fit into the legislation	Jon Rees: Centre for Environment, Fisheries and Aquaculture Science, UK	Sediment transport, morphology.	The last major field work campaign should have been taken place in summer 2004
53 **Potential impact of electromagnetic fields on fish from the cabling associated with wind farms**	COWRIE and Centre for Marine and Coastal Studies, Liverpool University	Electromagnetic fields, modelling, ground truthing.	Completion date: July 2003
54 **Displacement of common scoter (*Melanitta nigra*) from benthic feeding areas**	COWRIE and School of Ocean Sciences, Bangor University	• Modelling effects due to habitat loss and change. • Link non-breeding distribution with environmental variables. • Identify characteristics of referred feeding areas.	Completion date: June 2005
55 **Comparison of bird survey methodologies**	COWRIE and NIOZ	• Comparisons of variety of techniques. • Design standardised methodologies incl. recording parameters and correction factors.	Completion date: December 2003

56 **Impacts of subsea noise and vibration on marine life as a result of the turbines from construction through to operation**	COWRIE and Subacoustech Ltd.	• Desk based study and site measurements. • Determine hearing spectra and sensitivity to noise and vibration. • Determine sound pressure level and frequency spectrum during phases of wind farm project.	Not known
57 **Bio-Wind**	Torleif Malm: Department of Botany, University of Stockholm	• Possible changes of community structure and species composition due to artificial structures. • Necessary design of windturbines to favour establishment of perennial macro algae.	Completion date: May 2005
58 **Assessment of the significance of changes to the inshore wave regime as a consequence of an offshore wind array**	CEFAS (The Centre for Environment, Fisheries and Aquaculture Science)	Coastal processes: • Construction. Acceleration of currents around turbines: • Re-suspension of sediments. • Scour pits.	Completion date: March 2005
59 **Development of generic guidance for sediment transport monitoring programmes in response to construction of offshore wind farms**	CEFAS (The Centre for Environment, Fisheries and Aquaculture Science)	• Scour pits exacerbated by waves Environmental and engineering consequences. • Geomorphologic changes to coastline.	Completion date: March 2005
60 **Forschungsprojekt GIGAWIND** - Bau- und umwelttechnische Aspekte von Offshore Windenergieanlagen. Abschlussbericht 2000-2004	Zielke, W.: Institut für Strömungsmechanik, Universität Hannover	Civil engineering aspect and environmental aspect of offshore wind energy converters.	2004
61 **Aktuelle Studie zur Wärmeausbreitung im Seeboden infolge Seekabelanbindung**	OWT Offshore Wind Technologie GmbH, Leer	Stationary and transient calculations on temperature and temperature development within the environmental compartments as well as modelling and derivation of design parameters, transmission losses and economics.	General presentation of a confidential project: December, 2004
62 **Messungen der Schallimmissionen während der Bauphase** – Measurements of Noise Immission During the Bulding Phase	Gabriel J., Dr. Neumann, T. Deutsches Windenergie-Institut (DEWI), Wilhelmshaven	Schallimmissionen (noise immissions).	2003
63 **Development of an environmental strategy for the use of wind energy onshore and offshore**	Hannover University, Institute of Geography	Development of an environmental strategy for the wind energy use onshore and offshore, particularly with regard to environmental effects, grid connection, licensing procedures and repowering.	Ongoing project

64	**Strategic Environmental Assessment and strategic monitoring for offshore wind farms**	University of Lüneburg	Development of planning methods under methodical, technical and formal aspects for Strategic Environmental Assessment (SEA) in the marine area.	Project in preparation

Table 14: Research projects in Europe with no evaluation performed on the report

Appendix B

- Precedent studies and fundamental research with relevance to raise basic principles and knowledge -

65 Standardverfahren zur Ermittlung und Bewertung der Belastung der Meeresumwelt durch die Schallimmission von Offshore WEA - Noise emission and hearing abilities

Authors: Bollmann, Gerasch, Curt-Risch-Institut (CRI Hannover), Dr. Neumann, (DEWI Wilhelmshaven), Dr. Schultz-von Glahn (itap Oldenburg)
Publisher / Date: Curt-Risch-Institut für Dynamik, Schall- und Messtechnik, Uni Hannover / completion in work
Keyword(s): noise propagation, offshore wind energy

The goal of the project is the development and supply of standard techniques for determination and evaluation of noise immissions of offshore wind energy plants (WEP). Over an extensive measuring threshold the necessary data are received which are necessary for the definition of values for the noise entry of a construction in the sea. The project is accomplished in coordination with sea biologists. The project is divided into the following sections: measurement of the acoustic load that is observed in the North Sea, measurements of the noise pollution of the sea inhabitants in the building period of offshore WEP, measurement of the operating noise of existing WEP in the sea, computation of sound propagation in the water, detail investigations to the sound entry in the water of research platforms. The acoustic effect ranges of WEPs are derived from the test results. The acoustic disturbance potential for the sea fauna will be evaluated taking into consideration the source strengths of the plants and the constant noise in the water. On the basis of these data in cooperation with sea biologists threshold values for the noise entry of WEPs will be developed.

66 High Level Environmental Screening Study for Offshore Wind Farm Developments – Marine Habitats and Species Project

Author(s): Hiscock, K., Tyler-Walters, H. & Jones, H.
Publisher / Date: Marine Biological Association to DTI / 2002-06-00
Keywords: noise, vibration

This report provides an awareness of the environmental issues related to marine habitats and species for developers and regulators of offshore wind farms. The information is also relevant to other offshore renewable energy developments.

The marine habitats and species considered are those associated with the seabed, seabirds, and sea mammals. The report concludes that the following key ecological issues should be considered in the environmental assessment of offshore wind farm developments:

- likely changes in benthic communities within the affected area and resultant indirect impacts on fish, populations and their predators such as seabirds and sea mammals
- potential changes to the hydrography and wave climate over a wide area, and potential changes to coastal processes and the ecology of the region
- likely effects on spawning or nursery areas of commercially important fish and shellfish species
- likely effects on mating and social behaviour in sea mammals, including migration routes

- likely effects on feeding water birds, seal pupping sites and damage of sensitive or important intertidal sites where cables come onshore
- potential displacement of fish, seabird and sea mammals from preferred habitats
- potential effects on species and habitats of marine natural heritage importance
- potential cumulative effects on seabirds, due to displacement of flight paths, and any mortality from bird strike, especially in sensitive rare or scarce species
- possible effects of electromagnetic fields on feeding behaviour and migration, especially in sharks
- potential marine conservation and biodiversity benefits of offshore wind farm developments as artificial

The report provides an especially detailed assessment of likely sensitivity of seabed species and habitats in the proposed development areas. Although sensitive to some of the factors created by wind farm developments, they mainly have a high recovery potential.

67 Umweltverträglichkeitsprüfung (UVP), FFH-Verträglichkeitsprüfung und Strategische Umweltprüfung (SUP), für Offshore-Windparks in der Ausschließlichen Wirtschaftszone (AWZ) der deutschen Nord- und Ostsee

Authors: Köppel, J., Bruns, E., Langenheld, A., Peters, W., Wende, W.: TU Berlin; Kraetzschmer, D.: Planungsgruppe Ökologie+Umwelt Hannover
Publisher / Date: TU Berlin Institut für Landschafts- und Umweltplanung / 2003-00-00
Keyword(s): EIA, FFH, NATURA 2000, SEA, EEZ, offshore wind energy

Forms of use of offshore resources in Germany have to be considered within the licensing procedure according to the “Offshore Installations Ordinance” applied in the “Exclusive Economic Zone” (EEZ). This project deals with the adoption of Environmental Impact Assessment (EIA), assessment required under Article 6 of the Habitats Directive and future Strategic Environmental Assessment (SEA) to the special conditions existing in the EEZ. In current application procedures of pilot offshore wind farms a so-called “Standard Programme for environmental Examination” is applied as well as a comprehensive catalogue of possible effective. Furthermore it is necessary to take into account all requirements of the EIA procedure including the assessment of the environmental impacts. Due to the precautionary principle the environmental standard required by the EIA is stricter than the defined indicators of significance relating to the endangerment of the marine environment or the bird migration. The assessment required under Article 6 of the Habitats Directive has to be performed as soon as marine protection areas are identified to become “Natura 2000 areas”. Particularly for the identification of suitable areas for the use of wind energy the SEA is taken into consideration.

68 Ableitung der fachlichen Kriterien zur Ermittlung von besonderen Schutzgebieten nach Artikel 4 der Vogelschutzrichtlinie und Vorschlagsgebieten nach Artikel 4 der Fauna-Flora-Habitat-Richtlinie - Development of criteria to identify nature protection areas for birds

Authors: Dr. Schreiber, M. (Schreiber Umweltplanung, Bramsche)
Publisher / Date: Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit ‚Natura 2000 in der deutschen AWZ’ / 2003-10-02
Keyword(s): SPA, Birds Directive, pSCI, EEZ

Derivation of scientific criteria for selection of Special Protection Areas (SPA) according to article 4 of the Birds Directive and proposed Sites of Community Interest (pSCI) under article

4 of the Habitats Directive To get legal certainty for planning and erecting wind farms in the German Exclusive Economic Zone (EEZ), protected areas under the Birds and the Habitats Directive of the European Union have to be designated. In a first step the legal and scientific criteria shall be derived for designation of SPA and pSCI. To find out criteria for designating sites in the German EEZ, the directives themselves, appropriate judgements of the European Court of Justice and examples of good practice from other countries and e.g. the NGOs will be analysed. This includes a list of bird species, habitats and species, which have to be protected under the Birds respectively under the Habitats Directive. Further investigations will deal with the definition of concentrations and how to draw boundaries, if there are no firm structures to be leaned on. All scientific results shall be checked for their legal evidence.

69 Naturschutzfachlichen Kriterien zur Abgrenzung besonderen Eignungsgebieten für Offshore Windparks

Authors: Köppel, J., Peters, W., Steinhauer, I.
Publisher / Date: Bundesamt für Naturschütz / 2004-00-00
Keyword(s): mammals, fish, EIA, SEA, Natura2000, birds, benthos, seabed life, accidents, pollution

This report outlines the necessary process how to appoint specific areas for offshore wind energy utilisation within the German Exclusive Economic Zone. Thereby the focus lays on the compromise of pointing out areas that are not endangering the oceanic environment or limiting any NATURA 2000-Areas. Criteria are developed to derive an environmental relevant appraisal of different offshore areas in the context of suitability for offshore wind energy utilisation. This shall ensure a site selection approach for offshore wind energy utilisation that shows the lowest impact on nature and environment. The report therefore refers to mammals, bird migration, sea birds, fishes, benthos, hydrology and marine pollution by collision.

70 Proposed UK Offshore Renewable Energy Installations (OREI) - Guidance on Navigational Safety Issues

Publisher / Date: UK Maritime and Coastguard Agency / 2004-04-00
Keyword(s): accidents, pollution

The purpose of this guidance note is to highlight issues that need to be taken into consideration when assessing the impact on navigational safety from offshore renewable energy developments, proposed for United Kingdom waters.

Key points are

- The recommendations contained within this guidance note should be used, primarily, by offshore renewable energy installation developers, seeking consent to undertake marine works.
- Specific annexes address issues covering:
    - site position, structures and safety zones
    - developments, navigation, collision avoidance and communications
    - examples of additional routing safety measures
    - search and rescue matters
    - Article 60 UNCLOS

71 An assessment of the environmental effects of offshore windfarms

Publisher / Date: Metoc / 2000-00-00
Keyword(s): EIA, SEA, Natura2000

This Report was commissioned to help highlight key research requirements to address identified key environmental issues. The objectives of the project therefore were as follows:

(i) to identify the obligations on offshore wind farm developers to provide Environmental Assessments under the consents process to the adopted for their development

(ii) to identify those issues that will or may need to be addressed in the Environmental Assessment

(iii) to determine whether there are sufficient baseline data, scientific analysis and expertise on these issues top allow fill assessment of the likely effects

(iv) to identify research needs and other requirements for further work on understanding the potential environmental effects of offshore wind farms

(v) to achieve a degree of consensus as high as possible on the environmental requirements and issues to the benefit of industry, regulators and the public

72 Potential effects of offshore wind developments on coastal processes

Authors: Cooper, Bill; Beiboer, Frank
Publisher / Date: ABP Marine, Metoc / 2002-00-00
Keyword(s): sediment, soil, hydrology

The overall aim of the present study has been to identify, review and assess the potential effects on coastal processes related to the development of offshore wind farms around the UK coast. Thereby both, positive and negative effects on coastal processes shall be considered. Within the context of this study coastal processes are deemed to include the diffraction and focusing effects on waves and currents and their effect on long shore drift and erosion. From this work, the project outputs aim to provide generic guidance on these issues to stakeholders for use in the planning and consent stage prior to any development.

The study has carefully considered the issues of coastal processes related to UK Interest Areas and compiled the emerging detail related to the first round of proposed offshore wind farm developments to define ‘reasonable worst case’ and ‘typical’ scenarios.

The study recognises that, for a successful wind farm development, there needs to be a good understanding of the local coastal environmental in terms of:

- Designing a scheme that can cope with the environmental conditions (e.g. seabed, wind, wave, and tidal regimes, etc.) by establishing appropriate design parameters.
- Designing a scheme that the local environment can accommodate with minimum impact, by undertaking an Environmental Impact Assessment

Noting that the principal effects are likely to be associated with localised scour in the immediate vicinity of the structures and that scour around the cables could happen if care is not taken to secure adequate protection during and after laying.

73 Guidance note for EIA in respect of FEPA and CPA for Offshore Wind Farms

Publisher / Date: CEFAS / 2003-09-00
Keywords: sediment, soil, mammals, fish, EIA, SEA, Natura2000, bird, benthos, seabed life, archaeology, maritime traffic, fishery

The guidance is intended to supplement the Department of Trade and Industry's (DTI's) guidance note "Offshore Wind Farm Consents Process" [http://www.dti.gov.uk/energy/leg_and_reg/consents/guidance.pdf]. It is not definitive and it is therefore recommended that it be read in conjunction with the legislation and the other sources to which it refers. It replaces the November 2001 document of the same name.

Its purpose is to assist the offshore wind farm industry and their consultants; the primary aim being to provide scientific guidance to those involved with the gathering, interpretation and presentation of data within an Environmental Impact Assessment as part of the consents application process in England and Wales.

Within the documentation is dealt with regulations concerning

- Requirement for Environmental Impact Assessment
- Coastal & Sedimentary Processes
- Benthos
- Fish Resources
- Commercial Fisheries
- Marine Mammals
- Birds
- Designated Sites and other Nature Conservation Interests
- Cumulative impacts
- Decommissioning

74 Offshore wind energy in the North Sea - Technical possibilities and ecological considerations

Authors: Söker, Holger
Publisher / Date: DEWI / 2000-10-00
Keyword(s): International policy, EIA, SEA, Natura2000

This report focuses on many aspects of offshore wind energy. Therefore also disturbances to items during the construction phase incl. grid connection and the operation phase are considered.

Concerning the construction phase and grid connection is dealt with the following points:

- Structure of soil and seabed
- Water
- Benthos
- Fish
- Sea mammals
- Birds
- Archaeological sites

Concerning normal operation is dealt with the following points:

- Disturbance of water

- Disturbance of the seabed
- Poisoning of the ecosystem by material
- Impact by electric fields and heat generated from the cable links
- Disturbance of benthos, fish and sea mammals
- Collisions of birds on the turbines
- Wind turbines as barriers
- Ousting birds off their traditional feeding grounds
- Impact on landscape

Subsequently a 'Recommended Practice' for conduction of EIA is provided, which is a compromise out of limiting the environmental effects and the accessibility and available of knowledge.

75 Aerial Surveys of Birds in Proposed Areas for Offshore Windfarm Development; preliminary report

Author(s): Cranswick, Peter, Hall, Colette, Smith, Lucy
Publisher / Date: The Wildfowl & Wetlands Trust, UK / 2003-06-00
Keywords: birds

To provide contextual information for the proposed strategic areas for the second round of offshore wind farm development, a programme of bird survey was funded by DTI. This report provides preliminary results from the aerial surveys in the Greater Wash strategic area, undertaken by WWT in early 2003. It has been produced at this time to help inform the decision making process for Round 2 which was taking place in June 2003.

To assist with the environmental assessment of the UK's offshore wind farm development, these aerial surveys were undertaken to collect data on bird numbers and distributions. A series of transects were flown at 2 km intervals over the strategic area, and observers recorded the number of birds encountered. Combined with data from a Global Positioning System, used to record the flight path of the plane, their location could be calculated to a high degree of accuracy. A series of maps shows the distribution of the key bird species groups in 4 x 4 km cells, calculated as the number of birds encountered corrected for survey effort.

Subsequently recommendations for future work fields are given, highlighting subjects as inter-annual changes, intra-annual changes, grid size refinement and distribution patterns of terns around breeding colonies.

76 Recommendations for project-related studies of possible impacts of marine wind farms during construction and operation on birds

Authors: Hüppop, O., K.-M. Exo, S. Garthe
Publisher / Date: Institut für Vogelforschung „Vogelwarte Helgoland" / 2002-00-00
Keyword(s): marine wind energy, seabirds, bird migration, conservation, radar, EIA

For roughly a quarter of the area of Germany's Exclusive Economic Zone there are plans to erect offshore windfarms. Several international conventions as well as national laws necessitate environmental impact assessment studies. Within the report the authors suggest methods for standardised investigations on the distribution, movements and flight behaviour of birds at sea. They include visual, acoustic and radar- based techniques and observations in order to investigate on topics as:

- Collision
- Barrier effects
- Short-term loss of habitats
- Long-term loss of habitats
- Loss or change of feeding grounds

77 Background Information on Marine Mammals relevant to SEA2

Authors: Hammond, P.S.; Gordon, J.C.D.; Grelier, K.
Publisher / Date: SMRU / 2001-08-00
Keyword(s): mammals, noise, vibration, EIA, SEA, Natura2000, accidents, pollution

Within this report attention is given to provide background information on the impacts of disturbance, contamination and diseases on marine mammals. Therefore topics are addressed which also may play a role concerning the offshore wind energy development like

- noise
- contaminants
- oil spills
- ship collisions.

The report especially focuses on SEA2 areas in the Eastern of the UK and emphasises species living within these areas.

78 Maßnahmen zur Vermeidung und Verminderung negativer ökologischer Auswirkungen bei der Netzanbindung und -integration von Offshore- Windenergieparks

Authors: Dr. Rehfeldt, K. (Deutsche WindGuard GmbH, Varel), Dr. Schreiber, M. (Schreiber Umweltplanung, Bramsche)
Publisher / Date: Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit / 2003-15-05
Keyword(s): HHF, grid connection offshore, Natura 2000 Gebiete

In Germany wind energy use on land is growing since 1990. Any studies about future development of wind energy use in the next decades shows a big potential of offshore wind farms. Therefore a political strategy exists to develop 20 to 25 GW of offshore wind farms in the German sea until 2030. That means wind energy contribution of 21 % to the electricity supply in Germany. But a problem will be the grid connection of these wind capacity and the transport of the electrical energy to the consumer. That’s why a general strategy is necessary for the grid connection of total offshore wind capacity and the reinforcement of the grid. Within the scope of the presented project an analysis of the effects on ecology by connecting offshore wind capacity to the grid and by the reinforcement of the grid has to be made. Therefore technical solution of grid connection and reinforcement will be analysed and measures to reduce effects on ecology will be proposed.

79 Prognose des Schalldruckpegels im Meerwasser während der Bau- und Betriebsphase – Prognosis of the Sound Pressure Level in Salt-Water During Building and Operation Phase

Authors: Gerasch, W.-J., Uhl, A.
Publisher / Date: Curt-Risch-Institut für Dynamik, Schall- und Messtechnik, Universität Hannover / 2000-00-00
Keyword(s): Schallimmissionen (noise immissions)

80 Offshore Wind Farms: Guidance Note for Environmental Impact Assessment in Respect of FEPA and CPA Requirements

Authors: Centre for Environment, Fisheries and Aquaculture Science (CEFAS)
Publisher / Date: Crown / Version 2 - June 2004
Keyword(s): EIA, SEA

The purpose of this Guidance Note is to assist the offshore wind farm industry and their consultants. Primary aim is to provide scientific guidance to those involved with the gathering, interpretation and presentation of data within an Environmental Impact Assessment (EIA) as part of the consents application process in England and Wales. The guidance is intended to supplement the Department of Trade and Industry's (DTI's) guidance "Offshore Wind Farm Consents Process". It is not definitive and it is therefore recommended that it be read in conjunction with the legislation and the other sources to which it refers. It replaces the November 2001 document of the same name.

81 Standards for Environmental Impact Assessments Impacts of offshore wind turbines on the marine environment

Authors: Issued by Bundesamt für Seeschifffahrt und Hydrographie (BSH) and others
Publisher / Date: Federal Maritime and Hydrographic Agency (BSH) / 2003-2-25
Keyword(s): EIA, SEA,

Within the framework of the approval procedure for offshore wind farms in the Exclusive Economic Zone (EEZ), potential adverse impacts of the projected facilities on the marine environment have to be assessed. Besides, following the amendment to the *Seeanlagenverordnung* (effective 5 April 2002), an Environmental Impact Assessment according to Art. 2a Seeanlagenverordnung, is now mandatory for most projects. In the Standards for Environmental Impact Assessments, information is provided to applicants on the scope of investigations required by the approval authority, with all relevant details and explanations. The Standards for Environmental Impact Assessments constitute a framework of the thematic and technical minimum requirements for marine environmental surveys and monitoring in order to assess compliance with Art. 3 Seeanlagenverordnung.

Apart from the general increase in knowledge, experience from the German Marine Monitoring programme in the North Sea and Baltic Sea, the Helsinki Convention on the Protection of the Marine Environment of the Baltic Sea Area, and the OSPAR Convention for the Protection of the North Sea and North-East Atlantic has been taken into account as well for establishment of this standard.

Appendix C

- Further documentation on studies and research projects with direct link to impacts on birds through onshore wind energy or to environmental impacts of offshore wind energy projects represented in non-reviewed studies -

82 Impacts on biodiversity of exploitation of renewable energy sources: the example of birds and bats – facts, gaps in knowledge, demands for further research, and ornithological guidelines for the development of renewable energy exploitation / Auswirkungen regenerativer Energiegewinnung auf die biologische Vielfalt am Beispiel der Vögel und der Fledermäuse – Fakten, Wissenslücken, Anforderungen an die Forschung, ornithologische Kriterien zum Ausbau von regenerativen Energiegewinnungsformen

Authors: Dr. Hötker, H., Thomsen, K.-M., Köster, H.
Publisher / Date: Michael-Otto-Institut im NABU/ 2004-12-00
Keyword(s): Birds, Bats, Collision, Barrier Effects, Population Dynamics

The purpose of this report is to compile and to evaluate the available information on the impacts of exploitation of renewable energy sources on birds and bats. The focus is on wind energy as there is only little information on the impact on birds and bats of other sources of renewable energy. The report aims at better understanding the size of the impact, the potential effects of re-powering (exchanging small old wind turbines by new big turbines), and possible measures to reduce the negative impact on birds by wind turbines. In addition the need for further research is highlighted. The evaluation is based on **127 single studies** (wind farms) in **ten countries**, most of them in Germany as reflected by the right image. Most studies were brief (not more than two years) und did not include the pre-construction period. Before-After Control Impact studies that combine data collection before and after, in this case construction of a wind farm, on both the proposed development site and at least one reference site were rare. In few cases only, the design of the study and the length of the study period would theoretically allow to find statistically significant effects of wind farms on birds and bats at all. Assessments of impacts, therefore, are usually based on few studies only. The lower image describes the frequency that studies were performed before, during or after start-of-operation of the wind farm and whether an untouched reference control area has been investigated or not. This report in-

Land	Zahl der Studien
Belgien	4
Deutschland	75
Dänemark	2
Frankreich	2
Großbritannien	6
Niederlande	5
Österreich	2
Spanien	10
USA	27
Australien	2

Anzahl der Untersuchungen	Untersuchungsphasen		
8	vor Baubeginn,	während der Betriebszeit	und mit räumlich getrennte Kontrollfläche
23	vor Baubeginn und	während der Betriebszeit	
9		während der Betriebszeit	und mit räumlich getrennte Kontrollfläche
87		nur während der Betriebszeit	

cludes all studies readily available to the authors, independently of the length of the study period and the quality of the study design. The references and studies out of which basic data for this study were derived can be found below in Table 15.In order to base the assessments on as many independent samples as possible even rather unsystematic observations were included. The information of the data was reduced to a level that justified the application of sign tests. The compilation of many different single studies gave following results:

The main potential hazards to birds and bats from wind farms are disturbance leading to displacement or exclusion and collision mortality. Although there is a high degree of agreement among experts that wind farms may have negative impacts on bird populations no statistically significant evidence of negative impacts on populations of breeding birds could be found. There was a tendency for open nesting waders to be displaced by wind farms. Some passerines obviously profited from wind farms. They probably were affected by secondary effects, e.g. changes in land management or abandonment from agricultural use next to the wind plants.

The impact of wind farms on non-breeding birds was stronger. Wind farms had significantly negative effects on local populations of geese, Wigeons, Golden Plovers and Lapwings.

With the exceptions of Lapwings, Black-tailed Godwits and Redshanks most bird species used the space close to wind plants during the breeding season. The minimal distances between observed birds and pylons rarely exceeded 100 m during the breeding season. Some passerines showed a tendency to settle closer to bigger than to smaller wind plants.

During the non-breeding season many bird species of open landscapes avoided approaching wind parks closer than a few hundred metres. This particularly held true for geese and waders. In accordance to published information disturbance of geese may occur at least up to 500 m from wind turbines. In most species during the non-breeding season, the distances in which disturbance could be noted increased with the size of the wind plants. In Lapwings this relationship was statistically significant.

There was no evidence that birds generally „habituated" to wind farms in the years after their construction. The results of the few studies lasting longer than one season revealed about as many cases of birds occurring closer to wind farms (indications for the existence of habituation) in the course of the years as of birds occurring farer away from wind farms (indications for the lack of habituation).

The question whether wind farms act as barriers to movement of birds has received relatively little systematic scientific attention yet. Wind farms are thought to be barriers when birds approaching them change their flight direction, both on migration or during other regular flights. There is evidence for the occurrence of a barrier effect in 81 bird species. Geese, Common Cranes, waders and small passerines were affected in particular. It remains unknown, however, to what extend the disturbances by wind farms of migrating or flying birds influences the energy budgets or the timing of migration of birds.

Collision rates (annual number of killed individuals per turbine) have only rarely been studied with appropriate methods (e. g. with controls of scarvenger activities). Particularly in Germany such studies are missing. Collision rates varied between 0 and more than 50 for both birds and bats. Obviously the habitat influenced the number of collisions. Birds were in high risks at wind farms close to wetlands where gulls were the most common victims and in wind farms on mountain ridges (USA, Spain) where many raptors were killed. Wind farms in or close to forests posed high collision risks on bats. For both, birds and bats, the collision risk increased with increasing size of the wind plant. The relationship, however, was not statistically significant.

Among powerful methods to reduce the negative impacts on birds and bats of wind energy use are:

- choice of the right site for wind farms (avoidance of wetands, woodlands, important sites for sensitive non-breeding birds and mountain ridges with high numbers of raptors and vultures),
- measures to reduce the attractiveness of wind farm sites for potential collision victims,
- configuration of turbines within wind farms (placement of turbines parallel to and not across the main migration or flight directions of birds),
- construction of wind turbines: replacement of lattice towers, wire-cables and overhead power lines.

Measures to increase the visibility of wind turbines and to reduce the effects of illumination remain to be studied.

Finally a review is given on needs for further research activities. Especially the need for appropriate techniques and methodologies concerning research of interactions of birds and bats with wind turbines is highlighted in this context, as well as the need for long-term studies, to for example also investigate the potential of adaptive behaviour. Special attention should also be addressed to the most suffering species. Mortality and population dynamics need to be investigated in order to quantify the relevant impacts on the ability of reproduction.

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Table 15: Sources of basic data revised, evaluated or incorporated within the NABU study

83 Bremer Beiträge für Naturkunde und Naturschutz, Band 7 Themenheft “Vögel und Fledermäuse im Konflikt mid der Windenergie” / Contributions of the Federal State Bremen to Nature Study and Nature Conservation, Edition 7 Manual “Bird and Bats in Conflict with Wind Energy”

Compilation: Dr. Handke, K., Dr. Kulp, H.-G., Rode, M., Dr. Schuchardt, B., Seitz, J.
Publisher / Date: Bund für Umwelt und Naturschutz Deutschland (BUND) Landesverband Bremen e.V. / 2004-12-00
Keyword(s): Birds, Bats, Collision, Barrier Effects, Population Dynamics

The most effective way of describing this comprehensive work is to draw a picture on the subjects and studies dealt with in this report:

Birds and Bats in Conflict with Wind Energy - Insights concerning Sensitivity
Reichenbach, M., Sprötge, M.: Birds and Bats in Conflict with Wind Energy - Insights concerning Sensitivity *(orig.: Vögel und Fledermäuse im Konflikt mit der Windenergie - Erkenntnisse zur Empfindlichkeit)*
Case Studies
Handke, K., Adena, J., Handke, P., Sprötge, M.: Spacial Division of selected Species of Brood Birds and Resting Birds in relation to a present Wind Energy Converters in an Area near to the Near Shore Krummhörn *(orig.: Räumliche Verteilung ausgewählter Brut- und Rastvogelarten im Bezug auf vorhandene Windenergieanlagen in einem Bereich der küstennahem Krummhörn)*
Handke, K., Adena, J., Handke, P., Sprötge, M.: Influence of Wind Energy Converters on the Division of selected Species of Brood Birds and Resting Birds in an Area of the Krummhörn (Jennelt/Ostfriesland) *(orig.: Einfluss von Windenergieanlagen auf die Verteilung ausgewählter Brut- und Rastvogelarten in einem Bereich der Krummhörn (Jennelt/Ostfriesland))*
Handke, K., Adena, J., Handke, P., Sprötge, M.: Investigations on the Appearance of Lapwing (Vanellus vanellus) and Curlew (Numenius arquata) before and after Construction *(orig.: Untersuchung zum Vorkommen von Kiebitz (Vanellus vanellus) und Großem Brachvogel (Numenius arquata) vor und nach Errichtung)*
Handke, K., Adena, J., Handke, P., Sprötge, M.: Investigations on selected Species of Brood Birds after Construction of a Wind Farm in the Area of Stader Geest *(orig.: Untersuchung an ausgewählten Brutvogelarten nach Errichtung eines Windparks im Bereich der Stader Geest (Landkreis Rotenburg/Wümme und Stade))*

Sinning, F., Sprötge, M., de Bruyn, U. : Change in the Fauna of Breeding and Resting Birds after Construction of the Wind Farm Abens-Nord *(orig.: Veränderungen der Brut- und Rastvogelfauna nach Errichtung des Windparks Abens-Nord (Niedersachsen, LK Wittmund))*
Sinning, F.: Development of the Existence and Occurrence of Lapwing (Vanellus vanellus), Partridge (Perdix perdix) and Quali (Coturnix coturnix) in the Wind Farm Lahn - Results of a 6 year lasting investigation *(orig.: Bestandsentwicklung von Kiebitz (Vanellus vanellus), Rebhuh (Perdix perdix) und Wachtel (Coturnix coturnix) im Windpark Lahn (Niedersachsen, LK Emsland) - Ergebnisse einer 6-jährigen Untersuchung)*
Reichenbach, M.: Long Term Investigation concerning Impacts of Wind Energy Converters on Birds in Open Terrain - First Interim Results after Three Years *(orig.: Langzeituntersuchungen zu Auswirkungen auf Vögel des Offenlandes - erste Zwischenergebnisse nach drei Jahren)*
Reichenbach, M.: Results Regarding the Sensitivity of Endangered Species of Songbirds with Respect to Wind Energy Converters - Luscinia svecica, Acrocephalus schoenobaenus *(orig.: Ergebnisse zur Empfindlichkeit bestandsgefährdeter Singvogelarten gegenüber Windenergieanlagen - Blaukehlchen (Luscinia svecica), Schilfrohrsänger (Acrocephalus schoenobaenus)*
Schoppenhorst, A.: Grey Heron and Wind Energy Converter - Results of a Field Study in the Ochtum-Lowland near Delmenhorst *(orig.: Graureiher und Windenergieanlagen - Ergebnisse einer Feldstudie in der Ochtumniederung bei Delmenhorst)*
Sinnig, F., de Bruyn, U.: Spatial Usage of a Wind Farm Area through Birds during the Migration-Period - Results of a Survey on Migratory Bird in the Wind Farm Wehrder *(orig.: Raumnutzung eines Windparks durch Vögel während der Zugzeit - Ergebnisse einer Zugvogel-Untersuchung im Windpark Wehrder (Niedrsachsen, LK Wesermarsch))*
Stübling, S.: Reactions of Migratory Birds in Autumn with Respect to Wind Energy Converters in the German Low Mountain Range - Results of a Study at the Vogelsberg *(orig.: Reaktionen von Herbstdurchzüglern gegenüber Windenergieanlagen im Mittelgebirge - Ergebnisse einer Studie im Vogelsberg (Hessen))*
Papers / Essay's
Sinnig, F.: Short Contribution to the Occurrence of Grey Bunting (Miliarria calandar) and Other Selected Species in Brush-Woods in the Wind Farm Mallnow *(orig.: Kurzbeitrag zum Vorkommen der Grauammer (Miliarria calandar) und weiterer ausgewählter Arten an Gehölzreihen im Windpark Mallnow (Brandenburg, LK Märkisch Oderland)*
Sinnig, F.: Short Contribution to the Occurrence of Stonechat (Saxicola torquata) and Other Selected Species in two North-German Wind Farms *(orig.: Kurzbeitrag zum Vorkommen des Schwarzkehlchens (Saxicola torquata) und weiterer ausgewählter Arten in zwei norddeutschen Windparks (Niedersachsen, LK Ammerland, Leer und Stade)*
Kaatz, J.: Concerning the Behaviour of Emberiza hortulana in response to Wind Energy Converters (WEC) in Prignitz, Federal State Brandenburg *(orig.: Zum Verhalten von Ortolanen (Emberiza hortulana) gegenüber Windkraftanlagen (WKY) in der Prignitz, Land Brandenburg)*
Overviews
Reichenbach, M.: A Wider Perspective - International Studies Concerning the Impacts of Wind Energy Converter on Birds *(orig.: Ein Blick über den Tellerrand - Internationale Studien zu Auswirkungen von Windenergieanlagen auf Vögel)*

Dürr, T.: Birds as Victims During Approaches of Wind Energy Converters - a View into the National Trove-File *(orig.: Vögel als Anflugopfer an Windenergieanlagen in Deutschland - ein Einblick in die bundesweite Fundkartei)*
Reichenbach, M., Handke, K., Sinning, F.: Stand of Knowledge regarding the Sensitivity of Bird Species in Response to Disturbing Effects of Wind Energy Converters *(orig.: Der Stand des Wissens zur Empfindlichkeit von Vogelarten gegenüber Störungswirkungen von Windenergieanlagen)*

Bats
Bach, L., Rahmel, U.: Overview of Impacts of Wind Energy Converters on Bats - a Conflict Estimation *(orig.: Überblick zu Auswirkungen von Windkraftanlagen auf Fledermäuse - eine Konfliktabschätzung)*
Dürr, T., Bach, L.: Bats as Blow-Victims of Wind Energy Converter - Status on the Experiences and a View into the National Trove-File *(orig.: Fledermäuse als Schlagopfer von Windenergieanlagen - Stand der Erfahrungen mit Einblick in die bundesweite Fundkartei)*
Rahmel, U., Bach, L., Brinkmann, R., Limpens, H., Roschen, A.: Wind Energy Converters and Bats - Details on Registration Methodology and Aspects of Planning *(orig.: Windenergieanlagen und Fledermäuse - Hinweise zur Erfassungsmethodik und zu planerischen Aspekten)*
Planning / In Progress
Korn, M,. Strübling, S., Müller, A.: Protection of Huge Birds through across-the-board Regulations on Distances between Wind Energy Converters - Possibilities and Limitations *(orig.: Schutz von Großvögeln durch Festlegung pauschaler Abstandsradien zu Windenergieanlagen - Möglichkeiten und Grenzen)*
Sprötge, M., Sinning, F., Reichenbach, M.: About a Professional Environmental Management of Birds and Bats for Wind Energy Planning *(orig.: Zum naturschutzfachlichen Umgang mit Vögeln und Fledermäusen in der Windenergieplanung)*

84 Studying Wind Energy/Bird Interactions: A Guidance Document

Authors: Anderson, R., Morrison, M., Sinclair, K., Strickland, D., Davis, H., Kendall, W.
Publisher / Date: National Wind Coordinating Committee / 1999-12-00
Keyword(s): Birds, collision

Bird mortality is a concern and wind power is a potential clean and green source of electricity, making study of wind energy/bird interactions essential. An important first step in understanding these interactions and assessing potential effects is to use the same terminology and conduct research that will produce credible and comparable results. This guidance document seeks to:

1. Provide a reference document for use by all stakeholders that will, if followed, produce a body of information adequate to:
    a. assess the suitability of a proposed wind plant site with regard to birds of concern
    b. assess the potential effects of a wind plant on birds of concern
    c. evaluate the potential effects of wind energy technology on birds
2. Provide sufficiently detailed and clearly understandable methods, metrics, and definitions for use in the study of wind energy/bird interactions

3. Promote efficient, cost-effective study designs, methods, and metrics that will produce comparable data and reduce the overall need for some future studies
4. Provide study designs and methods for the collection of information useful in reducing risk to birds in existing and future wind plants

85 Windfarms and Birds: An analysis of the effects of windfarms on birds, and guidance on environmental assessment criteria and site selection issues

Authors: Langston, R.H.W., Pullan, J.D.
Publisher / Date: BirdLife / 2002-09-00
Keyword(s): bird collision risks, barrier effects, EIA, SEA, Natura2000

Key objectives of the report are

- to analyse the impact of wind farms on birds
- establishing criteria for their environmental impact assessment
- developing guidelines on precautions to be taken when selecting sites for wind farms

Whereby these objectives have to be places in the context of

- disturbance leading to displacement, including barriers to movement
- collision mortality
- direct loss of habitat to wind turbines and associated infrastructure

The report hence serves as guidance for defining

- criteria for EIA of wind farms on birds and
- precautions to be taken when selecting sites for wind farm planning.

86 Wind turbines and birds in Flanders: preliminary study results and recommendations

Authors: Everaert, J.
Publisher / Date: Instituut voor Natuurbehoud, Brussel / -
Keyword(s): Birds

This article presents some preliminary results from a research on the impacts of three wind farms in Flanders (Belgium) on birds. The collision numbers varied from 0 to 125 birds per wind turbine per year. The mean victim numbers of the wind farms in 2002 was 24, 35 and 18 birds per wind turbine per year respectively. The number of collisions on the three studied locations seems to be dependent on the number of passing birds, and in less degree with the size of the wind turbine.

Author's intermezzo: As only three wind farm sites have been considered within the above study, and as the areas are assumed to be of a bird rich kind, these numbers are not representative for general onshore situations. This also becomes clear if considering other mentioned reports as for example 82 and 83. Sites with that high numbers in victims are mostly excluded from nowadays wind farm plannings due to more reasons:

a. The latest allocations of protection areas in context with Directives and treaties as introduced in chapter 3.2 also have as aim to take account for preventing wind farm siting there, where the impacts on birds is assumed to be as high as stated in report 86 above.

For example has one observed site been in immediate vicinity to a bird protection area following the European Directive on bird protection and its Appendix I-list [24]. Grievances during the planning may not be excluded in this context. Also turbines may have been built in the mid 80th already, which is roundabout 20 years ago[25]! That was a time when certain protective areas did not even exist.

b. A better picture at the newer wind farm sites would have given a comparison of the situation before erection of the wind farm site and thereafter. Enhanced frequency of dead birds also can be an indicator showing solely that many birds are around, however dieing by other (perhaps natural) reasons. Hence the ratio of dead birds over total number of birds around for both cases (before and after erection) and classified into tracking birds, breading birds, etc. may give a more representative picture for this specific mentioned sites.

If significantly many dead birds were counted, maybe not enough attention has been given to the site selection or searching for alternatives.

87 Auswirkung elektrischer und magnetischer Felder auf Meeresfische in der Nor- und Ostsee

Authors: Fricke, R.
Publisher / Date: Staatliches Museum für Naturkunde, Stuttgart / 0000-00-00
Keyword(s): EMF, seabed, fish

88 Abschätzung direkter und indirekter biologischer Wirkungen der elektrischen und magnetischen Felder des EuroKabel / Viking Cable HGÜ-Bipols auf Lebewesen der Nordsee und des Wattenmeeres

Authors: Kullnick, U., Marhold, S.
Publisher / Date: EuroKabel / Viking Cable / 1999-00-00
Keyword(s): EMF, seabed, fish

89 Vorläufige Ergebnisse von Felduntersuchungen an einer Elektrode in der Ostsee

Authors: Debus, L., Winkler, H., Zettler, M.L.
Publisher / Date: Institut für Ostseeforschung, Universität Rostock / 0000-00-00
Keyword(s): Ringelektrode, Meeresboden

90 Incidencia de las plantas de aerogeneradores sobre la avifauna en la comarac del campo de gibraltar

Authors: Barrios, L. and Aguilar, E.
Publisher / Date: Sociedad Espanola de Ornitologia (SEO / BirdLife), Madrid / 1995-00-00
Keyword(s): ave, avifauna, birds

91 Nocturnal collision risks with wind turbines in tidal and semi-offshore areas

Authors: Dirksen, S., Spaans, A.L. and Winden, van der J.
Publisher / Date: 2nd European and African Conference on Wind Engineering / 1997
Keyword(s): birds, collision risk

[24] www.mumm.ac.be/Common/Windmills/ SPE/4%20mer-spezeebrugge_bijlagefoto_scenarios.pdf at 10/02/05
[25] www.vliz.be/Docs/Groterede/p02_07.pdf at 10/02/2005

92 Review of the impacts of wind farms and other aerial structures upon birds

Authors: Gill, J.P., Townsley, M. and Mudge, G.P.
Publisher / Date: Scottish Natural Heritage Review 21 / 1996-00-00
Keyword(s): birds, collision risk

93 A continued examination of avian mortality in the Altamont Pass Wind Resource Area. Report to California Energy Commission

Authors: Orloff, S., and A. Flannery .
Publisher / Date: California Energy Commission / 1996-00-00
Keyword(s): Birds

94 Abschätzung von Verteilungsmustern und Definition von möglichen Schutzgebieten für die anadrome Wanderfischart Finte (*Alosa fallax*) in der Nordsee mittels nicht-linearer Geostatistik

Authors: Stelzenmüller, V., Maynou, F., Ehrich, S., Zauke, G.-P.
Publisher / Date: Carl von Ossietzky Universität Oldenburg / 2003-00-00
Keyword(s): fish, *Alosa fallax*

95 Continuation of bird studies at Blyth Harbour wind farm and the implications for offshore wind farms

Authors: Painter, A., Little, B. and Lawrence, S.
Publisher / Date: DTI ETSU, report no *W/13/00485/00/00* **/** 1999-00-00
Keyword(s): birds

96 Impact of a 90m/2MW wind turbine on birds: Avian response to the implementation of the Tjaereborg Wind Turbine at the Danish Wadden Sea

Authors: Pedersen, M.B. and Poulsen, E.
Publisher / Date: Danske Vlindtundersogelser Haefte 47 / 1991-00-00
Keyword(s): birds

97 The effect of wind turbines on the bird population at Blyth Harbour

Authors: Still, D., Little, B. and Lawrence, S.
Publisher / Date: Report to Border Wind Limited (UK) ETSU W/13/00394/REP / 1996-00-00
Keyword(s): birds

98 Auswirkungen von Windenergieanlagen auf Vögel – Ausmaß und planerische Bewältigung

Authors: Reichenbach, M.
Publisher / Date: Technische Universität Berlin, Fakultät VII / 2002-12-13
Keyword(s): birds

99 Langzeituntersuchungen zum Konfliktthema „Windkraft und Vögel" 2. Zwischenbericht

Authors: Reichenbach, M., Schadek, U.,
Publisher / Date: Bundesverband WindEnergie BWE Service GmbH / 2003-02-00
Keyword(s): birds

Appendix D

- Non-evaluated reports or papers that may contain more relevant information on what the potentially impacts of noise on the marine environment could be -

- Abbott, R. (2001). San Francisco – Oakland Bay Bridge East Span Seismic Safety Project, Pile Installation Demonstration Project, Fisheries Impact Assessment. Report PIDP EA 012081 on CalTrans Contract 04A014 8
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Appendix E

Standards for Environmental Impact Assessments Impacts of offshore wind turbines on the marine environment [Ref 44]
Authors: Issued by Bundesamt für Seeschifffahrt und Hydrographie (BSH) and others
Publisher / Date: Federal Maritime and Hydrographic Agency (BSH) / 2003-2-25

Any potential adverse impacts of the projected facilities on the marine environment have to be assessed within the framework of the approval procedure for offshore wind farms in the Exclusive Economic Zone (EEZ). In addition to following the amendment to the Seeanlagenverordnung (effective 5 April 2002), an EIA is now mandatory for most projects, according to Article 2a of the Seeanlagenverordnung. In the Standards for Environmental Impact Assessments, information is provided to applicants on the scope of investigations required by the approval authority, with all relevant details and explanations. The Standards for Environmental Impact Assessments constitute a framework of the thematic and technical minimum requirements for marine environmental surveys and monitoring in order to assess compliance with Article 3, Seeanlagenverordnung.

The standard has been established based on both the general increased knowledge and experience provide by the German Marine Monitoring programme in the North and Baltic Seas, and the Helsinki Convention on the Protection of the Marine Environment of the Baltic Sea Area, and the OSPAR Convention for the Protection of the North Sea and North-East Atlantic.

The German EIA standard is divided into two parts: a set of general conditions (Part A), and a technical code of practice (Part B). The main features of this standard are represented below.

Chapter 2 of Part A deals with possible adverse impacts of offshore wind farms on the marine environment. Various risks have been identified for the construction, operation and decommissioning phases. These risks involve:

- Visual and acoustic effects;
- Adverse impacts of specific use of vehicle and machinery;
- Loss of habitats (e.g. resting and feeding areas) or barrier effects (e.g. on birds during migration, or blocking of paths between different resting and/or feeding areas);
- Pollutant emissions;
- Turbidity of water or changed sediment distribution and dynamics;
- etc.

The objective is given as the investigation of impacts on environmental features that should be protected (i.e. fish, benthos, birds, and mammals), by means of:

- Determining their spatial distribution and temporal variability in the pre-construction phase (baseline survey);
- Monitoring the effects of construction, operation and removal;
- Evaluating the monitoring results, with the baseline data serving as a basis for comparison; and

- Conducting within the preliminary fish studies a quantitative determination of the near-bottom stationary fish species to the extent that suitable methods are available.

In a correct evaluation the data collected must be correct and comparable. Those participating in the surveys have to be adequately qualified and able to prove that they have acquired sufficient experience. The names of the observers have to be noted on the survey forms.

A distinction is made in terms of the degree of progress of a particular project, as presented below.

"Pilot phase

Large-scale wind farm projects presently have to be preceded by a pilot phase to establish whether the authorisation requirements are met. Prior to and after the pilot phase, baseline surveys and monitoring have to be carried out following notification of the probable scope of the investigations based on the Standards for Environmental Impact Assessments. The scope of the monitoring will depend on the results of the baseline surveys, taking into account experience gained in the process.

Expansion phase

For every expansion step following the pilot phase, baseline surveys and monitoring in accordance with the Standards for Environmental Impact Assessments will be mandatory. Modifications required at individual sites will be laid down in the notification of the scope of monitoring.

Removal phase

The wind turbines including their foundations have to be removed completely, with subsequent onshore disposal. In principle, the monitoring requirements during this phase correspond to those in the construction phase, as specified in the Standards for Environmental Impact Assessments. Possible environmental impacts depend mainly on the dismantling techniques used. Dismantling techniques are expected to undergo major developments over the coming decades, as numerous oil and gas platforms are due for removal. Therefore, the scope of monitoring will be determined at a later date."

Moreover a photo-realistic simulation (text and visualisation) of the landscape affected by the project has to be presented for projects closer than 50 km from the nearest point on the coast within the framework of the baseline survey preceding the pilot phase.

Chapter 10 deals with risk analysis. A state-of-the art risk analysis assessing the probability of a ship collision with a wind turbine, including an example study of the consequences of a potential pollutant spill has to be presented in the framework of the baseline surveys preceding the pilot phase. The procedure for the implementation and evaluation of studies relating to the construction and operation of offshore wind farms is described in chapter 11 and shown in the flowchart below:

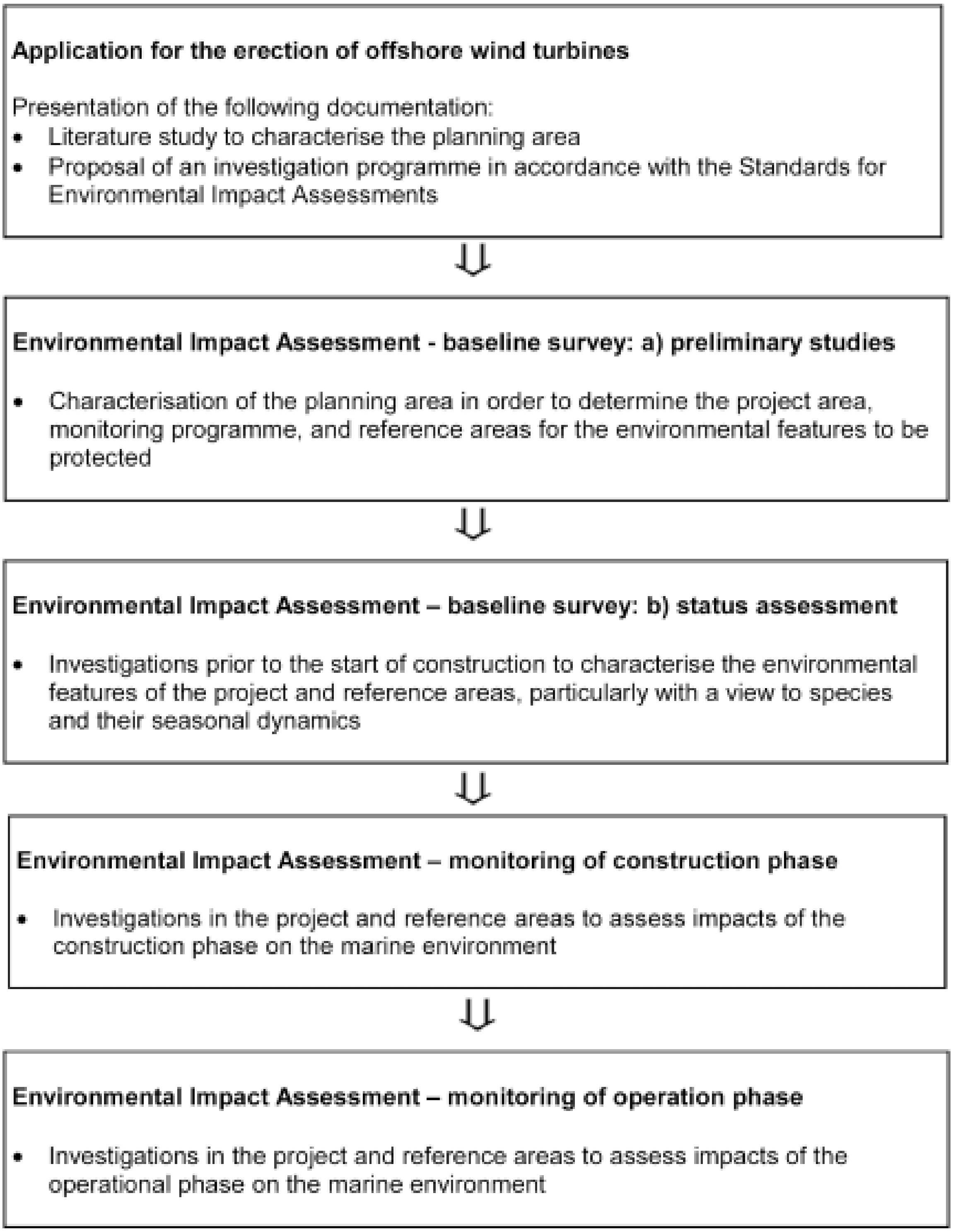

Fig. 30: Procedure for implementation and evaluation of studies relating to the construction and operation of offshore wind farms according to the German EIA standard

Periods of assessment apply to all project phases (pilot phase, expansion phases) and are described in Chapter 12 as follows:

“Baseline survey

Prior to the start of construction, in accordance with the Standards for Environmental Impact Assessments, a baseline survey has to be performed which covers the investigations made during two successive, uninterrupted complete seasonal cycles. One seasonal cycle comprises 12 calendar months including the month in which the survey begins. The baseline survey remains valid for two complete years. If construction work is not begun in the third year after completion of the baseline survey, the baseline survey should be updated with an additional seasonal cycle. Other details regarding the follow-up period will be dealt with on an individual case basis.

Construction phase

The construction phase covers the period from the start of construction work until completion of the construction project. Construction-phase monitoring has to be performed throughout this period. If essential components are put into operation prior to completion of the construction project, operation monitoring in the project section concerned may be started in co-ordination with the approval authority. However, it must be ensured that such continued construction activities do not have a significant impact on the results of operation monitoring. The precise time for stopping the construction monitoring will be determined by the approval authority in each individual case.

Operation phase

The Standards for Environmental Impact Assessments define the operation phase as the phase following the completion of construction work, when the wind turbines are put into operation. After the wind farm has become operational, operation monitoring has to be performed for a period of at least three years or, if required, up to five years in the entire project area The end of operation monitoring will be determined by the approval authority in each individual case.”

Excerpt on assessment areas from chapter 13 - Assessment areas:

“Assessment areas in each case are the project area (pilot phase, expansion phases) and the reference area. When indicating the size of a project area, the safety zone should not be included. The individual environmental features to be protected require different assessment areas in terms of size and location. If the specific conditions in individual cases are such that the size of an assessment area does not conform to the requirements for assessment areas as indicated below, such assessment areas have to be adjusted to local conditions in agreement with the approval authority.

Project area

Benthos/fish:

The assessment area has the same size as the project area.

Birds

- Ship based counts:
  The assessment area of a project area must cover at least 200km^2 in principle. The whole project area must always be surrounded by a 2nm wide assessment area.
- Aerial counts:
  The area including reference area must cover at least 2’000 km^2.

Mammals

- Aerial counts:
  The assessment area including the reference area must cover at least 2'000km^2 and the assessment area must have a rectangular shape. The project area should be located in the middle of the assessment area if possible. The distance between the boundaries of the wind farm and those of the assessment area must be at least 20 km.
- Ship-based counts:
  The assessment area has the same size as the assessment area for birds (see Birds).

Reference areas

Reference areas will be used for comparison, to document the condition, in areas not subject to the impact of wind turbines, of the environmental features to be protected within the project area. Reference areas should be located outside the planning areas for later wind farm expansion phases and should also be suitable as reference areas for such expansion phases. The natural environmental conditions in reference areas (location, current conditions, water depth, sediment properties, species spectrum, number of individuals) must correspond to those in the project area concerned. They must also be of a comparable size and distance from the coast. Reference areas should be free of any direct influences from wind turbines. If the reference area chosen for the pilot phase is located within the planning area for later expansion phases, the following points must be taken into account:

- The distance must be large enough to avoid any impacts from pilot phase activities.
- A separate reference area will also be required for the expansion phases

The individual environmental features to be protected require reference areas of different size, location, and quality.

Benthos / fish:

The size of the reference area should correspond to that of the project area. If the habitat of the project area is very heterogeneous (e.g. different sediment properties, hydrography or water depth), a reference area should be chosen which has a very similar habitat pattern. If such conditions do not exist in a single reference area, the reference area may also be composed of several smaller areas whose habitat patterns, in combination, correspond to that in the construction area. The individual areas should be located as close together as possible.

The reference area should be located in the vicinity of the project area but should be largely free of any impacts from the construction area. This implies that it must also be outside of the propagation range of operational noise from the wind farm. Whether and to what extent wind farms affect the individual environmental features to be protected often cannot be determined prior to the operation phase. Therefore, the minimum distance should be 500m for benthos (infauna) and 1 km for fish and epifauna.

Anthropogenic influences in the reference area should be comparable to those in the construction area but without the impact of the construction activities, turbine operation and related activities. The location of reference areas for macrozoobenthos and fishes should be largely identical.

Birds

- Aerial counts

  See project area (see birds at project area).

- Ship-based counts

  The size of the reference area corresponds to the size of the assessment area for the project area.

Mammals

- Aerial counts

  See project area (see birds at project area).

- Ship-based counts

  The size of the reference area corresponds to the size of the assessment area for the project area.

Reporting:

The results of the baseline surveys and monitoring have to be submitted to the approval authority in the form of comprehensible expert reports. The complete raw data and investigation documents in their original form should be stored in a suitable way by the applicant or holder of the permit and should be made available in whole or in part to the approval authority upon request. Different storage arrangements for the raw data may be agreed with the approval authority. The data formats to be used have to be agreed with the approval authority.

Baseline surveys

After completion of the baseline surveys, an EIA should be presented to the approval authority. If an EIA has already been made on the basis of a study covering one annual cycle, it has to be supplemented with the data of the second annual cycle. The research data should be provided to the approval authority upon request, but not later than the date on which the EIA is submitted. If the planning area is located in a National Park or in its vicinity, in a Marine Protected Area or an area that has been classified as ecologically valuable by conservation experts, an FFH study must be submitted in addition to the EIA in order to obtain approval (Art. 34, BNatSchG – Federal Nature Conservation Act).

Monitoring

The monitoring data should be presented to the approval authority once a year, four months after completion of the annual cycle in each case. The monitoring data shall include a documentation of the status before the construction phase and of developments and changes during and after the construction phase. On the basis of the monitoring results, the approval authority will decide on the type and scope of further investigations. Unless the applicant or permit holder in charge of the investigations proposes further investigations differing from the scope of investigations specified in the notification and from the present Standards for Environmental Impact Assessments, the existing arrangements and monitoring periods specified in the Standards for Environmental Impact Assessments shall continue to apply.”

Part B of the standards specifically aims on the protection of environmental features. Technical details of the investigation and monitoring to be carried out in order to protect benthos, fish, birds, and mammals are provided. The scope and targets of the investigations, methods to be used, and the evaluation basis are described for each of the environmental features to be protected.

"Benthos

The benthos investigations and monitoring comprise:

- Investigation of the sediment and habitat structure and their dynamics using side scan sonar and sediment sampling;
- Investigation of epifauna using video equipment and beam trawl/dredge;
- Investigation of infauna by means of grab sampling;
- Investigation of fouling on piles and foundations; and
- Investigation of macrophytobenthos, if present in the area investigated.

During the above investigations, measurements of salinity, temperature and oxygen levels have to be carried out at the sea surface and near the bottom in order to obtain a representative picture of the hydrographic situation in the area.

Additionally, the sediment properties grain size distribution and organic carbon content have to be determined per station and throughout the assessment period.

The investigations should be carried out at the same time as the fish investigations if possible, but mutual disturbance should be avoided.

In homogeneous sandy areas, side-scan sonar surveys have to be carried out with 500m spacing. Areas with a heterogeneous sediment structure have to be covered completely by the surveys.

The results of the sedimentological and benthological investigations should be combined in a single study."

The results of the sedimentological and benthological investigations should be combined in a single study.

Based on the required investigations and monitoring, explanatory tables concerning targets, scope, timing, method and presentation of results for the baseline survey and the monitoring are given within Part B of the standard for several categories. Table 16 shows exemplary one table for epifauna-survey element.

	Baseline survey a) Preliminary investigations	Baseline survey b) Status assessment	Monitoring construction phase	Monitoring operation phase
Targets	Baseline description of epifauna in the project area and determination of a suitable reference area	Medium and small scale survey of *status quo ante* as a basis for evaluating potential impacts of wind turbines	Medium and small scale survey of impacts from construction activities	Medium and small scale survey of impacts in the operation phase
Scope	Video transects in the area of all beam trawl surveys (small beam trawl) and/or dredge surveys. The minimum number of video transects and/or photo stations is 10. Video surveys have to be carried out together with the epifauna sampling.			
Timing	Together with the other benthos investigations			
Method	Video transects of about 15 - 30 min duration with a drift velocity of max 1 knot, geographic positioning of the transect and/or photo (high-resolution 6x6 camera) with 10 to 20 photos per station. The video surveys should be made using a digital camera, with each picture showing the station number, GPS data, date, and water depth if possible. At least the geographic positions have to be recorded.			
Presentation of results	Video recordings and/or photos showing at least the following details: • Abundance/frequency of rocks, shell banks etc. • Frequency of epifauna (percent cover) • Traces/dwellings of infauna (e.g. Lanice tubes) • Visible disturbances of the sediment surface (e.g. caused by fisheries) The geographic position must be allocated to each recording. A cut of the videos has to be presented.			

Table 16: Examples of requirements concerning targets, scope, timing, method and presentation of results for the Epifauna-survey element of the EIA.

Fish

Fish surveys and monitoring have to be carried out using bottom trawls and/or beam trawls. Additionally, measurements of weather, depth, salinity, temperature, and oxygen levels have to be made and recorded.

Resting and migratory birds (avifauna)

Surveying of foraging, moulting and resting birds should be undertaken, along with recording of bird migration and other flight movements in the survey area (radar surveys and visual observations/recording of flight calls).

Marine mammals

"The investigations and monitoring relating to marine mammals comprise studies of their abundance and distribution, possibly their habitat use, as well as noise emission and immission studies.

Sightings from transects allow conclusions as to the abundance and distribution of marine mammals in the assessment area.

Stationary click detectors allow continuous monitoring of the habitat use of harbour porpoises. Click detectors have to be deployed in addition to ship and aerial surveys as a monitoring basis.

During the construction and operation of wind turbines, a broadband noise spectrum (including structure-borne and airborne noise) is likely to be emitted into the water. The occurrence of interferences cannot be ruled out. Measurements of immissions at particular locations and of emissions at the noise source should be made during the construction and operation phases.

Not only emitted frequencies but also noise characteristics (impulsiveness/tonality) have to be recorded. Via propagation computations, predictions of the expected noise pollution have to be made using noise emission data of the turbines and suitable models."

Topics especially concerned are:

- Abundance, distribution
- Habitat use
- Emission and immission of waterborne noise.

Table of Figures

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