REGIONAL COUNCIL KOP VAN NOORD-HOLLAND

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INTERREG PROJECT POWER

PUSHING OFFSHORE WIND ENERGY REGIONS WORKPACKAGE 2, SUPPLY CHAIN

Kop van Noord-Holland strong contender for offshore wind farm maintenance

Part 1: Technical Inventory: pages 2 - 59

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KOP VAN NOORD-HOLLAND STRONG CONTENDER FOR OFFSHORE WIND FARM MAINTENANCE

Part 1: Technical Inventory

H. Braam
L..W.M.M. Rademakers

Responsible party

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Abstract

The Regional Council of Kop van Noord-Holland / Kop & Munt is partner in the Interreg project Pushing Offshore Wind Energy Regions POWER. Workpackage 2 of this project consists of a regional supply chain study.
The Dutch government has the ambitious objective of creating large-scale offshore wind farms in the next few years. Its 2002 policy document on energy states that by the year 2010 about 1,000 MW of wind power should be installed in the Dutch sector of the North Sea, and in the year 2020 6,000 MW. It is Den Helder's ambition to become the base from which maintenance operations for offshore wind turbines are conducted. In order to prepare itself for the prominent role the *Kop van Noord-Holland* (the northern tip of North Holland province) aims to play in the sphere of offshore wind turbine maintenance, the project office of the economic incentive programme *Kop & Munt* granted a assignment in early 2005 to the technology transfer association ATO Maritime Platform (ATO-MP) to conduct the project "*De regio sterk voor onderhoud offshore wind*" ("Region strong contender for offshore wind farm maintenance"), in order of the Interregproject POWER Pushing Offshore Wind Energy Regions. ATO-MP conducted the project in collaboration with the Netherlands Energy Research

Centre (ECN), the regional training centre ROC Kop van Noord-Holland and the regional development agency *Bedrijfsregio Noord-Holland* (details of the partners and their part in the project are given in Annexe A). The project comprised three phases:

1. Compiling an inventory of technical facilities and services.
2. Compiling an inventory of businesses in the region.
3. Drawing up recommendations.

This report contains the results of phase 1 and was conducted by ECN. ECN itself performed analyses to establish the scale of the maintenance requirement for large offshore wind farms. Interviews were then held with companies that will be carrying out maintenance on offshore wind turbines in order to verify the views of ECN. The chief results, in particular the recommendations of phase 1 made to ATO-MP, Bedrijfsregio Noord-Holland and Projectbureau Kop & Munt are given below.

The following table shows the number of wind turbines that can be maintained from Den Helder. It also shows the equipment and immediate personnel required. It assumes that a number of wind farms in German waters can also be maintained from Den Helder.

2010:	2,000 MW	500 turbines	6 supply boats	130 technicians
2020:	7,000 MW	1,750 turbines	16 supply boats	450 technicians

Indirect employment is expected in particular for supply boat crews and dockworkers for the transport in, storage and shipping out of supplies and spare parts. To a lesser extent jobs will be created for personnel for online monitoring of the wind farms in the control room, in overhaul businesses, haulage companies and training institutes.

If one considers the amount of maintenance that needs to be done on wind turbines and the continuity of the work, then it is probably most worthwhile for Den Helder to focus on accommodating preventive maintenance and minor corrective maintenance.

Den Helder can expect competition from North German ports, from which the first wind farms will be installed and maintained. In fact, they will be gaining an advantage regarding infrastructure and the development of know-how. Maintenance on the first Dutch offshore wind farms will be carried out from IJmuiden. Den Helder will need to make haste in determining its own strong points for the maintenance of offshore wind farms and to use these to project itself. The already planned collaboration with IJmuiden will be necessary to be able to take on the foreign competition.

The peak of the maintenance work will be in the summer. If employment opportunities can be created in the region that enable personnel to be employed offshore in the summer and onshore for a different activity during the winter months, maintenance personnel can be tied to the region.

It did not emerge from interviews with current and potential offshore wind turbine maintenance contractors why Den Helder makes an attractive base for these companies on technical grounds. The technical requirements a port needs to meet to act as a base for minor maintenance on offshore wind farms are not so great. Supply boats need to be able to tie up and take on supplies. If Den Helder does aim to attract companies to the region and to encourage job creation, it will need more decisive arguments than just technical ones. It will need to focus on, for example, financial incentives, or creating good conditions (legal, economic, etc.).

A number of the parties interviewed were familiar with Den Helder Training Centre (DHTC) and were very impressed with its training courses. It is thought that if DHTC were to project itself more forcefully among potential maintenance contractors, the demand for these courses could increase.

CONTENTS

Introduction

Background

The Dutch government has the ambitious objective of creating large-scale wind farms offshore in the next few years. Its 2002 policy document on energy states that by the year 2010 about 1,000 MW of wind power should be installed in the Dutch sector of the North Sea, and in the year 2020 6,000 MW. Plans are being prepared in other countries bordering the North Sea, in particular in Germany, for the construction of North Sea wind farms, making the total capacity installed in the North Sea a multiple of that in the Dutch sector. The total involved would be between 4,200 and 7,000 large wind turbines, 1,200-2,000 of which in the Dutch sector, which will need to be installed, maintained and dismantled. In view of Den Helder's central location in respect of a large part of the North Sea and the infrastructure it already has, this port could become an excellent base from which to conduct maintenance operations for these offshore wind turbines. This presents the Kop van Noord-Holland with a tremendous challenge to give the region an economic impulse by concentrating the maintenance activities for these offshore wind turbines in the region.

Other ports will naturally have the same goal, but Den Helder has several big points in its favour, as it is already an important centre for offshore platform maintenance and the region already has a significant concentration of wind power-related companies and institutions, viz.:

- the Netherlands Energy Research Centre's Wind Power Unit in Petten;
- the ECN Wind Turbine Test Farm Wieringermeer, where prototypes of offshore wind turbines are tested;
- the testing centre for wind turbine materials and constructions (WMC) in the Wieringermeer, where large rotor blades are tested.

Besides the comprehensive facilities afforded by Den Helder's existing port infrastructure, there are also a large number of companies and facilities in the region that can and would like to play a part in wind power. Examples include:

- Den Helder port, from which maintenance operations on a large number of offshore platforms are conducted. There is potential for expanding the existing port infrastructure to facilitate the maintenance of offshore wind turbines.
- The regional training centre ROC in Den Helder with its special training courses focusing on the maintenance of offshore installations and on safety.
- Den Helder Airport, from where offshore locations can be easily reached.
- A large number of specialist companies engaged in the maintenance of offshore installations.

So it transpires that the Kop van Noord-Holland, with Den Helder as base, has the potential to develop into a leading centre for the maintenance of offshore wind farms in the North Sea.

Plan of Attack

In order to prepare itself for the prominent role the Kop van Noord-Holland intends to play in the sphere of offshore wind turbine maintenance, the project office of the economic incentive programme Kop & Munt granted a subsidy in early 2003 to the technology transfer association ATO Maritime Platform (ATO-MP) to conduct the project *"Region strong contender for offshore wind farm maintenance*". ATO-MP conducted the project in collaboration with the Netherlands Energy Research Centre (ECN), the regional training centre ROC Kop van Noord-Holland and the regional development agency Bedrijfsregio Noord-Holland (details of the partners and their part in the project are given in Annexe A). The aim of the project is to draw up recommendations for the provincial authorities and other interested parties for encouraging the concentration of offshore wind turbine maintenance operations in the region. The project comprised three phases:

1. *Compiling an inventory of technical facilities and services.*
   In this phase an inventory was compiled - through analyses and interviews with companies that might carry out or be involved in offshore wind turbine maintenance - of the requisite technical

aspects for the maintenance of large-scale offshore wind farms. For example, the type of maintenance required, how often, by whom, which vessels or other equipment are required, which port facilities, etc. Interviews were conducted with companies that already carry out maintenance work on wind turbines (onshore) and with companies operating in the offshore oil and gas industry. This task was performed mainly by ECN.

2. *Compiling an inventory of businesses in the region.*
   In this phase, the maintenance services already present in the Kop van Noord-Holland, e.g. companies, facilities, training courses, etc., were surveyed. For this purpose the results of phase 1 were discussed with provincial and local authorities. For example: does the region afford the necessary conditions (technical, such as ports and infrastructure, favourable economic climate, training, personnel, etc.) for it to be attractive for companies to concentrate their activities or to establish their businesses here. This phase was mainly carried out by the regional development agency Bedrijfsregio Noord-Holland and the Netherlands Energy Research Centre (ECN).

3. *Drawing up recommendations.*
   Finally, a report was prepared containing recommendations for attracting maintenance contractors. They include the development or provision of facilities and infrastructure, the flexible deployment of personnel in summer and winter, or the creation of specific facilities.

Obviously, phase 1 was highly technical, whereas phases 2 and 3 focused more on policy aspects, both in regard to authorities and to business management.

Guide to the report

This report outlines the result of phase 1. Section 2 explains the method employed for phase 1 in greater detail. In Section 3, an estimate is made of the total number of wind turbines that will be installed and easily accessible from Den Helder up to 2020. Section 4 summarises the technical aspects that are of importance for offshore wind turbine maintenance.

The results of the ECN survey and the results of the interviews are discussed in Section 5. The questionnaire used during the interviews with parties from the industry forms a guide to the report. The report draws a clear distinction between the smaller wind farms that will be built in the short term relatively close inshore, e.g. NSW and Q7, and the large wind farms that will be built in the longer term far offshore.

Finally, Section 6 presents the chief conclusions.

METHOD

Applying ECN Know-how

ECN Wind Power has in recent years carried out detailed research in the field of offshore wind power, during which it considered the following topics in particular: the design of large offshore wind turbines of up to more than 5 MW, the possibilities for installing, maintaining and operating these turbines at sea, and linking large-scale offshore wind farms to the grid and transporting the power to shore. With respect to offshore wind turbine maintenance ECN performed cost modelling for various parties in order to arrive at a cost-effective strategy for the maintenance of wind farms. The objective was to arrive at the lowest possible cost and highest possible availability of the farm and hence power generation. The cost models allow for the reliability and failure rate of the wind turbine, which in effect determines the maintenance requirement of a wind farm. Allowance was also made for the manner in which maintenance and repairs are carried out, e.g. which personnel are required, which vessels and cranes, how often and at what cost. In conclusion, the cost model also allowed for the on-site wind and wave conditions, as these are one of the determining factors as to whether or not maintenance work or repairs can be carried out and so are decisive for the duration of a malfunction and hence for loss of output.
The manner in which ECN Wind Power modelled the costs is shown diagrammatically in Fig. 2.1. The know-how ECN has developed in the field of offshore wind turbine maintenance has been put to use in this project; see also [1], [2], [3], [4] and [5].

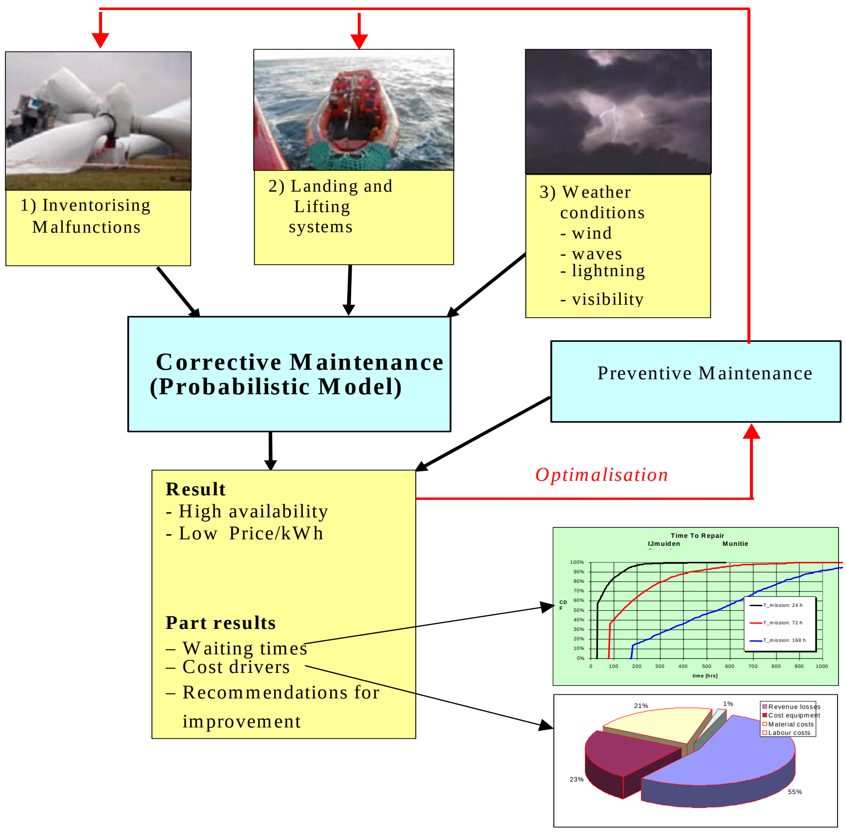


Fig. 2.1: *Diagram of cost modelling for optimising the maintenance strategy for offshore wind farms*

Studies of the literature

Besides the know-how developed by ECN itself, use was also made of data from the literature, in particular in regard to:

- indicators of cost and growth expectations (see, for example, [6], [7], [8], [9], [10], [11], [12], [13], [14]) .

- new developments in the field of offshore wind power (turbine designs, lifting equipment, landing systems and vessels, operational and condition monitoring systems, etc., see also [10] and conference proceedings from 1999-2003); and
- initial experiences with offshore wind farms in Denmark and Sweden.

Interviews

Practical experience can mainly be found in companies that carry out maintenance on wind turbines and offshore installations. ECN conducted interviews with a number of these parties to hear their views on offshore wind turbine maintenance in the short term, but especially in the long term.

1. Service department of a wind turbine manufacturer

NEG-Micon in Rhenen, responsible for the maintenance of the Near Shore Windpark (NSW) off the coast of IJmuiden, contacts Mr F. Brekelmans and Mr D. Knoppers.

2. Property developer and main contractor of the consortium

E-Connection in Bunnik, property developer of the Q7 park just outside the 12 mile zone, contact Mr H. den Boon.

3. Large maintenance contractor specialising in the maintenance of offshore oil and gas platforms

Fabricom Oil & Gas in Beverwijk, contact Mr J. Berg.

4. Maintenance and construction company for onshore and offshore installations

Multimetaal Constructie in Den Helder, contact Mr A. Hulsebos

5. Independent maintenance contractor for wind turbines

MainWind in Schagen, contacts Mr R. de Knecht and Mr J. Portegijs.

In order to structure the interviews, all those interviewed were first sent the questionnaire shown in Table 2.1. In as far as was possible this questionnaire was also used as a guide during the interviews. Vestas Nederland (Mr E. Coolen) was also consulted briefly by telephone, during which conversation some, but not all of the questions were posed. Lack of time at Vestas made it impossible to make an appointment for an interview.

After the meetings with the above parties, it was decided that the topic of "offshore wind turbine maintenance in the long and short term" had been covered from sufficient angles. In view of the resources available for the project, the added value of additional interviews was deemed limited.

Table 2.1: *Questionnaire for interviews with industrial parties*

General

1. *How much and what kind of maintenance work (corrective and preventive) will need to be carried out?*
   We need this information in order to be able to estimate the scale and type of facilities and services required (see questions 4 and 8). Given the nature of the work, it makes sense to draw a distinction between maintenance on the wind turbines, the supporting structures and the electrical infrastructure both inside and outside the wind farm.
   Little practical experience with offshore wind power has been gained until now, so this question will mainly have to be answered on the basis of engineering judgement. That is why it is important to distinguish between what is deemed necessary in the short and medium term and what is deemed advisable in the longer term in the context of an optimum commercial operation.
2. *How will the central monitoring and control facilities be handled, and how many people will be manning them?*
   Both the number and the qualifications of the staff are important in this respect. The position of the maintenance management is also a point for consideration.
3. *What are the requirements regarding the site of the central control room?*
   Aspects that could play a part include the requisite digital infrastructure and geographic location in respect of the companies that will carry out the actual maintenance work.

Equipment

4. *How much and what type of equipment will be used?*
   This is closely linked to question 1.
5. *How will the various types of equipment be mobilised?*
   Aspects that play a part in this are whether or not a vessel needs to take maintenance crews and/or spare parts on board. Also of importance is whether the maintenance crews maintenance staffwill go aboard on a daily or a weekly basis.
6. *What port infrastructure is required?*
   The same aspects as in question 5 are relevant here.
7. *Which companies are eligible for carrying out this type of work and where are they currently located?*

Maintenance crews

8. *How many and what type of technician will be used?*
   This is linked to question 1.
9. *What kind of courses and training programmes will the personnel have to take in the areas of maintenance, working offshore, safety at work and wind power?*
10. *How is this kind of training currently provided?*
11. *Is there a need for further training facilities?*
    Is there a need to transfer courses that are now given "in-house" to an external institute?
12. *Which companies are eligible for carrying out which type of maintenance and where are they currently located?*
13. *Which companies do you think you will collaborate with?*

Spare parts and repairs

14. *How will the logistical aspects be organised, e.g. storing parts, etc.?*
15. *What kind of infrastructure (roads, port, etc.) is required to bring in spare parts?*
16. *What kind of premises and facilities will be required for storing spare parts and carrying out repairs and overhauls?*

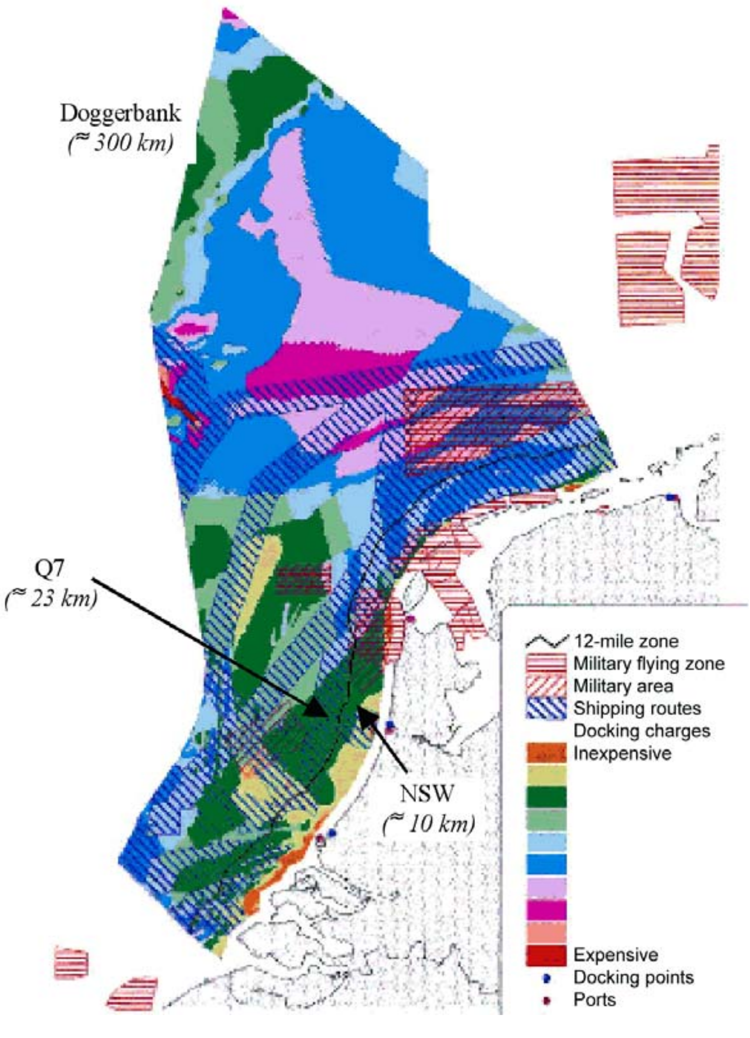
SCALE OF OFFSHORE WIND POWER

Offshore companies are generally geared to the international market; they operate on a global scale. Offshore wind power should also be placed in this perspective. Maintenance contractors will therefore focus not only on the wind farms in the Dutch sector, but will see the entire North Sea as their field of operations. It is therefore necessary to look at the activities in neighbouring countries bordering the North Sea, in particular Germany, Denmark, the United Kingdom and to a lesser extent Belgium, Sweden Norway and Ireland, for the development of offshore maintenance activities in the Kop van Noord-Holland. The last four were left out of this study as they are too far away from Den Helder. A complete overview of built and planned wind farms is given in Annexe B and Annexe C.

Netherlands

In the Netherlands expectations are that in 2010 about 2,500 MW of wind power will have been realised (1,500 MW of which onshore). By 2020, about 6,000 MW of offshore wind capacity should be in place. The first wind farms will be built close inshore (NSW, 100 MW and Q7, 120 MW). After 2010, larger farms will probably be built further offshore, possibly on the Doggerbank. The potential locations are marked in Figure 3.1. The colours indicate the relative cost per kWh for offshore wind power, calculated using the OWECOP model developed by

ECN.Fig. 3.1: Dutch exclusive economic zone with planned offshore wind farms



Germany

Within the German exclusive economic zone applications have been submitted for approx. 6,500 MW in the period up to 2010 and ultimately for 58,500 MW even. The areas in Germany that are suitable for offshore wind power are more limited. The available areas could in the short term accommodate the total of 6,500 MW applied for. Of this, about 5,000 MW has been applied for in the North Sea sector. In the long term, 20,000-25,000 MW should be possible between 2010 and 2030, the majority of which in the North Sea.

The areas for which applications have been submitted are shown in Fig. 3.2

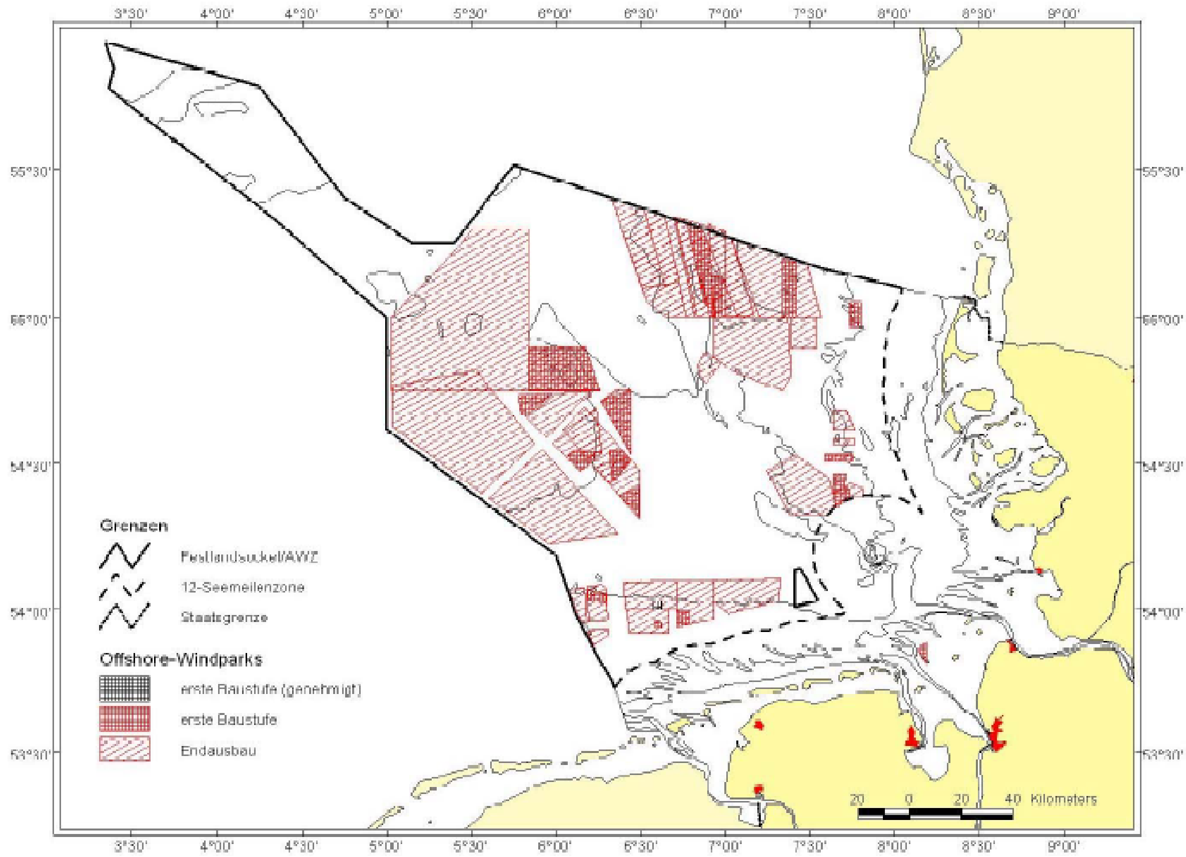


Fig. 3.2 German exclusive economic zone with offshore wind farms for which applications have been submitted

United Kingdom

The potential locations for offshore wind power in the United Kingdom are marked in Fig. 3.3. In the short term, about 350 to 400 MW will be built off the southeast coast. Unfortunately, there are no concrete plans for the long term.

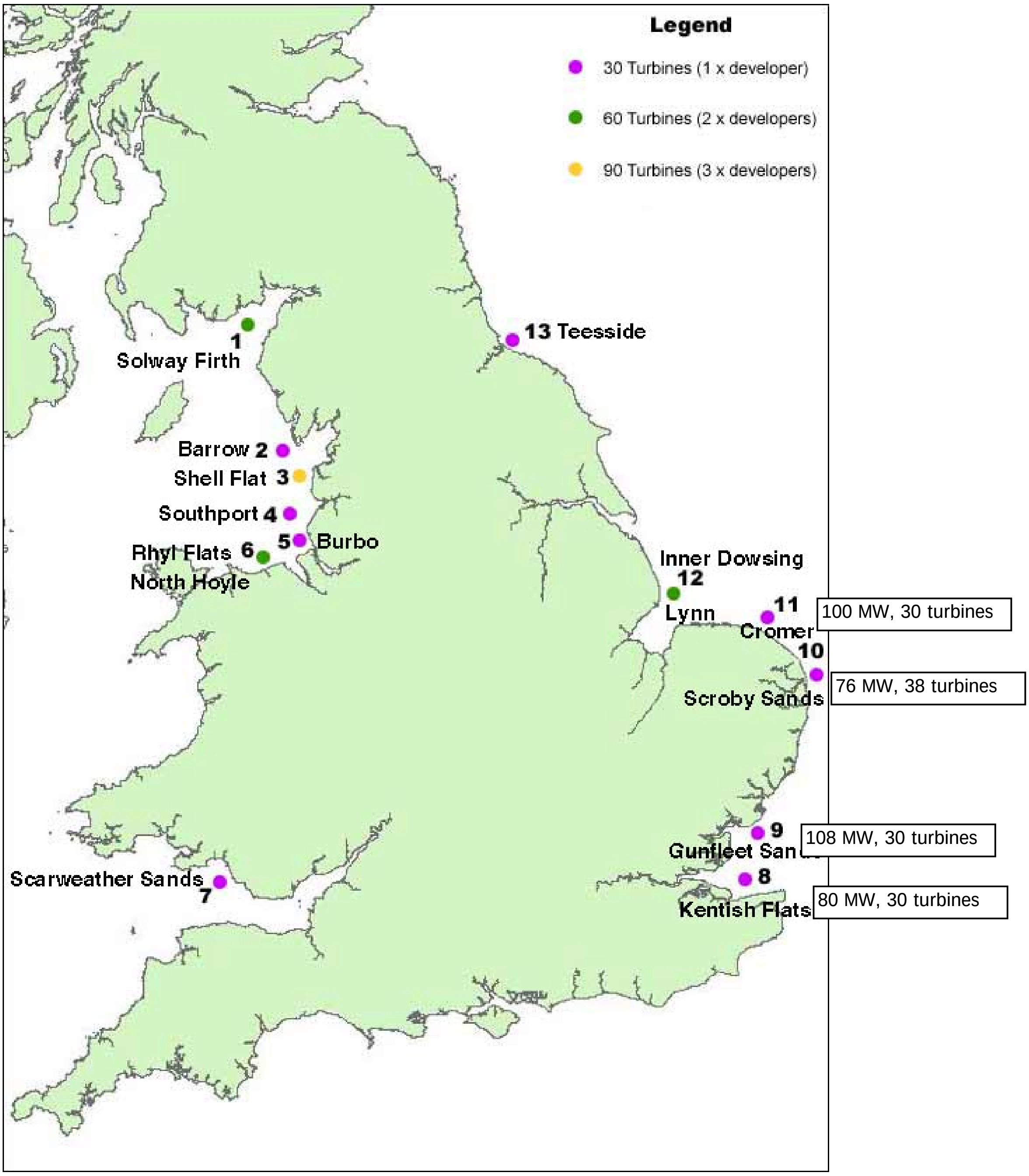


Fig. 3.3: *Offshore wind power off the southeast coast of the United Kingdom*

Denmark

At present, the plans for offshore wind power in Denmark are the most complete and consequently most of the farms have already been installed or are being installed. Fig. 3.4 shows their locations. The plans for the long term, around 2030, are for 3,000 MW. Only a small portion of this is expected to be realised in the North Sea because the locations on the east side of Denmark are cheaper to develop. The wave conditions and water depths require less expensive installations and maintenance procedures.

Blue: Operating Projects
1. Vindeby, 11 * 450 kW Bonus
2. Tunø Knob, 10 * 500 kW Vestas
3. Middelgrunden, 20 * 2000 kW Bonus
4. Horns Rev, 80 * 2000 kW Vestas
5a.Samsø, 10 * 2,3 MW Bonus

Green: Under construction
5. Nysted, 72 * 2,2 MW Bonus, 2003
5b.Frederikshavn, 11 MW
(Bonus,Nordex,Vestas)

Red: Other planned projects, tenders planned
6. Leasø
7. Omø/ Stålgrun
8. Gedser Rev

Yellow : Planned German Projects

Fig. 3.4 *Danish offshore locations, built, under construction or planned*

Competitors for Den Helder

From the preceding sections it emerges that all the Netherlands' neighbours have ambitious plans for developing offshore wind power. From Den Helder it will be possible to maintain a large number of the offshore wind turbines to the north and west of the Netherlands. The distance to the Danish wind farms appears too great. Besides, Denmark has few concrete plans for offshore wind power in the North Sea. The distance to the planned wind farms off the coast of the United Kingdom is also too great. When the United Kingdom plans to build wind farms far offshore, Den Helder will become an attractive base. So far there are no such plans.
IJmuiden could be a potential competitor for Den Helder because that is the location from which the first two farms (NSW and Q7) will be maintained and because that will be the base from which these two wind farms will be installed. IJmuiden is thus building a track record and that is beneficial for follow-up work. However, the two regions have already decided to collaborate and to coordinate their developments.
More competition is to be expected from German ports, in particular Cuxhaven. Activities recently initiated include the establishment of the DEWI-OCC GmbH (DEWI = German Wind Power Institute); OCC = Offshore and Certification Centre) and the setting up of a test site for five prototypes close inshore. Furthermore, the German government has had a measurement mast positioned at sea to obtain long-term wind and wave data. These are activities which demonstrate that Germany is taking the development of offshore wind power seriously. North Germany too will build up a track record sooner than Den Helder.

Conclusions

For calculating the scale of the operations we have confined ourselves to the Dutch and the German plans, because it is unlikely that wind farms in the UK and Danish sectors of the North Sea will be maintained from Den Helder.
To summarise, it can be said that the offshore wind capacity that may be realised off the Dutch and German North Sea coast will be as follows:
2006 220 MW + 300 MW ≈ 500-550 MW (very advanced plans)

2010 1,000 MW + 5,000 MW ≈ 6,000 MW
2020 6,000 MW + 15,000 ≈ MW 21,000 MW

These are the figures that will also be used in the further consideration of the scale of the maintenance operations. At the same time it should be noted that these wind turbines will also be maintained from other ports and regions. For the time being it seems realistic to assume that about one-third of the capacity will be maintained from Den Helder: in **2010: 2,000 MW, in 2020: 7,000 MW** This corresponds with 500 and 1,750 4 MW turbines respectively.

OFFSHORE WIND TURBINE MAINTENANCE

Onshore Wind Power

Wind turbine maintenance comprises preventive and corrective maintenance. Preventive maintenance is usually carried out onshore twice a year. It takes a team of two technicians an average of 2-3 days to carry out a small service and 3-5 days for a big service. The work mostly involves inspections, lubricating, cleaning, function testing and making minor repairs.

Corrective maintenance is determined by the nature of the malfunction. Current turbines malfunction on average 2-8 times a year. In most cases the turbines can be restarted remotely. In 2-3 instances a year, a technician needs to make an on-site repair. This can vary between replacing a fuse to repairing or replacing a rotor or gearbox.

Major maintenance is carried out once every 5-10 years. This involves, for example, changing the gearbox lubricant or replacing the blade pitch mechanism and torque motors.

Onshore the technicians drive to the turbine in a van, which also contains the necessary tools and consumables (lubricants, bolts, etc.) Repairs to or the replacement of larger components is usually planned separately. The turbine is often equipped with a crane for lifting smaller components. An external crane is used for larger components. As wind turbines increase in size, they are increasingly equipped with an internal crane for lifting relatively small components weighing up to 500 or 1,000 kg.

Offshore Wind Power

Offshore wind turbine maintenance differs somewhat from the maintenance of onshore turbines. The design of a wind turbine is aimed at preventive maintenance being required only once a year. This should be carried out in the summer months because that is when the turbines are most easily accessible. In order to limit the number of landings, crews of five or six technicians are more likely to be used than two-man crews. The full team will be required to complete the work within two days.

Between the services, 2-3 additional visits are expected to offshore wind turbines to carry out corrective maintenance. The current design philosophy for offshore wind turbines places emphasis on reducing the number of additional visits to one or none. For the moment it is not clear whether this will be achieved.

A big difference between maintenance on onshore and offshore wind turbines is the accessibility of the turbine and the transport of manpower and resources. For minor repairs (cleaning etc.) only technicians and tool boxes need to be ferried across. In some instances, parts that are too heavy to lift need to be replaced. This requires the use of a small crane. Replacing an entire nacelle requires the hire of an external crane on a derrick or jack-up. Naturally, the use of vessels and cranes is highly dependent on the weather conditions, wind and wave conditions especially. In the winter, accessibility can be reduced to 30% of the time or less even. If a malfunction cannot be remedied immediately, a wind turbine can be out of operation for a month or even longer in the winter.

Besides maintenance on the turbines themselves, the subsea electrical infrastructure and supporting structures also need to be maintained. The next sections look at the different technical aspects individually.

Offshore Wind Turbines

Offshore wind turbines differ from onshore turbines on a number points. This sections looks at those aspects that are of significance for maintenance and port facilities, in particular the weights and dimensions the port will need to be able to handle. It also looks at the facilities already available in the turbines to enable maintenance to be carried out and their consequences for the external equipment still required.

Dimensions

In the first place, they are larger than the current generation of commercially available onshore turbines. At present, the largest land turbines have a capacity of approximately 2.5 MW and a diameter of up to 90 metres. The first generation of offshore turbines was derived from the current onshore turbines such as the Vestas V80 (2 MW) and V90 (3 MW) and the DOWEC 2.75 MW with a diameter of 92 m (see Fig. 4.1 and 4.2). The V80 and V90 will probably be used for the Q7 wind farm. The DOWEC 2.75 MW will be used for the NSW wind farm. Other examples of first generation offshore turbines are the Nordex N80 (2.5 MW), the Bonus 2.0 and 2.3 MW, Repower and DE-Wind.

Fig 4.1: *Vestas V80 in Horns Rev (DK)* Fig. 4.2: *DOWEC 2.75 MW in Wieringermeer*

The second generation offshore turbines will be larger, 3 to 5 MW and maybe even 6 MW. They are expected to be operational on land only as prototypes or in very remote locations. One example is the GE-Wind 3.6 MW turbine with a rotor diameter of 104 m, see Fig. 4.3. The first prototype has been operational in Spain for twelve months.

Currently, 5 and 6 MW turbines appear to be the optimum size for third generation offshore wind farms. A number of manufacturers are busy developing a turbine in this class. The world's largest turbine was recently installed in Germany. The Enercon 4.5 MW turbine has a rotor diameter of 112 m, see Fig. 4.4. The unique feature of this turbine is that it does not have a gearbox, as is customary in the turbines mentioned above. The rotor is connected direct to a slow-moving generator. Consequently, this generator is larger in diameter and heavier than the customary high-speed generators. Other manufacturers busy developing large offshore turbines include Nordex and Repower, both 5 MW and with a rotor diameter of up to 125 m. The hub height is approximately 100-120 m.

Fig. 4.3 *GE-Wind 3.6 MW turbine with a diameter of 104 m*

Fig. 4.4: *Enercon 112 with a capacity of 4.5 MW*

Reliability and maintainability

A second difference between onshore and offshore wind turbines is their reliability and maintainability. Reliability is in effect a mark of how many malfunctions a turbine suffers and what its maintenance requirement is. Maintainability indicates how swiftly a faulty turbine can be operational again. This section explains maintainability in particular in more detail. (Section 0 looks in greater depth at reliability: the number of malfunctions and the way in which malfunctions are remedied.)

One of the present design challenges is to increase turbine reliability. The failure rate (the number of malfunctions a wind turbine suffers per year) of onshore turbines, which averages 1.5-4, needs to be reduced to a maximum of 2 a year in the case of offshore turbines. Also, the number of times preventive maintenance is carried out must be reduced from twice a year to once a year. Most offshore preventive maintenance will have to be carried out in the summer. Attention also focuses on good corrosion protection, condition monitoring in order to identify malfunctions early, and remote control.

In order to be able to maintain turbines properly, even in strong winds and high seas, there need to be facilities for landing personnel and parts. This is taken into account right from the initial design of offshore wind turbines. For example, to land personnel platforms are attached to the nacelle for hoisting, and dedicated vessels are being developed. Most turbines are already equipped with small cranes for lifting small parts weighing up to 1,000 kg, and some even have cranes that can lift an entire generator or gearbox. Added to this, dedicated vessels with a crane are being developed which can swiftly replace a whole nacelle or rotor. (This is considered in more detail in the next sections.) Attention is being focused on a modular construction for the nacelle to enable components to be replaced swiftly and on the safety of personnel working offshore.

Table 4.1 gives an overview of the current operational offshore turbines and the larger prototypes together with their dimensions and weights and those of their main components. These dimensions and weights are needed in case parts have to be stored and handled in a port. Figures 4.5 to 4.8 present the dimensions and weights of the main components as a function of the nominal capacity in graph form. Den Helder will probably maintain mostly second and third generation turbines (larger than 3 MW).

Table 4.1: *Dimensions and weights of main components of various offshore turbines*

Manufacturerer	Turbine type	Nominal output [MW]	Tower-height [m]	Tower-mass [MT]	Rotor-diameter [m]	Rotor-massa [MT]	Rotor mass [m]	Blade-mass [kg]	Nacelle-mass [MT]	Nacelle dimensions l*b*h
NEG Micon	NM82	1.50			82		39.4			
GE Wind Energy	1.5 S Offshore	1.50	61.0	80.0	70.5	29.6	33.8	5,230	49.0	11.8*3.6*3.7
Vestas	V66 offshore	2.00	60.0	105.0	66	23.0	31.7		57.0	
Vestas	V80	2.00	60.0	110.0	80	34.0	38.4		61.2	
NEG Micon	NM 2000/72	2.00	64.0	100.0	72	40.0	34.6		82.0	
RePower	MM82	2.00	59.0		82	33.3	39.4	6,000	60.0	
DeWind	D8	2.00	80.0		80		38.4			
AN Bonus	2.3 MW / offshore	2.30	60.0	98.4	82.4	52.0	40.0		82.5	
AN Bonus	2.3 MW / 82.4	2.30	60.0	81.4	82.4	52.0	39.6		82.5	
Nordex	N-90	2.30	80.0	178.8	90	51.0	43.2	9,600		
Nordex	N-80	2.50	60.0	115.9	80	48.0	38.8	8,600		13.4*3.4*4.7
NEG Micon	NM80	2.75	60.0		80		38.4			
NEG Micon	NM92	2.75	70.0	155.0	92	45.0	44.8		92.0	
Vestas	V90	3.00	80.0		90		43.2			
GE Wind Energy	3.2s	3.20	98.0		104		49.9			
DeWind	D9	3.50			90		43.2			
GE Wind Energy	3.6 offshore	3.60			100		48.0			
NEG Micon	NM110	4.20			110		52.8			
Enercon	E-112	4.50	124.0		112.8	111.1	50.0	20,000	440.0	
RePower	MD 5MW	5.00			125	110.0	60.0	19,000	240.0	22*6.0*6.5
NEG Micon	DOWEC 6MW	6.00	91.0	225.0	129	90.0	61.9		190.0	

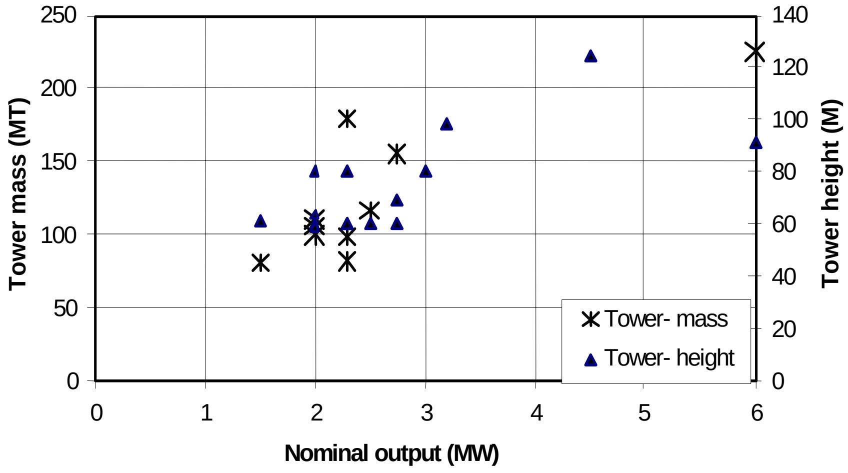


Fig. 4.5: Tower mass and height as a function of the nominal turbine capacity

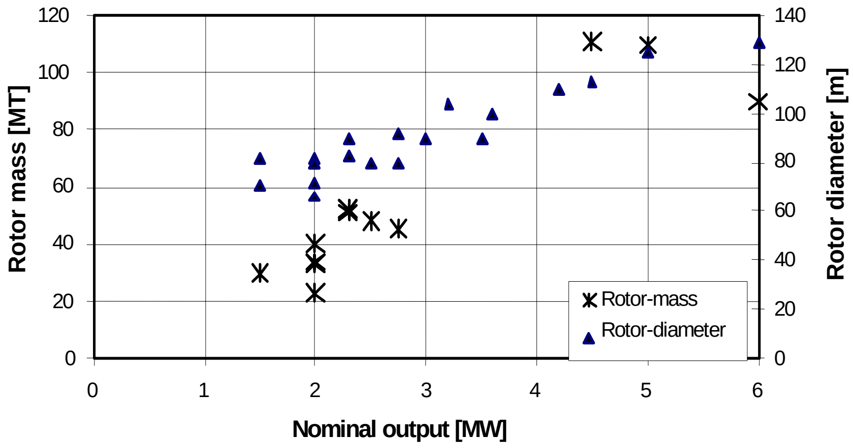


Fig. 4.6: Rotor mass and diameter as a function of the nominal turbine capacity

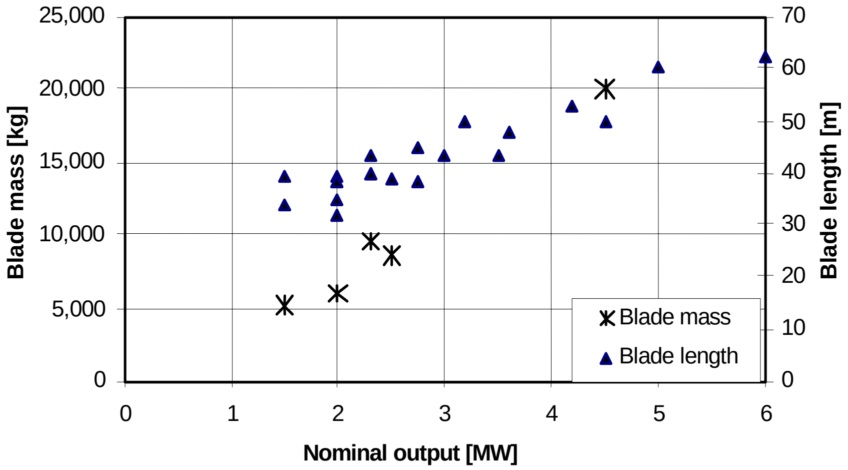


Fig. 4.7: *Blade mass and length as a function of the nominal turbine capacity*

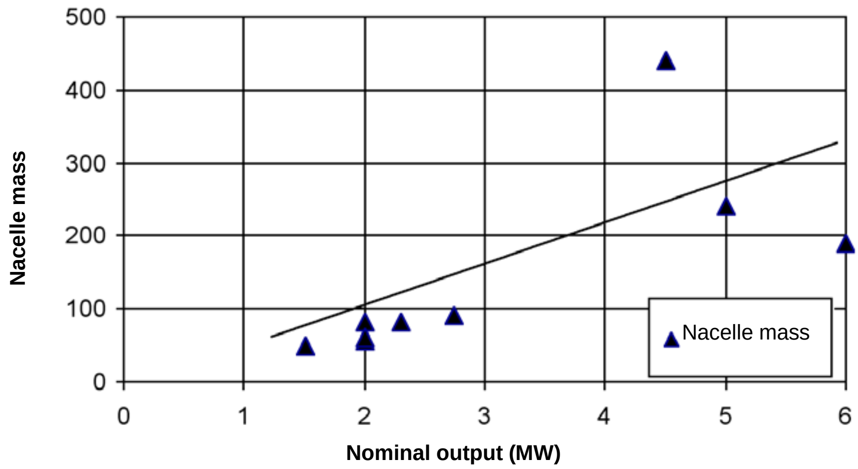


Fig. 4.8: *Nacelle mass as a function of the nominal turbine capacity. (The points below the line relate to turbines with a gearbox and a high-speed generator. The topmost point (440 tons) is the nacelle mass with a direct-drive generator.)*

The length of a nacelle with hub varies between 11 and 13 m for turbines up to 2 MW. The nacelle of a 6 MW turbine is expected to be roughly 22 m long, its height and width a maximum of 7 m.

To summarise,

- If major maintenance is carried out on rotor blades, the port will need to have facilities and infrastructure to receive, temporarily store, lift and ship out rotor blades of up to 70 m in length and weighing up to 25 tons. Fig. 4.9 shows how a blade is mounted.
- Some types of rotor that need replacing are not replaced blade by blade but are assembled onshore, including the hub (see Fig. 4.10). The receiving facilities need to be the same as for the blades. The quayside must be spacious enough to enable complete rotors of up to a maximum diameter of 140 m and weighing up to 120 tons to be assembled, lifted and shipped out.
- If an entire nacelle needs replacing, receiving and lifting facilities will need to be available to accommodate nacelles up to 25 m long, 7 m wide and 7 m high and weighing up to 300 tons. Only direct-drive turbines (E-112 turbines) are larger (440 tons). Another scenario is for two blades to be first mounted onshore, with the third blade only being fitted after the nacelle and hub with blades have been mounted. (Fig. 4.9). This brings the total weight to a maximum of 400 tons.
- Towers will probably be delivered in sections and assembled on the quayside. Then they will need to be lifted onto a boat. The maximum length is approximately 140 m, and the heaviest towers will weigh around 250 tons. Tower maintenance involving replacement is not expected to occur, or hardly ever. The handling of towers on the quayside is of particular relevance in regard to installation.
- Individual components such as gearboxes and generators weigh between 10 and 20 tons in the case of the slightly smaller turbines. Allowance will only need to be made for heavier gearboxes for turbines larger than 3 MW. The gearbox of the RePower 5 MW turbine will weigh around 60 tons.

Fig. 4.9: *Blade being mounted; the nacelle, hub and two blades have already been assembled onshore*

Fig. 4.10: *Entire rotor being assembled*

Organisation of Maintenance

The way maintenance is organised will have an impact on where spare parts are kept, where parts are overhauled and where the control room will be located.
In general, the developer and owner of an offshore wind farm is a consortium. In many cases this consortium comprises at least one large financially strong industrial party and an electricity company and is represented by a main contractor. This consortium concludes contracts with various parties for the supply and installation of components (cables, foundations, turbines, etc.). It also concludes contracts with the suppliers for the maintenance of these components. Often they are 5-year contracts with a guarantee on availability and materials. After that the consortium will have to choose a maintenance contractor for the subsequent years. It may conclude a new maintenance contract with the suppliers or it may engage the services of an independent party. It may also opt to assign responsibility for maintenance to a party that is actually in charge of the technical management of the wind farm and that concludes and monitors contracts with the individual parties. The technical manager will in any event have remote control of the wind farm.
If we confine ourselves to the maintenance of the wind turbines, we see that the service departments of the turbine manufacturers are responsible for maintaining the turbines in the first few years and will use their own employees for this as much as they can. They will contract vessels or helicopters for transport to and from the turbines. Depending on the in-company manpower available, they will decide to engage the services of offshore companies or other maintenance contractors to carry out various maintenance work.
If the consortium concludes a contract with a turbine supplier to carry out maintenance work, the turbine supplier will be responsible for guarantees, management and storage of spare parts and responding to alarms, etc. So there will be an office-based computer that monitors the status of the wind farm. When parts are replaced or overhauled, the manufacturer will do this itself, usually in its own factory. If the consortium decides to do this itself in collaboration with a local overhaul business, there is a big risk of the manufacturer's guarantees being invalidated. There will therefore not be much demand for small, specialist overhaul businesses in the short term. In the longer term, when maintenance is no longer automatically carried out by the turbine manufacturer or when service companies establish themselves in the port, the chance that local overhaul businesses and storage facilities for consumables will be required is greater.
As for large spare parts (blades, gearboxes, etc.) these are not expected to be stored near the port. The number of expected malfunctions is low. Replacing these parts requires good weather and heavy equipment with a long mobilisation time. Major repairs require good planning and lengthy preparations. The spare parts will be supplied from the blade or gearbox factory; either first to the port and straight onto the boat to the wind farm or straight from the factory to the wind farm.
Gearbox maintenance is often specialist work that a turbine manufacturer carries out in consultation with the gearbox supplier. An increasing number of gearboxes are fitted with condition monitoring systems and the turbine manufacturer as well as the gearbox manufacturer have access to these systems in order to identify problems early.
To summarise,

- We cannot speak of a central control room. Virtually every party responsible for operating the wind farm or for maintaining important systems will have access to the central computer monitoring the status of the wind farm. As a minimum, the wind farm manager, the turbine manufacturer's service department and some suppliers will have access to this computer. These parties will be established in different locations. With current ICT solutions it is therefore not (yet) necessary to have a separate control room for wind farm maintenance.
- In the short term there will be little demand for small, specialist overhaul businesses. In the longer term, when maintenance is no longer automatically carried out by the turbine manufacturer or when service companies establish themselves in the port, the chance that local overhaul businesses and storage facilities for consumables will be required is greater.
- As regards large spare parts (blades, gearboxes, etc.) these are not expected to be stored near the port. The spare parts will be transported straight from the blade or gearbox factory, for example, to the port.

Preventive maintenance

To estimate the required preventive maintenance capacity it is necessary to distinguish between:

- the turbine
- the electrical infrastructure
- the supporting structures

The control room is not considered separately. As already outlined in the previous section, the control room could be in various locations. Each wind farm is expected to need 1 fte for monitoring.

Turbine

Preventive maintenance comprises a service once (or for the first generation of offshore turbines perhaps twice) a year. The aim is to limit preventive maintenance to once a year for the second and third generation of offshore wind turbines. (Incidentally, not everyone agrees that this is a realistic objective.)

The maintenance work mainly comprises carrying out inspections, cleaning parts, checking bolted connections, lubricating parts and replacing faulty parts and consumables. Crews of 2-5 technicians will take about 3 days to carry out a preventive maintenance service. A major service will be required once every 4-8 years, during which larger components such as motors for adjusting the blade pitch and parts of the torque mechanism will need to be replaced. These activities will need to be planned well in advance, because they require additional manpower and equipment.

In the case of the first generation of wind farms (near shore) the technicians will travel to and from the farm on a daily basis. Several maintenance crews will be aboard the vessel, 12-20 technicians it is thought. If several farms are built far offshore, ships will ply the seas on a permanent basis during the workable periods, taking personnel from one turbine to another. The personnel will in that case remain on board the ship for a whole week or two weeks, for example.

The requisite number of boats, technicians and man-years are estimated as follows:

- for preventive maintenance an average of 3 technicians will be at work 3 x 10-12 hours (incl. travel); approximately 100 hours a year per turbine. One crew can maintain an average of two turbines a week.
- If a supply boat is chosen to transport personnel and small parts with an average workforce of 15 technicians (5 crews), about 10 turbines can be maintained per week (6 days working, 1 day travelling). As the technicians work one week on, one week off, 30 people will in fact be required for continuity. Based on 30 workable weeks at sea (in 22 weeks the weather conditions will be so bad that personnel cannot get onto the turbines), 1 boat and 30 technicians can maintain 300 turbines in 1 year.
- Based on 2,000 MW with an average capacity of 4 MW (500 turbines) in 2010 and 7,000 MW (1,750 turbines) in 2020 which can be maintained from Den Helder, approximately 2 boats and 50 technicians will be needed for preventive maintenance in 2010 and 6 boats and 180 technicians in 2020.

It is estimated that a quarter of the above capacity will be needed annually to carry out major maintenance once every 4-8 years. The total amount of preventive maintenance thus works out at (rounded off):

2010:	3 boats	65 technicians
2020:	8 boats	225 technicians

In the case of preventive maintenance, small parts also need to be transported and transferred. The obvious solution is for the supply boats to take on board a number of containers with tools, spare parts, lubricants, consumables, etc. and a small workshop each time they come into port. The ports must therefore be equipped to regularly supply the boats with personnel and containers.

At present, each turbine manufacturer will obviously maintain its own wind farm and so will be responsible for hiring or purchasing and using a supply boat. In the case of smaller farms, or if the farms are far apart, this could mean that the boats will not always be used efficiently. The above numbers for boats and technicians are based on all resources being deployed efficiently. The maintenance services of various wind farms could, for example, agree to coordinate the use of personnel and equipment in order to reduce costs. This already happens in the oil and gas industry, but not yet in the wind power sector. In the initial phase, 1 boat will probably be used per wind farm.

Electrical infrastructure

It seems that inspection and maintenance once every five years is sufficient for maintaining the electrical infrastructure (cables, transformers and other HV equipment). Specialist companies already performing similar work will be used for this.

Supporting structures
The supporting structures will probably be inspected visually by divers once every three years.

To summarise,

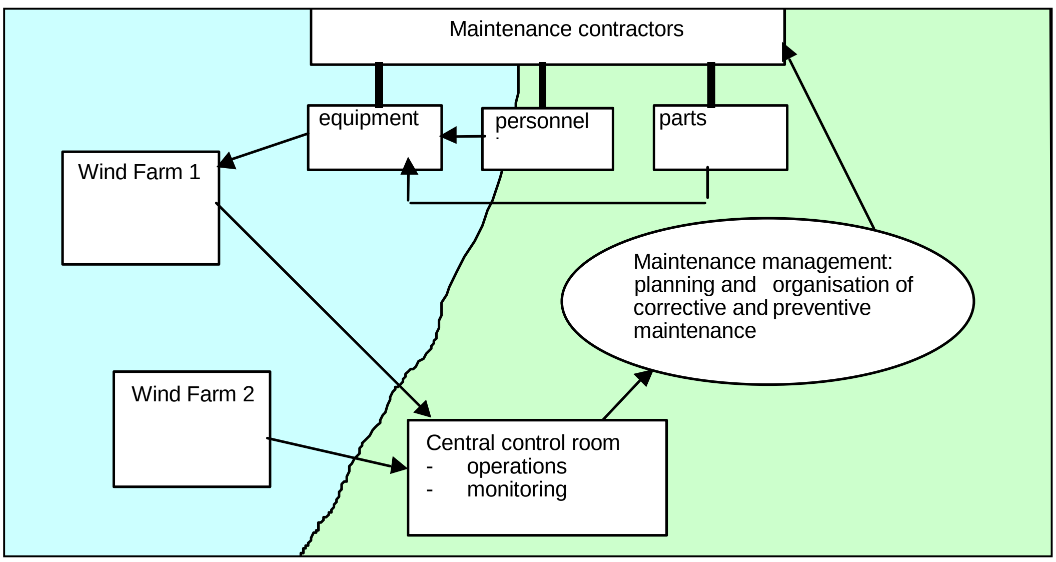
- The requisite ships and manpower for the preventive maintenance of offshore turbines from Den Helder are estimated as follows:
  2010: 3 boats, a total of 65 technicians
  2020: 8 boats, a total of 225 technicians
  The boats need to be suitable to accommodate approximately 5 crews of 3 technicians and must be able to carry enough tools and spare parts in containers. However, because not all the wind farms will make use of a pool of boats (certainly to start with, each wind farm will claim its own supply boat) and technicians, the total numbers will be greater. On the other hand, the boats will not always be used efficiently. During the non-workable days technicians will be deployed elsewhere. These boats are expected to come into Den Helder port once a week or once a fortnight to pick up supplies and change out crews.

Corrective Maintenance

To estimate the requisite capacity for corrective maintenance, a brief outline is given below of how corrective maintenance will be carried out. All this is shown in diagram form in Fig. 4.11.

1. When a malfunction occurs in a turbine or the electrical infrastructure of a wind farm, the monitoring system will signal this malfunction to a central point. This will generally be the central control room, from where daily operations are coordinated by the wind farm operator. The individual service companies may also be notified directly.
2. Based on the report received, a process will be set in motion that ultimately results in one or several companies being commissioned to carry out the maintenance. This item is shown in the above figure as maintenance management. This does not look purely at remedying the malfunction that has occurred, but the corrective maintenance will be planned in with the preventive maintenance. The organisation may be part of the control room if maintenance in carried out under control of the wind farm operator, or a third party if maintenance is contracted out.
3. Once an order has been placed, the maintenance (corrective and/or preventive) will be carried out. There are a number of aspects of importance in this. First of all, if parts need replacing, it is important that they be brought in. Secondly, the maintenance personnel need to be available and taken on board. And thirdly, the equipment necessary for the maintenance work needs to be mobilised and, if necessary, the spare parts placed on board.
4. When the maintenance crew and equipment have been mobilised, the repair can be carried out. If parts are swapped, of if entire systems are replaced, the faulty part or system will be brought ashore, where it will then be repaired.

Fig. 4.11: *Diagram of solving malfunctions in offshore wind turbines*



The type of corrective maintenance that will be carried out can be roughly divided into 5 classes. The total number of malfunctions requiring a visit to the turbines (classes 2-5) varies onshore between 1.5 and 4 a year per turbine. It is the ambition of turbine designers to reduce this to a maximum of once or twice a year. In many cases, in particular class 2, corrective maintenance work can be combined in the summer with preventive maintenance, as the boats with the technicians are on site anyway.

The cost of corrective maintenance is about four times as much as of preventive maintenance, mainly on account of the heavy equipment used. (N.B. onshore the cost of preventive maintenance is of the same order as corrective.) The use of technicians and supply boats for transport is roughly the same as that for preventive maintenance.
The five maintenance and repair classes are briefly elucidated below.

Class 1: Alarm with reset
The class 1 malfunctions constitute the majority. These malfunctions can usually be remedied by remote control and do not require a visit to the turbines.

Class 2: Minor maintenance with personnel and consumables
This involves repairing small parts. Two technicians can carry out this class of repairs without the need to lift or transport heavy materials. This class covers about two thirds of the total number of visits on account of a malfunction. Expressed in cost, this class of malfunction makes only a minor contribution to the total cost of corrective maintenance, about 5-15%. A choice can be made between supply boats with a special gangplank, supply boats plus a Zodiac inflatable, or helicopters for transporting personnel. Section 4.7 describes this in more detail.

Class 3: Replacement of medium-sized parts
This involves the replacement of parts that technicians cannot take themselves to the turbine, e.g. motors for blade pitch adjustment. A small crane is necessary on the supply boat or on the turbine to transfer parts weighing around 500 to 1,000 kg and to lift them to the nacelle. The lifting can usually be done inside the tower so that weather conditions are of less importance. The number of visits in this class is about a quarter of the total number of visits and corresponds to 15-20% of preventive maintenance costs.

Class 4: Replacement of large parts (lifting using internal or external crane)
In this class larger components, e.g. rotor blades, gearboxes and generators, are replaced. These components are brought in on a slightly larger supply boat or a derrick barge. They are then hoisted up by crane and assembled. The faulty parts are taken away in the same manner. Many offshore turbines are equipped with internal cranes that can hoist parts weighing up to 50 tons. If this facility is not available, a crane will need to be deployed on a derrick, ship or jack-up. Given the necessary parts and equipment and given the fact that the parts have to be hoisted up on the outside in good weather, this class of malfunction is the main cause of the non-availability of a wind farm. The total number of malfunctions in this class is about 5-10% of the total number of malfunctions; expressed in costs, corrective maintenance accounts for about 50% of total maintenance costs. With 500 turbines in 2010 and 1,750 in 2020 and an average of 3 malfunctions a year, the deployment of external cranes (about half of the incidents in this class) is about 500 x 3 x 0.04 = 60 a year in 2010 and over 200 in 2020.

Class 5: Replacement of rotor and nacelle
Replacing the entire rotor and nacelle requires the use of an external crane. The total number of malfunctions is estimated at fewer than 1% of the total number of corrective maintenance activities. The costs are estimated at 5-15% of the total cost. With 500 turbines in 2010 and 1,750 in 2020 and an average of 3 malfunctions a year (may ultimately be reduced to 2 a year!), external cranes will be used about 500 x 3 x 0.01 = 15 times a year in 2010 and over 50 times in 2020.

In conclusion, the electrical infrastructure and supporting structures also require maintenance. As regards the electrical infrastructure, cables can be damaged by fishing boats dragging their nets and breaking the cables or by the legs of a jack-up being placed on a cable. The total cost of these repairs is estimated at 1-5% of the total maintenance cost for a wind farm.

To summarise,

- The number of ships and personnel is roughly the same as for preventive maintenance.
  2010: 3 boats, a total of 65 technicians
  2020: 8 boats, a total of 225 technicians

  Contrary to the use of the above people and resources for preventive maintenance, their use for corrective maintenance is not confined to the summer. Corrective maintenance will take place year-round. It is further assumed that around half of the turbines is equipped with a large internal crane and that a modified supply boat will be sufficient for transporting and transferring large components.
- The use of large cranes for lifting large components externally is estimated as follows:
  2010: 75 times a year
  2020: 250 times a year

Transport of Personnel and Parts

This section provides an overview of equipment that can be used to transport personnel, drop off personnel, and for transporting and lifting components. An overview of the various resources used in the classic offshore oil and gas industry is given in Fig. 4.12. New vessels are currently being developed for offshore wind power. The following sections look at the various means of transport and lifting gear, analogous to the above-mentioned classes:

- transport of personnel, small and medium-sized components,
- transport and lifting of large components, including nacelle and rotor.

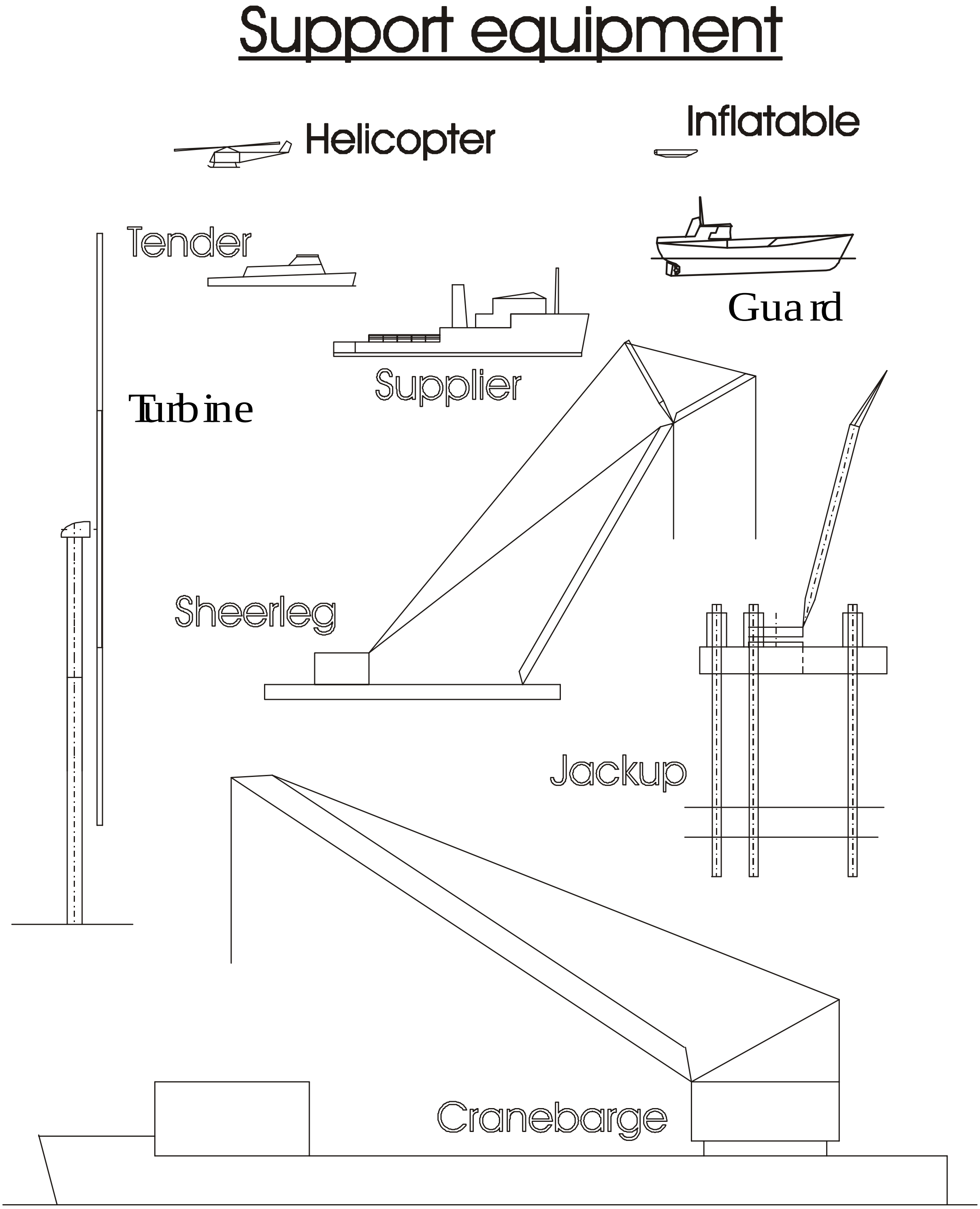


Fig. 4.12: *Overview of transport means and lifting gear customary in the "classic" offshore sector*

Transport of Personnel and Small and Medium-Sized Components

Rubber boats (Zodiacs) are often used to transport personnel in calm waters (see Fig. 4.13). If the port is too far away, the people are first transported from the port to the wind farm aboard a supply boat of tender vessel, from where they jump into a Zodiac. See Fig. 4.14. A major problem with the use of Zodiacs is that if the waves are high personnel can have difficulty getting from the Zodiac onto the turbine or vice versa. Also, the amount of equipment that can be carried is limited.

Fig. 4.13: *Zodiac for transferring personnel*

Fig. 4.14: *Tender vessel for transport from port to wind farm*

A second method used is to "hoist" personnel and small parts. This method is currently used on the Horns Rev wind farm, for example. See Fig. 4.15. This method does not depend on the wave conditions, so a technician can be placed on the turbine to carry out repairs in virtually any weather condition. A disadvantage is that the cost is rather high per drop-off and the amount of equipment that can be carried is very limited. There are also concerns about safety, as the turbines have to be parked in a specific position to allow a helicopter hoist. However, it transpires that from shore it is not always possible to guarantee that the turbine will be in the correct position. If there is uncertainty, flights will not be carried out and a boat will have to be used.

Fig. 4.15: *Hoisting personnel onto a turbine*

New developments are also currently under way. Special vessels are being developed for transporting

personnel to and from the wind farm and for providing access to the turbine. The departure point is that a technician should have to transfer from a floating system (supply boat, tender vessel or Zodiac) to a fixed system (turbine or transformer station) as few times as possible. Two systems currently under development are the OAS (Offshore Access System), being developed by Genius Vos together with Fabricom (Fig. 4.16) and a modified supply boat with a platform on the turbine (artist's impression of Nordex, Fig. 4.17).

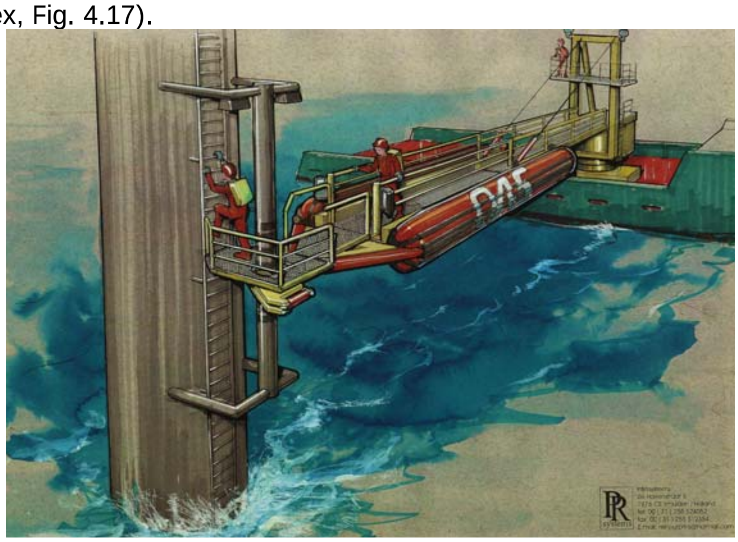


Fig. 4.16: *OAS on supply boat*

Fig. 4.17: *Nordex' ideas for landing personnel & equipment*

Besides the above systems for transporting and landing personnel, the so-called Davit system was also considered. In this case, the entire boat is lifted out of the water. At present, this system does not appear feasible because the Davit system needs to be mounted on each turbine and be operable remotely. The system could fail during lifting, leaving the boat hanging between the waves and a platform. For safety reasons this system has so far not found favour.

As small items of equipment need to be transferred as well as personnel, the supply boats are also equipped with small or medium-sized cranes with a capacity of up to about 1,000 kg. Obviously, for large, far-offshore wind farms personnel will spend the night on board a supply boat. The boats that will be used for the second and third generation wind farms are therefore most likely to be larger than the tender vessels currently used. This affords the opportunity to install larger cranes on the supply boats (see Fig. 4.18) and, for example, to move gearboxes from a supply boat to a platform on a turbine. The boat shown in Fig. 4.18 is probably rather large for wind turbine maintenance; the boats that will be used are expected to be smaller. It is also conceivable that supply boats will be equipped with an OAS system as well as a crane.

Fig. 4.18: *Supply boat with crane*

Medium-sized parts transferred from a supply boat to a platform must then be hoisted to the nacelle.

Turbines can be equipped for this purpose with an internal crane. Fig. 4.19 shows the GE Wind 1.5 MW turbine with a crane that allows the gearbox, for example, to be hoisted. Smaller parts are often lifted through the tower using a small, permanent crane. Fig. 4.20 shows the draft of the RePower 5

MW turbine with a 6-ton crane. This crane is intended especially for medium-sized components. It is capable of hoisting an entire gearbox. This turbine is currently at the design stage.

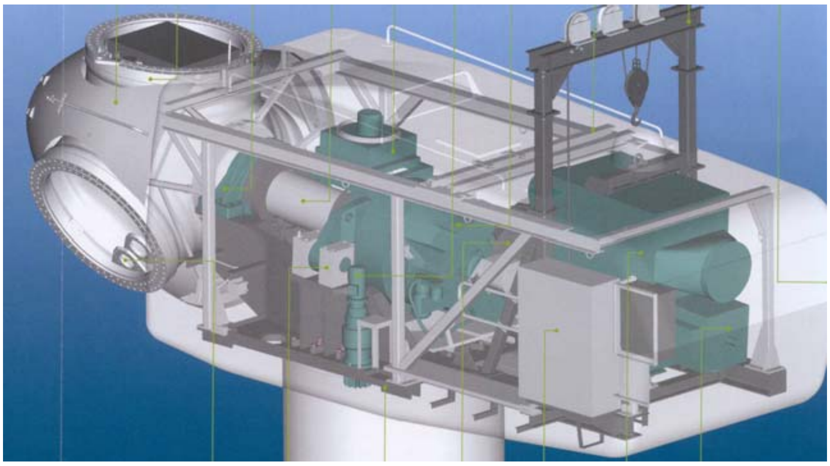


Fig. 4.19: *GE Wind 1.5S turbine with built-on crane*

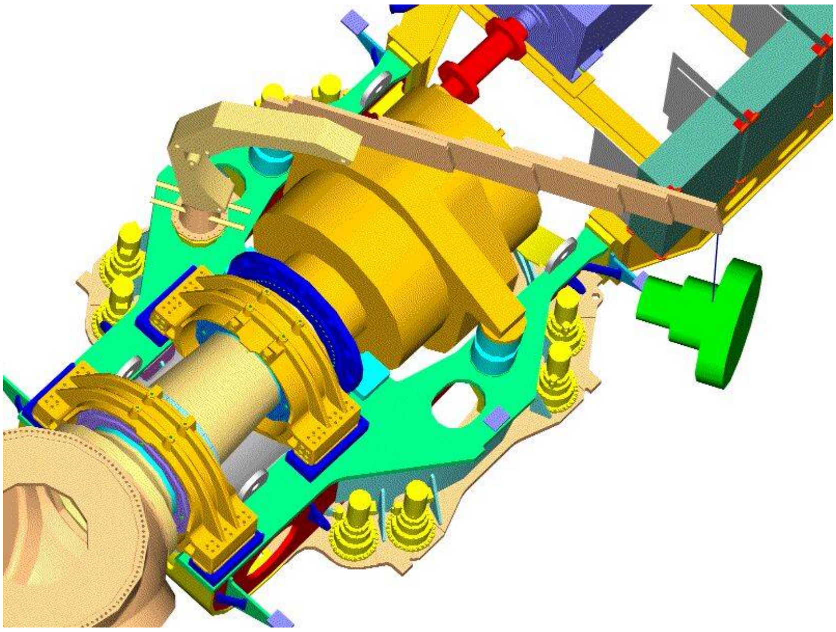


Fig. 4.20: *RePower 5 MW turbine with 6-ton service crane*

Replacing Large Components, Nacelles and Rotors

If larger components such as gearboxes, etc. cannot be lifted using a crane on the turbine, an external crane will have to be brought in. In the classic offshore oil and gas industry jack-ups are used for this purpose, and this proved to be the best solution for the first generation of offshore wind farms as well. See also Fig. 4.21. Floating cranes are not a good idea because even small waves often cause such deviations at hub height that positioning is only possible in very calm conditions. A disadvantage of a jack-up is that it has to rise out of the water entirely and that requires good weather as well. New ships for installing and maintaining wind turbines which do not have the disadvantages of jack-ups and floating cranes are currently under development. They have stabilising by jacks but they do not emerge entirely from the water. This increases their weather window, so they can be used in less favourable conditions as well. Other advantages are that they do not require tugs and that they have sufficient space to carry large components. An example is the A2SEA, which was also used for the installation of Horns Rev and to replace gearboxes on the wind turbines in Utgrunden (Fig. 4.22). Also, stabilising them does not take as long as with jack-ups. A disadvantage of systems with jacks is that they could damage the electrical infrastructure.

Fig. 4.21: *Jack-up for installation and maintenance*

Fig. 4.22: *A2SEA, example of modified hoisting vessel for installation and maintenance of offshore wind turbines*

To summarise:

- Based on developments in the special hoisting and dedicated vessels for the offshore wind industry it is very likely that modified supply boats will be used for wind farm maintenance in rougher waters like the North Sea. These supply boats will be modified so as to allow personnel access to the turbines even in bad weather conditions, e.g. using an OAS. They will also be equipped with a crane that will allow loads of up to one or two tons to be transferred to a platform on the turbine. The supplier will have facilities to sleep about 10-20 technicians for a period of one or two weeks.
- More and more crane ships like the A2SEA will be developed for major maintenance. The advantage of these is that they are on site quickly, can stabilise swiftly, can carry sufficient spare parts and can position the parts in one go. It also appears that a crane for changing out main components is being installed in fewer and fewer large turbines or is not incorporated in the design. A disadvantage of these permanent large cranes is the additional investment required and the fact that they need to be periodically maintained and tested. Also, the use of smaller crane ships remains a necessity.

5. INTERVIEWS

5.1 Introduction

If the Dutch and German plans become reality, the future will see some four to seven thousand large wind turbines in operation in the North Sea, and all of them will need to be maintained. How this is going to be done and how these matters will be organised still remains unclear. It transpires that a number of parties are of the opinion that Dutch industry can make a major contribution to this, in particular in view of the fact that many Dutch-based companies are already providing maintenance facilities for offshore installations. However, as far as is known, this has not yet resulted in a commercial strategy to secure a part of this new market. On the other hand, a number of businesses are aware of the fact that offshore wind power may well become a major item, so they are watching developments closely in order to be ready to act when the time is ripe. Although Dutch offshore companies have been involved in the installation of offshore wind turbines, maintenance is not yet relevant.

However, in order to be able to develop a policy that will enable the Kop van Noord Holland to establish itself as a key base for offshore wind turbine maintenance, a survey of the anticipated developments in this field is required. There are at present two parties that have the background information necessary to form an impression based on practical experience. On the one hand, the companies involved are autonomous businesses or subsidiaries of wind turbine manufacturers that are responsible for wind turbine maintenance. On the other, we find specialist offshore installation maintenance companies, some of which are already trying to qualify themselves to undertake the maintenance of the near shore wind farms now under development.

As ideas and views on the subject have yet to take concrete shape, it was decided to collect the necessary information by means of a series of interviews. To enable the companies involved to prepare for the interview, they were sent the list of questions included in Table 2.1 in advance. During the actual interview the same list was used as a discussion guide.

5.2 Summary of interviews

5.2.1 General

In order to gain insight into the practice of offshore wind turbine maintenance, interviews were set up with the following parties.

1. Service department of a wind turbine manufacturer

NEG-Micon in Rhenen, responsible for the maintenance of the Near Shore Windpark (NSW) off the coast of IJmuiden, contacts Mr F. Brekelmans and Mr D. Knoppers.

2. Property developer and main contractor of the consortium

E-Connection in Bunnik, property developer of the Q7 park just outside the 12 mile zone, contact Mr H. den Boon.

3. Large maintenance contractor specialising in the maintenance of offshore oil and gas platforms

Fabricom Oil & Gas in Beverwijk, contact Mr J. Berg.

4. Maintenance and construction company for onshore and offshore installations

Multimetaal Constructie in Den Helder, contact Mr A. Hulsebos

5. Independent maintenance contractor for wind turbines

MainWind in Schagen, contact Mr R. de Knecht and Mr J. Portegijs.

This document attempts to show what the similarities and differences in outlook are for each of the questions. However, in order to provide the right context for the facts presented, some aspects that give a general impression of the interviews will be discussed first.

- Service companies of wind turbine manufacturers (NEG-Micon and Vestas Nederland) replied to the questions by considering the problems they envisage with the wind farms that will be created in the near future, i.e. NSW and Q7. The maintenance problems associated with the large wind farms that may be established in a few years' time were touched upon only marginally. The policy of Dutch national and local authorities for the longer term, i.e. 5 to 15 years, is perceived to be so unpredictable as to be not yet worth serious consideration. The short-term problems are much more urgent. On the other hand, the maintenance companies that are used to working with the offshore oil and gas industry tend to look much further ahead. They see analogies between the start-up period of the oil and gas industry and its subsequent development on the one hand, and the current status of offshore wind power on the other.

- All the parties mentioned clearly consider the maintenance of offshore wind power equipment a major market with growth potential. The responses to the questions contributed by ECN are somewhat skewed by the fact that the respondents were either trying to protect their patch, or were hoping to market their specific expertise in the near future. For example, service company subsidiaries of wind turbine manufacturers tended to emphasise that the technology involved in the construction and operation of wind turbines requires such high-level specialist knowledge that independent maintenance contractors would not be able to cope, nor give the necessary guarantees. Independent maintenance contractors tended to counter this by pointing out that compared with oil and gas installations a wind turbine was a relatively simple mechanism and that much of the maintenance could easily be carried out by workers with a lower level of skill. Companies with offshore experience liked to emphasise that wind turbine manufacturers still think too much in terms of onshore operations, and that things become much more complex once they move offshore. Nevertheless, the parties agree that cooperation between the various fields of expertise will be necessary in order to make offshore wind power a viable proposition.
- All the parties indicated that currently, and certainly in the future, offshore wind power will not be a national or regional matter. They all think on a global scale. It will soon not matter much whether a wind farm is located in Dutch, German, British or Danish waters, which is why the plans of the Dutch government (1,000 MW in 2010 and 6,000 MW in 2020) have been receiving rather less attention than the plans and projects in the neighbouring countries.

ECN has taken the above remarks into account in its interpretation of the interview results.

5.2.2 Concrete questions

<u>General</u>

1. *How much and what kind of maintenance work (corrective and preventive) will need to be carried out?*

   The current assumption for new wind farms is that they will require preventive maintenance once a year, and corrective maintenance approximately three times a year. Based on experience gained in the offshore industry, the aim is to complete the preventive maintenance within a single day, with 3, 4 or more people working on a wind turbine for a period of 12 hours, the idea being to minimise the number of days at sea.

   These figures all apply to the wind turbine. Maintenance will also have to be carried out on the supporting structure and the electrical infrastructure within the wind farm. None of the parties was able to provide an estimate regarding the amount of work this would involve.

2. *How will the central monitoring and control facilities be handled, and how many people will be manning them ?*

   The wind farms will certainly be monitored from an onshore location.

   For the first wind farms, NSW and Q7, this will be done from a location at IJmuiden, which will be manned round the clock.

   What monitoring and control room facilities will be like in the longer term is not yet clear, and this will probably be affected by the extent to which the recipient of the wind power will wish to control the wind farm's production in connection with other power stations in order to maintain the balance of the power grid. Integration in the recipient's existing systems would be an obvious solution. In other words, separate control facilities will not be needed for each wind farm.

   The monitoring and control facilities will play a minor preventive maintenance role. This type of maintenance will be planned well in advance by the parties involved. The corrective maintenance role of the control facilities will be determined by the way in which maintenance will be organised. Equipment faults will always be reported to the control room, but the way in which they will be dealt with depends on the maintenance philosophy adopted. A party may opt to coordinate the maintenance work itself and may even carry out some or all of the work itself. A completely different approach is to report the malfunction to a maintenance contractor that will in its turn deal with the matter as necessary. Based on the contracts they have concluded, the operator/owner and the maintenance contractor will determine the maintenance strategy in the event of a malfunction. Intermediate forms are also possible, but in any event the maintenance technicians and any supporting facilities, e.g. ships, need not be physically present at the control room location. Even if maintenance coordination is handled by the operator, it need not be done from the control room.

The first generation of offshore wind farms will be monitored from control rooms manned round the clock. The interviewees indicated that in view of the size of the wind farms, this was overdoing things. However, the feeling was that at 6,000 MW the control rooms would create a reasonable number of jobs at the higher vocational level, but information regarding the exact number of jobs was not forthcoming.

3. *What are the requirements regarding the site of the central control room?*

There are no specific requirements regarding the site of the central monitoring facilities other than a good digital infrastructure. The operator of a wind farm could in principle be located anywhere in the world. One of the interviewees thought that in the long run, approximately four large monitoring centres would exist around the North Sea

Equipment

4. *How much and what type of equipment will be used?*

Periodic summer maintenance and inspections as well as regular maintenance will probably require the use of supply boats. This type of vessel is often used for various types of offshore work, and is available in large numbers and in a variety of sizes. These vessels feature facilities for the transfer of maintenance crews to and from the wind turbine, e.g. a gangway or something similar. The use of Zodiac inflatables for ferrying maintenance crews in open sea is open to question. Some parties are considering using these vessels, whereas other parties consider them unacceptable. The matter is of little importance if we consider the interests of the Kop van Noord-Holland region as a whole. The important point is to make sure that Den Helder becomes the home base for the supply boats that will be used for the offshore wind farms. Whether maintenance teams will be delivered to their destination by Zodiac or by means of a special gangway facility is irrelevant.

In addition, supply boats will become available that, in addition to facilities for transferring maintenance crews, will feature lifting equipment for transferring heavy components to and from the wind turbine platforms. It is assumed that each wind turbine will be equipped with one or more internal cranes to enable parts to be hoisted up to and down from the generator platform.

For the Q7 wind farm, the possibility is being kept open of using a helicopter outside the summer months for inspections and minor repairs (limited size of spare parts), in which case a Dutch Air Ministry permit will be required. However, the general feeling is that the use of helicopters will be impractical due to the high cost involved.

In the event that large components that cannot be lifted by the internal crane need to be replaced, special offshore equipment (crane barges, jack-ups, etc.) will have to be used. The drawback of jack-ups and other equipment stabilised on the sea bed is that the legs or anchors may damage the wind farm’s electrical infrastructure.

Maintenance on the electrical infrastructure will be carried out using specially equipped vessels, like the ones in use for maintaining the various cables already running across the bottom of the North Sea.

None of the interviewees was able to provide an estimate of the number of ships they expected to require for the work.

5. *How will the various types of equipment be mobilised?*

For near shore wind farms a shuttle service between the wind farm and port can be used in 12 hour on, 12 hour off shifts. The maintenance crew will spend the night on the vessel or in a hotel near the port. To minimise travel times, ports close to the wind farm will be used. For NSW and Q7 this will be IJmuiden.

For wind farms further out to sea travel times will be too long for a shuttle service, so the supply boat carrying the maintenance crews and materials will stay out for 1 – 2 weeks. This means that the ship will return to port once a week or once a fortnight to change crews and take on supplies and spare parts for the next period. The ship will then return to sea as quickly as possible. These ships, which will be chartered from a shipowner, will probably need to have sufficient capacity to accommodate a maintenance crew of 12 – 16 men as well as supplies and sufficient spare parts. In this case nights will be spent on board. The disadvantage of using a substation with hotel facilities is that the crew will need to be transferred an additional two times a day. For the week on/week off option, the total trip time is very short relative to the time spent at sea, and therefore will have little impact on the choice of port. The travelling distance from home of the maintenance crews will not greatly affect the choice of port either. In the oil and gas industry, the week on/week off routine is common practice, and crews live all over the country. Having to travel long distances to and from home once a fortnight is not considered to be a problem. Although it is unusual, some of the crews even live abroad (Greece, UK). The choice of port is therefore determined mainly by logistic facilities, restrictions of access to spare parts, harbour fees, and the requirements of the shipowner running the supply vessels. As explained in section 13, in some cases it is not even necessary to have a fixed home port.

Larger pieces of equipment such as crane barges and jack-ups do not operate from a fixed port, but roam the seas from job to job. If the need for such a vessel arises, the turbine operator will wait for it to be in the vicinity, and then engage it to carry out the repair work. Once the number of turbines in the North Sea grows large enough, dedicated vessels will probably be developed that will be operated from a pool, permanently roaming the North Sea. Until then, standard offshore vessels will be used.

The offshore industry has gained much experience in laying and maintaining cables. The same vessels will in principle be used for maintaining the electrical infrastructure of offshore wind farms. These vessels will be mobilised from their home ports.

A shipowner's office can be located anywhere in the world, in some cases far from the nearest port. Ships will be located throughout the world, where the is.

If helicopters are to be used, these will be operated from the airport at De Kooy.

6. *What port infrastructure is required?*

For maintenance purposes, supply vessels in particular will play a major role. So there will have to be facilities for these ships to dock and take on spare parts. It is therefore important to have sufficient road capacity to bring in the spare parts by road, and there will need to be lifting facilities to place parts and large containers on board. Generally speaking, the existing port infrastructure will meet the purpose, although capacity may have to be increased.

7. *Which companies are eligible for carrying out this type of work and where are they currently located?*

In view of the diverse nature of the companies involved in maintenance work, the following four different types of company will be considered:

1. Companies for maintenance work on the wind turbine;
2. Companies for maintenance work on the electrical infrastructure;
3. Companies for maintenance work on the supporting structure, including the subsea section;

4. Companies providing support facilities, such as shipowners operating supply vessels or other offshore equipment.

In addition there are specialist companies that are contracted by the companies listed above to carry out specialist work.

(1) Companies for maintenance work on the wind turbine:
At the moment, there are two types of company, with totally different backgrounds, which could play a major role in maintenance work on the actual wind turbines.

- The maintenance services of the wind turbine manufacturers and the independent maintenance contractors now carrying out the maintenance work on onshore wind turbines. Examples include Vestas Nederland BV (Rheden), NEG-Micon (Rhenen), and MainWind (Schagen). These companies are based at locations all over the Netherlands. They all have in common that they have ample knowledge of wind turbine technology, but no offshore experience (as yet). These companies are aiming to extend their sphere of operations to include offshore work.
- Maintenance contractors such as Fabricom (IJmuiden) and Multimetaal (Den Helder), with ample experience in maintenance work on offshore installations. These companies can be found in any main port. A feature of this type of company is that they all have extensive offshore experience, and in many cases experience in maintaining complex installations on offshore platforms.

(2) Companies for maintenance work on the electrical infrastructure:
The bed of the North Sea is criss-crossed by cables (e.g. telecommunications) and pipelines that once laid, require maintenance. Maintaining the electrical infrastructure of offshore wind farms is essentially similar work, so it is expected that these companies will also undertake the maintenance of the cables inside and outside the wind farm.

(3) Companies for maintenance work on the supporting structure, including the subsea section:
This type of work is no different to that done on oil and gas installations, so companies with experience in this field will find it easy to expand their sphere of operations to include wind turbines.

(4) Companies providing support facilities, such as shipowners operating supply vessels or other offshore equipment:
Companies of this type can generally be found in most ports, although shipowners need not necessarily have their offices at or near a port.

<u>Maintenance personnel</u>

8. How many and what type of technician will be used?

The maintenance of the near-shore wind farms Q7 and NSW will in all probability be carried out by the manufacturers’ maintenance services, in this case Vestas and NEG-Micon. Another company, Fabricom, is also involved in the maintenance of Q7. A pool of 6-8 men will be created for the maintenance of the NSW wind farm (100 MW). They will be on permanent call, and will also carry out other, onshore, work. This is important to ensure continuity during the winter months, as the offshore work peaks during the summer.

In the short term, the maintenance work will mostly be carried out by the manufacturer's maintenance service. Although the manufacturers plan to continue doing this during the future expansion of offshore wind power, the conventional offshore maintenance companies expect to be able to capture a substantial part of the work for themselves. Roughly speaking, the maintenance work on a turbine can be divided in two parts, i.e. the mechanical side and the more specialised control side. It is expected that 80% of the work can be carried out by independent

maintenance contractors such as Fabricom and Multimetaal, and that the manufacturer will be called in for the specialist work.
The problem is that offshore maintenance, which includes the maintenance on offshore wind farms, has to be carried out mainly during the summer. This means that work force requirements will peak during the summer, to ebb during the winter months. Although temporary manpower can be hired during the summer, in order to safeguard the continuity of the operation, the majority of the maintenance crews will need to be employed on a permanent basis. One of the companies interviewed stated that 80% of the employees would have to be employed on a permanent basis, with 20% being hired on a temporary basis to handle peak demand. Reducing the number of permanent employees can lead to capacity problems during peak periods due to shortages of temporary manpower.
It is therefore important that sufficient work be found during the winter months to tide over the permanent work force. A large degree of flexibility will be required of these employees. To maintain continuity, in summer the emphasis will be on offshore work, whereas the winter will offer mainly onshore activities. One option could be to use the winter period to carry out in-house maintenance on parts replaced during the summer.

The maintenance services of the wind turbine manufacturers will have to deal with the same problem, although to date they have managed to cope by moving preventive onshore maintenance to the winter months.It remains to be seen to what extent this strategy will be successful once the North Sea potential becomes substantial. Another option is to shift part of the work to less favourable periods and simply accept reduced workability. Additional days on shore may well turn out to be cheaper than having an enormous peak during the summer.

If an offshore capacity of 6,000 MW is realised, this is expected to create 300 – 350 direct jobs, with a peak during the summer. Both the 12 hour on, 12 hour off option and week on/week off option will place non-technical demands on employees. Recruiting will take place mainly from navy and fishery crews, who have the necessary offshore experience.

In addition to maintenance on the wind turbines, other systems such as cables and supporting structures will also need to be maintained. This work will be contracted out to specialist companies.

9. *What kind of courses and training programmes will the personnel have to take in the areas of maintenance, working offshore, safety at work and wind power?*

A maintenance technician working on offshore wind turbines will require a variety of knowledge and skills, both technical as well as safety aspects. A basic set of requirements would be as follows:

- basic technical training;
- wind turbine-specific training;
- offshore training.

The technicians currently employed by the maintenance services of the manufacturers generally have technical training at secondary level, and have received specific in-house training focusing on wind turbine technology. Previous training in wind turbine technology is considered nice to have, but is not really essential. Even with previous training, in-house training for a specific type of wind turbine remains necessary. The high training level is required because employees must be capable of working on complex installations without supervision. For work on offshore wind turbines, larger maintenance crews may be used for each turbine in order to reduce the number of days at sea. In that case there will be more opportunity to call in third-party expertise and to divide the work, which will create more opportunities for technicians at the lower vocational training levels.

The maintenance crews currently used in oil and gas extraction can also be used for wind power, provided they receive additional training in matters specific to wind turbines. The additional training varies according to manufacturer and will therefore need to be arranged in cooperation with the manufacturers. If we draw an analogy with car maintenance, we see that although any car mechanic can do a lot of the maintenance on any type of car, different makes still require specific knowledge that has to be obtained through additional training.

There is no fear that manufacturers would oppose this scheme to safeguard their own employment opportunities, because if everything goes according to plan there will be a shortage of maintenance technicians.

10. *How is this kind of training currently provided?*

Technical

- General technical training is provided by normal secondary schools.
- Specific wind technology training courses are provided by the manufacturers of wind turbines.

Offshore

- ROC Den Helder offers various offshore training programmes. Employees of wind turbine manufacturers have also participated in these courses at ROC Den Helder in order to gain the necessary qualifications to be allowed to visit offshore wind turbines.

11. *Is there a need for further training facilities?*

Technical

- There is no general wind turbine technician training available in the Netherlands. The current general idea about the need for such a training programme can be summarised as “nice, but not really necessary" at present. Technicians will continue to have to attend turbine-specific training courses, and experience shows that normal vocational training provides sufficient foundation for these specialist courses.
  The independent maintenance companies have more need of wind turbine technician training at the secondary vocational level than do the service departments of the turbine manufacturers. This stands to reason, as the independent maintenance contractors have less access to the in-house training courses provided by the manufacturers.
  The philosophy expressed by the offshore companies is that they will carry out maintenance work in a collaborative effort with the manufacturer, and that specific training will be arranged accordingly.

Offshore

- The training facilities offered by ROC Den Helder will probably suffice, although some of the traditional onshore companies do not have a full picture of the demands made on offshore work.

12. *Which companies are eligible for carrying out which type of maintenance and where are they currently located?*

See question 7

13. *Which companies do you think you will collaborate with?*

There is no clear view on this point, but it is expected that the maintenance services and companies operating in the wind power industry will start collaborating with maintenance companies already active in the offshore business. In particular during the early years, companies will need each other for the — largely complementary — knowledge and experience of the two different industries, offshore and wind energy. The offshore industry is also known to hire specialist companies on a regular basis for specific jobs. In addition to the existing specialist companies, new businesses may be formed, for example specialising in replacing and processing the lubricant from the gearboxes in wind turbines.

Spare parts and repairs

14. *How will the logistical aspects be organised, e.g. storing parts, etc.?*

    For regular maintenance work (not requiring a crane barge or jack-up), a supply ship will remain at sea for a week or a fortnight. The obvious solution is to fit out the vessel with a small workshop and put the spare parts in a sea container to be loaded onto the ship. On return to port the used container can be exchanged for a fresh one. This will require a lifting facility on the quayside. As the containers can in principle be filled anywhere, there is no need to establish central storage facilities in or close to the port. This method offers great flexibility. The supply boat need not return to a fixed home port, but can be diverted to Den Helder or even Rotterdam if the circumstances so require. Storing spare parts in a central location at sea is not a viable option from a logistic point of view, since it would involve additional lifting operations at sea.

    Spare parts such as blades and generators will be supplied by the manufacturer on special order.

    Special ships will be used for cables, so cable maintenance will be organised from the home ports of these ships. The ship owner will decide where the ship will dock. For Q7 this is Delfzijl.

    Spare parts for Q7 will be transported to IJmuiden by road or rail.

15. *What kind of infrastructure (roads, port, etc.) is required to bring in spare parts?*

    There need to be facilities to bring in spare parts by road or rail, or perhaps even by water (e.g. rotor blades). In addition, there need be facilities (e.g. cranes) to load and unload the parts onto and from the ships. Generally speaking, the existing dockside infrastructure will be sufficient for the purpose, so no special facilities will be required other than perhaps the creation of additional capacity.

16. *What kind of premises and facilities will be required for the storage of parts and carrying out repairs and overhauls?*

    Current practice for wind turbine maintenance is that components are returned to the supplier for overhaul. The wind turbine manufacturers have given no indication yet that they want this to change in the future. Offshore maintenance companies with their own workshops see possibilities for carrying out overhaul work.

5.3 Evaluation

Based on the interview results, the following general conclusions can be drawn.

- Offshore wind farms will be monitored from a control room on shore. A control room plays a pivotal role in maintenance, since it is where reports of malfunctions are received, and where maintenance work must be planned. On the other hand, the control room is not connected with the actual maintenance work, so it could be located anywhere in the world, provided the required digital infrastructure is available. From the point of view of the control room there is no need at all for it to be located in the Kop van Noord-Holland, even if the maintenance facilities were to be concentrated in this region.
  However, in order to enable the Kop van Noord-Holland to develop into a maintenance centre for offshore wind turbines, the presence of one or more management centres could help to attract various companies involved in offshore wind turbine maintenance work. It may also stimulate existing companies in the region to expand their activities to include offshore wind power.
  In addition to providing this promotional value, such a centre would create jobs, although limited in number. The exact number and composition would have to be investigated.
  In all probability the first remote monitoring centre will be established in the region, at IJmuiden, since it is from there that the first offshore wind farms will be operated.

- In order to enable the effects of offshore wind turbine maintenance on employment and infrastructure requirements to be estimated, it should be borne in mind that the maintenance

work on the various main systems of an offshore wind farm requires a number of completely different fields of expertise. For this reason a distinction is drawn between:
- maintenance of the wind turbine itself;
- maintenance of the electrical infrastructure;
- maintenance of the supporting structure.

Of these three different types of maintenance the first, i.e. the maintenance of offshore wind turbines, is still in its infancy. There is no essential difference between the maintenance and inspection of the supporting structure of a wind turbine and what is usual practice for oil and gas installations. Ample expertise is also available regarding the inspection and maintenance of the electrical infrastructure. It is therefore to be expected that the main development will be in the field of wind turbine maintenance. For this purpose, two fields of expertise will need to be integrated, i.e. those of offshore work and wind turbine technology. This will eventually result in a new type of offshore activity. The type of work to be done on the supporting structure and the electrical infrastructure is not specific to wind turbine technology, and existing companies are expected to take up this work. Although wind power-specific matters do play a part, there will be much less need for integration with wind power technology. Existing companies will, however, be in a position to add to their order book.

- In the short term the maintenance services of the wind turbine manufacturers will play a pivotal role in wind turbine maintenance. Since offshore work is a totally different matter from onshore work, an ordinary wind turbine technician will not automatically make an offshore wind turbine technician. This is due not only to the conditions at sea, but also to the working hours involved (week on/week off shifts). The work will therefore probably be carried out in collaboration with offshore maintenance contractors which have the necessary experience not only with offshore work, but also with offshore-specific safety procedures, and with shipowners for the hire of offshore equipment. In the longer term, this may result in the creation of independent companies. As a result of spin-off, specialist businesses will also be formed.

  One example of the collaborative efforts mentioned above is the expected use of Fabricom for the Q7 wind farm. The wind turbine manufacturers appear to be reluctant to go looking for opportunities to collaborate, probably because the matter is not yet very relevant. It is unclear to what extent protectionism plays a part in this, but the offshore companies see no objection to collaboration, since the demand for maintenance work will outstrip the available resources if everything goes as planned.

  All in all, collaboration is not a hot item on the agenda of wind turbine manufacturers. So to promote the interests of the Kop van Noord Holland, by the time the matter does become relevant the wind turbine manufacturers will need to be aware of the potential in the region and a bond will need to be created between the companies involved. It would appear that the potential afforded by Den Helder and the surrounding area is largely unknown, so a promotional campaign is very necessary.

- Generally speaking, offshore maintenance is not tied to any specific port. The spare parts for regular maintenance can be brought in by container to any port. The replacement of large components, e.g. rotor blades or generators, depends on the availability of the necessary equipment. These components will be ordered from the manufacturer and transported by road, rail or water. They may even be shipped directly to the wind farm. The only requirement is a normal infrastructure offering facilities for transferring large components and containers. For reasons of economy, harbour fees will be an important factor.

- In the oil and gas industry, the week on/week off routine is common practice, and crews live throughout the country. Having to travel long distances to and from home once every fortnight is not regarded as a problem. Even if the maintenance work were to be conducted from a fixed home port, this would not mean that the technicians would be to the area. Offshore wind turbine maintenance peaks heavily during the summer. In order to ensure the continuity of operations, most of the crews will have to be employed on a permanent basis. This however will require that sufficient work be found to keep the wind turbine crews occupied during the winter months. So, if a combination of employment can be created in the region that will enable employees to work offshore during the summer and spend the winter months working on shore, the maintenance crews can be tied to the region. In this respect, an important role could be reserved for overhaul work carried out on behalf of, or in collaboration with, suppliers of wind turbine components.

- In addition to staff, the maintenance of offshore wind turbines requires equipment to transport crews and parts. It is expected that most of this will be done using supply boats. In order to develop the area into the main centre of maintenance, it is important that these ships take on their supplies in the port of Den Helder. In other words, the port must have sufficient capacity, and the logistic infrastructure must be such that the spare parts can be brought in and transferred on board. Generally speaking, the infrastructure of any normal port meets these requirements. Therefore, economic aspects will be the deciding factor in the choice of home port. On the other hand, it is only logical that the port involved with the maintenance work right from the start will be in the best position to develop into a major maintenance centre. IJmuiden appears to have the best credentials, since a day on/day off routine will be used for the first offshore wind farms. For NSW as well as Q7, the port of IJmuiden affords the best location.

- In maintenance terms, the role of the airport at De Kooy will be minor, since the use of helicopters will be limited. Even so, De Kooy may be important in a rescue capacity.

- The ROC can play an important part by providing offshore training to maintenance technicians. Some manufacturers are already in contact with the ROC, but it may be necessary for the ROC to promote itself more within the wind power community.

- Although familiar with the existence of the knowledge centres in the area (ECN, WMC, and EWTW), none of the interviewees indicated that their presence could be of benefit to maintenance companies.

6 CONCLUSIONS AND RECOMMENDATIONS

In the previous chapters, and in Chapters 2, 3 and 4 in particular, the following were discussed in depth: the amount of wind power capacity that could be maintained from the port of Den Helder, the type of maintenance to be carried out, the type of equipment required, and the scope of the work. The detailed descriptions are intended partly to provide background information, but their primary purpose is to provide insight into the reasoning and assumptions that have resulted in the estimates of the number of employees and the amount of equipment involved.
Chapter 5 provided an overview of a series of interviews conducted with parties that are currently or that may become involved in the maintenance of offshore wind turbines. The purpose of these interviews was to verify the views of ECN and to underpin certain aspects with practical experience.
The main conclusions and recommendations are given below.

6.1 Conclusions

Wind power capacity to be maintained
The offshore wind power capacity that may possibly be installed off the Dutch and German North Sea coasts is as follows:
2006 220 MW + 300 MW ≈ 500 to 550 MW (very advanced plans)
2010 1,000 MW + 5,000 MW ≈ 6,000 MW
2020 6,000 MW + 15,000 ≈ MW 21,000 MW
Assuming that approximately one third of this capacity will be maintained from Den Helder and putting the average turbine capacity at 4 MW, the potential becomes:
2010 2,000 MW; equivalent to approximately 500 turbines
2020 7,000 MW; equivalent to approximately 1,750 turbines.

Maintenance of wind farms
The maintenance of offshore wind farms consists of maintenance work on the turbines themselves, on the electrical infrastructure, and on the supporting structures. The maintenance work to be carried out on the electrical infrastructure and the supporting structures is considered to be identical to the maintenance work currently being done in the offshore oil and gas industry. For companies already maintaining electrical systems and supporting structures, wind farm maintenance will simply mean an expansion of their normal activities. These companies are not expected to relocate to Den Helder. An example is the repair work to be done on cables running along the sea floor. E-Connection indicated that in the Q7 wind farm this will be done by a company (Van der Stoel) located in Eemshaven, which operates a purpose-built ship.
Wind turbine maintenance will involve the creation of an entirely new market.

Turbine maintenance
The preventive and corrective maintenance of wind turbines will be done mostly by means of supply boats. In addition, the replacement of large components during corrective maintenance will involve the use of larger crane barges such as the type A2SEA (a crane barge with four stabilising jacks that can be used to transport large components).
The estimated total deployment of supply boats including crew and the number of maintenance technicians is as follows:

2010:	500 turbines	6 boats	130 technicians
2020:	1,750 turbines	16 boats	450 technicians

The use of helicopters in the long term is expected to be very limited for a variety of reasons. With regard to the above figures, the following should be noted:

- The number of boats and technicians is based on the assumption that they will be working on a full-time basis (the figures therefore indicate FTEs), and that the boats will be used for several different wind farms. In actual practice this will not always be the case. During the early stages in particular, the service companies of the wind turbine manufacturers will opt for a situation that is optimised to their own wind farm rather than to a number of different wind farms in which turbines of other manufacturers need to be maintained. In addition, a situation could arise in which the sailing time between two wind farms is comparable to the sailing time from port to wind farm. During the early stages in particular, several wind farms may well choose to operate their own vessels in spite of the fact that these will not be in full-time use. Consequently, the total number of vessels that may be receiving supplies through the port of Den Helder could exceed the figures given above. The same goes for the number of technicians. In the offshore oil and gas industry is has become common practice for maintenance services to maintain installations from various manufacturers, and this is expected to become the standard within the offshore wind power industry within 5 to 10 years.
- Supply boats will be used in equal measures for preventive and corrective maintenance. Preventive maintenance will take place mainly during the summer, whereas corrective maintenance will occur throughout the year. In all probability, preventive maintenance during the summer period will be combined with repair work.
- For the second generation of offshore wind farms, preventive maintenance is expected to take place with supply boats carrying approximately 4 or 5 maintenance crews of 3 technicians each, staying at sea for a week or a fortnight and returning to port only for provisioning and to change crews.
- Maintenance crews can be transferred between the supply boat and the turbines using a specially developed gangway system, but they may also use inflatables to cover the last few yards. Whichever method is used, it does not affect the facilities required at Den Helder.

Relatively small spare parts and tools (up to 500 or 1,000 kg) will be required for preventive and minor corrective maintenance. These are expected to be stored in containers which will be transferred to the supply vessel when it comes in (weekly or fortnightly) to take on supplies.
Large external cranes will be required for carrying out major maintenance work. The estimated frequency at which this will occur is as follows (for all major components):
2010: 75 times a year
2020: 250 times a year
If Den Helder also wishes this type of maintenance to be carried out from its port, facilities must be provided to enable components of the following dimensions and weight to be brought in, stored, assembled, and shipped out:

- Separate rotor blades up to 70 m long and weighing up to 25 tons.
- Complete rotors up to 140 m in diameter and weighing up to 120 tons.
- Nacelles up to 25 m long, 7 m wide, 7 m high, and weighing up to 300 tons. Only direct-drive turbines (E-112 turbines) are of larger dimension (440 tons). In some cases two of the rotor blades will be fitted on shore, with the third blade being fitted once the nacelle and the hub carrying the first two blades have been installed. This brings the total weight to a maximum of 400 tons.
- Towers up to 140 m long and weighing up to 250 tons. Towers will probably be delivered in sections and mounted on the quayside. Then they will need to be lifted onto a boat. Tower maintenance involving replacement is not expected to occur, or hardly ever.

- Individual components such as gearboxes and generators weighing up to 60 tons. Note that most first and second generation wind turbine gearboxes weigh considerably less, up to 20 tons.

The large external cranes mounted on jack-ups or barges such as the A2SEA will only rarely put into port. On the whole these vessels ply the seas on a permanent basis, carrying out repairs on wind turbines if and when they happen to be in the vicinity. These large vessels will not often put into port since they are too expensive to remain idle for any length of time. If the need arises to take on supplies or to carry out repairs, these vessels will call at the nearest port, which need not be Den Helder. They may also choose not to put into port at all, and to have supply boats come out to them instead.

<u>Employment</u>
An estimate of the resultant direct employment has already been given.
2010: 130 technicians
2020: 450 technicians
These figures are in fact FTEs. The actual number of technicians is expected to exceed this.
Indirect employment is expected for:

1. staff manning the control room for on-line monitoring of the wind farms;
2. supply boat crews,
3. dockside workers handling the transport, storage, and transfer on board of supplies and spare parts;
4. overhaul businesses;
5. haulage companies; and
6. training institutes.

(1) On-line monitoring of one or more wind farms is not tied to any specific location in the area. Most wind farm owners, maintenance services, and suppliers of components that also carry our maintenance will have access to the wind farm controls at a certain level. In addition the network operator will have access to the wind farm controls to measure and adjust the generated power. It is therefore impossible to give an exact figure for the number of jobs involved. Most of these jobs will probably be outside the area.

(2) Supply ships will carry a standard crew. An estimate of the number of jobs involved forms part of phase 2 of this project.

(3) An estimate of the required number of dockside employees also forms part of phase 2.

(4) There will be no great demand in the short term for small specialist overhaul companies at the port. Turbine owners will mostly have their components overhauled at or through the manufacturer in order not to jeopardise their guarantees. In the longer term, when maintenance is no longer automatically carried out by the turbine manufacturer or when service companies establish themselves in the port, there is then a big chance that local overhaul businesses will be required, as will storage facilities for consumables. At this point no estimate can be given as to the number of jobs involved.

(5) Transport companies moving components by road, rail, or water will not relocate to the area specially for the offshore wind power industry. Bringing in wind turbine components is simply an expansion of their current activities.

(6) The ROC can play a major role in providing offshore training (DHTC) to maintenance technicians. Apart from this, practically all the maintenance contractors indicated that they saw no need for specific courses to train wind turbine technicians. On the whole, the in-house training provided by the manufacturers is sufficient. Once offshore companies start to cooperate with turbine manufacturers, they too will receive training.

Maintenance work on wind turbines will take place mainly during the summer. The division of work is expected to be about 70% during the summer period and 30% during the winter period. In order to ensure the continuity of operations and to maintain the level of knowledge regarding wind turbine maintenance, most of the maintenance crews will have to be employed on a permanent basis. However, this requires that employment be found for the wind turbine technicians during the winter months.

6.2 Recommendations

In this section the salient passages have been underlined.

1. The potential offshore wind power capacity to be maintained from Den Helder is as follows:

2006 220 MW + 300 MW ≈ 500 to 550 MW (very advanced plans)
2010 1,000 ≈ MW + 5,000 MW = 6,000 MW
2020 6,000 MW + 15,000 ≈ MW 21,000 MW

However, Den Helder can expect competition from North German ports, from which the first wind farms will be installed and maintained. In fact, they will be gaining the advantage regarding infrastructure and the development of know-how. Maintenance on the first Dutch offshore wind farms will be carried out from IJmuiden. Den Helder will need to make haste in determining its own strong points for the maintenance of offshore wind farms and to use these to project itself. The collaboration with IJmuiden that is already planned will be necessary to be able to take on the foreign competition.

2. If one considers the amount of maintenance that needs to be done on wind turbines and the continuity of the work, then it is probably most worthwhile for Den Helder to focus on accommodating preventive maintenance and minor corrective maintenance. This type of maintenance is done using supply ships that will put into port once every week or fortnight to take on supplies, as well as to change crews and containers with small parts and tools. It is expected that in the longer term overhaul companies will be given the opportunity to overhaul the smaller parts. Major maintenance however will result in a non-continuous workflow limited to the transfer of large components, since the new parts will be shipped straight from the factory to the wind farm via the shortest route. Rather than via Den Helder, this will be done through the ports from which the initial installation took place, since their local industry will already be familiar with the transport of large components. In addition to this, the large crane barges and other vessels required for replacing major components will not often put into port, and even if they do, they will call at the nearest port.
3. The peak of the maintenance work will be in the summer. In the short term, offshore wind turbine technicians can be found work on shore during the winter. It appears that after 2010 this scenario will not be sufficient to employ the full complement of technicians through the winter months, as offshore maintenance requirements will grow faster than the onshore work. In order to ensure the continuity of operations, the majority of the maintenance crews will have to be employed on a permanent basis. However, this requires that employment be found for the wind turbine technicians during the winter months. Therefore, if a combination of employment can be created in the area that will enable employees to work offshore during the summer and spend the winter months working on shore, the maintenance crews can be tied to the area. In this respect, an important role could be reserved for overhaul work carried out on behalf of, or in collaboration with, suppliers of wind turbine components.
4. From interviews with current and potential maintenance contractors for offshore wind turbines, the reason why Den Helder makes an attractive base on technical grounds did not emerge. Below are some of the comments given:
   - Crews need not live in the area. Crews from outside the area would only have to travel to Den Helder once a week or once a fortnight. This is common practice in the offshore oil and gas industry.
   - Given a "two weeks on/two weeks off" scenario, it does not really matter whether the supply boat sails from Den Helder or from IJmuiden.
   - Our first wind farms will be maintained from IJmuiden, and we see no need to relocate our business to Den Helder or establish a branch office there specially for this purpose.
   - The offshore industry is an international activity. Ships can take on supplies in any port.
   - The control rooms with on-line access to the wind farm's computers need not be located in the Kop van Noord Holland.
   - We hire specialist companies for the maintenance of the electrical infrastructure (which are not located in the Den Helder area).
   - Helicopters will be used only sporadically. In the short term, helicopters will still be used on a regular basis for corrective maintenance to the Q7 wind farm. Later, for reasons of safety and economy, the use of helicopters will be limited to emergency operations.

   The technical requirements of a home port for minor maintenance on offshore wind farms are not particularly high. Facilities need to be available for supply boats to dock and take on supplies. If Den Helder does aim to attract companies to the region and to encourage job creation, it will need more decisive arguments than just technical ones. It will need to focus on, for example, financial incentives, or creating good conditions (legal, economic, etc.).

5. A number of the parties interviewed were familiar with Den Helder Training Centre (DHTC) and were highly impressed with the training courses given at DHTC. It is believed that the demand for training courses might be stimulated if the DHTC were to promote itself among potential maintenance companies.

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ANNEXE A PROJECT PARTNERS AND THEIR ROLES

Projectbureau Kop & Munt

The Kop & Munt 2000-2006 programme comprises a coordinated package of measures, including substantial investments to restructure the economic functions of the Noordkop region and to initiate a sustainable and balanced economic development of the Kop van Noord-Holland.

Marsdiepstraat 621
1784 AM Den Helder
Phone +31 (0)223 661373
E-mail info@kopenmunt.nl

Technology Transfer Association, Maritime Platform (ATO-MP)

ATO-MP, which is a collaborative effort of knowledge centres in the region, focuses on knowledge consolidation and transfer and is supported by Projectbureau Kop & Munt and the North Holland Province authorities. ATO-MP is project coordinator.

Het Nieuwe Diep 8 (Het Klooster)

Den Helder
Phone +31 (0) 223 684161
Fax +31 (0) 223 683125
E-mail info@ato.nl

Netherlands Energy Research Centre (ECN)

The ECN Wind Energy unit occupies a strategic position between universities and the industry. The services and know-how provided by ECN cover practically every aspect of wind energy. In the context of this project ECN contributes its knowledge regarding the maintenance, management, and monitoring of offshore wind farms to enable the maintenance requirements of new offshore wind farms to be gauged. The results will be evaluated in consultation with specialist maintenance companies for the wind power and offshore industries.

Postbus 1
1755 ZG Petten
Phone +31 (0)224 564943
E-mail info@ecn.nl

Regionaal Opleidingencentrum Kop van Noord-Holland (ROC)

The ROC is an educational organisation that plays a major role in secondary vocational education and adult education within the northern part of North Holland province. In the context of this project, the ROC is assessing training requirements.

Sperwerstraat 4
1781 XC Den Helder
Phone +31 (0)223 611200
E-mail info@rockopnh.nl

Stichting Bedrijfsregio Kop van Noord-Holland

Bedrijfsregio Kop van Noord-Holland is an agency that provides local authorities and industries in the Kop van Noord-Holland with support for the initiation, development, implementation and execution of economic policy, programmes and projects. In the context of this project, Bedrijfsregio will use its know-how and contacts with the industry within and outside the region to improve the quality of the assessment. In addition, Bedrijfsregio will provide promotional support.

Postbus 94
1780 AB Den Helder
Phone +31 (0)223 668033
E-mail post@bedrijfsregio.nl

ANNEXE B OPERATIONAL OFFSHORE WIND FARMS

Site-Picture/ Country	Start	# turbines rotor / kW Total Capacity, lay-out	Distance to shore	Water Depth m.	Hub height m.	Foundation	kWh/m^2/y kWh / y
Nogersund / Sweden	1990	1 * Wind World 25 / 220	350 m.	6	37,5	Tripod	Out of operation
Vindeby / * Lolland - Denmark	1991	11 * Bonus 35 / 450 5 MW / two rows	1,5 – 3 km.	2,5 – 5	37,5	Concrete caisson	1.13 11.200.000
Lely IJsselmeer / Netherlands	1994	4 * NedWind 40 / 500 2 MW / single line	800 m.	4 – 5	39	Driven monopile	800 4.000.000
Tuna Knob / Denmark	1995	10 * Vestas V 39 / 500 5 MW / two rows	6 km.	03-May	40,5	Concrete caisson	1.046 12.500.000
Dronten / Netherlands	1996	28 * Nordtank 43 / 600 14 MW / single line	30 m.	01-Feb	50	Driven monopile	900 36.700.000
Bockstigen / Gotland - Sweden	March 1998	5 * Wind World 37 / 550 2,8 MW / cluster	4 km.	6		Drilled monopile	1.544 8.300.000
Utgrunden / Oland / Sweden	Dec. 2000	7 * Enron Wind 70 / 1500 10,5 MW / cluster	12 km.	07-Oct		Driven monopile	1.37 36.900.000
Blyth / * United Kingdom	2000	2 * Vestas V 66 / 2.000 4 MW	1 km.	6 m. 5 m. tide	58	Drilled monopile	1.754 12.000.000
Middelgrunden ** Denmark	March 2001	20 * Bonus 76 / 2.000 40 MW, curved line	2 - 3	02-Jun	60	Concrete caisson	1.1 99.000.000
Yttre Stengrund / Oland - Sweden	July 2001	5 * NEG-Micon 72 / 2 000 10 MW / line	5 km	8	60	Drilled monopile	1.475 30.000.000
Horns Rev *** Esbjerg - Denmark	Dec. 2002	80 * Vestas V 80 / 2.000 160 MW, cluster	14 - 20 km.	6 - 14 m.	70	Drilled monopile	1.493 600.000.000
Frederikshaven Denmark	Dec 2002	1 * Vestas V 90 - 3.000	500 m.	1	80	Bucket	1200 ? 7.600.000
Samso , Denmark	Febr. 2003	10 * 82,4 / 2.300 Bonus 23 MW, line	3,5 km	11 - 18	61	Monopile	78.000.000
Frederikshaven Denmark	May 2003	1 * Nordex 90 / 2.300	500 m.	1			1200 ? 7.600.000
TOTAL		**285 units / 280,6 MW**				**kWh/y : 943.800.000**	

ANNEXE C PLANNED OFFSHORE LOCATIONS

Site , Country	On-line	Turbines / Hubh. / Capacity	Water depth m.	Distance to shore	kWh / Y
Frederikshavn Denmark	2003	1*Vestas V 90 - 3.000 1*Bonus 2,3 MW	1	0 - 800 m.	
Nysted , Lolland, Denmark	Okt. 2003	72 * Bonus 2.2 MW Hubh. 70, 158 MW	6 – 9,5	Ca. 9 km.	500 million
Klasarden Gotland, Sweden	2004	NEG-Micon, 16 * 2,75 MW / 90 m. 44 MW	7 – 11	1,5 km	120 million
Rostock, Breitling River Germany	2003	1 * Nordex N 90 / 2.300			
Wilhelmshaven, Germany	2003	1 * Enercon E 112 4,5 MW		500 m.	
Arklow Bank Irish Sea, Ireland	2003 - 2005	7 * GEW 3.6 MW hubh. 73 m. / 25 - 520 MW	5 +	7 - 12 km	
Scroby Sands Norfolk, UK	August 2004	38 * Vestas V 80/2.000		3 km	
North Hoyle,Wales	Summer 2003	30 * Vestas V 80/2.000	12 m. ; 8 m. tide	6 km	
Rhyl Flats, Wales	2004	30 turbines, 100 MW		8 km.	
Barrow, UK Irisch Sea	Autumn 2004	30 turbines , 108 MW		10 km.	
Kentish flats, UK Thames Estuary	2005	30 MW NEG-Micon		8 km.	
Utgrunden-2, Oland , Sweden	2004	24 turbines		7 km.	
Borkum-West , Germany	2004 -2010	60 - 1000 MW	± 30	45 km. North of Borkum	200 -3500 million
Long Island New York, USA	2004	33 turbines, 100 MW			
"Vlakte vd Raan", Knokke, Belgium	2004 ?	40 * Vestas V 80-2.000	10	15 km.	300 million
Oresund, Sweden	2004 ?	48 turbines		10 km from Malmo	400 million
North-See Q7-WP, Netherlands	2004	60 * Vestas V 66 120 MW	19 - 24	23 km.	350 million
NSWP, North Sea, Netherlands **	2005	36 * NEG-Micon 92 / 2.750 99 MW	15 - 20	8 - 12 km.	300 million
Solway Firth South West Scotland	2004	60 turbines, 199 MW		9 km.	
Cape Cod , Boston, Mass. USA *	2005	130 * 3.6 GEW 468 MW		9 km.	
Butendiek , Germany North Sea	2006	240 MW	16 - 20	34 km West from Sylt	800 million
Queen Charlotte Isl., Canada (Br. Col.)	2005 ?	700 MW			
Pommersche Bucht Baltic Sea, Germany	2005 -	350 - 1000 MW	Dec-20	42 km from Rugen	
Nordsee-Ost North Sea, Germany	2006 -	1000 - 1250 MW		30 km North of Helgoland	
Cape Trafalgar, Gibraltar Spain	?	200 & 250 MW			

Authors: H. Braam, L.W.M.M. Rademakers	
Client: Associatie Technologie Overdracht (ATO)	
ECN project number: 8.40154 **Job number:**	
Programme(s):	

Abstract:

It is Den Helder's ambition to become the base from which maintenance operations for offshore wind turbines are conducted. In order to prepare itself for the prominent role the *Kop van Noord-Holland* (the northern tip of North Holland province) aims to play in the sphere of offshore wind turbine maintenance, the project office of the economic incentive programme *Kop & Munt* granted a subsidy in early 2003 to the technology transfer association ATO Maritime Platform (ATO-MP) to conduct the project "The region strong contender for offshore wind farm maintenance". ATO-MP conducted the project in collaboration with the Netherlands Energy Research Centre (ECN), the regional training centre ROC Kop van Noord-Holland and the regional development agency *Bedrijfsregio Noord-Holland.*

This report contains the results of phase 1 and was conducted by ECN. ECN itself performed analyses to establish the scale of the maintenance requirement for large offshore wind farms. Interviews were then held with companies that will be carrying out maintenance on offshore wind turbines in order to verify the views of ECN.
The following table shows the number of wind turbines that can be maintained from Den Helder. It also shows the equipment and immediate personnel required. It assumes that a number of wind farms in German waters can also be maintained from Den Helder.

2010:	2000 MW	500 turbines	6 supply boats	130 technicians
2020:	7000 MW	1,750 turbines	16 supply boats	450 technicians

Indirect employment is expected in particular for supply boat crews and dockworkers for the transport in, storage, and shipping out of supplies and spare parts.

The report ultimately makes recommendations to the region on how to best prepare itself to accommodate maintenance on large-scale offshore wind farms.

- It is probably worthwhile for Den Helder to focus on preventive maintenance and minor corrective maintenance.
- Den Helder can expect competition from North German ports. The planned collaboration with IJmuiden will be necessary to combat the foreign competition.
- Maintenance work will peak in the summer. If a combination of employment can be created which will enable personnel to be used for offshore maintenance in the summer months and for onshore activities in the winter, maintenance technicians can be tied to the region.
- If Den Helder aims to attract businesses to the region and to encourage job creation, arguments other than technical ones will be required. The technical requirements ports need to meet for offshore wind turbine maintenance are not so high. Den Helder will need to focus on financial incentives, or creating good conditions (legal, economic, etc).
- DHTC is well-known internationally. It is thought that if DHTC were to project itself more forcefully among potential maintenance contractors, the demand for these courses could increase.

Headwords: Offshore wind power, maintenance

Name
J.M. Bais
L.W.M.M. Rademakers
H.J.M. Beurskens

December 2005

Kop van Noord-Holland strong contender for offshore wind farm maintenance

Part 2: Analysis of the available facilities and infrastructure in the Kop van Noord-Holland

Bedrijfsregio Kop van Noord-Holland

BDR/JN/JS 12/2006

1 Introduction

In part 1 of the 'Kop van Noord-Holland strong contender for offshore wind farm maintenance' an estimate was made of the size of the offshore wind market in the Netherlands and neighbouring countries in the near future. On the basis of this, a rough indication was given of the potential market share of maintenance for the (yet to be built) wind farms for Den Helder. An inventory was also compiled of the technical facilities required for the construction and maintenance of near- and offshore wind farms. An indication was given of the type of equipment needed to organise the maintenance and the demands it must satisfy. Also, an estimate was made of the requisite manpower.

Besides the equipment that will be used for the maintenance, the port and surrounding area require the appropriate infrastructure and support services. The demands this infrastructure and these services need to meet depend on the equipment used. This report will go into little detail about the equipment needed, as this has already been dealt with in part 1 of the project. Section 2 summarises the requisite infrastructure and services that emerged from part 1.

The infrastructure already available and/or that will be developed in the region in the near future is discussed in section 3. The infrastructure available in the area of the port used by the Navy could afford additional opportunities for the offshore wind industry. An increase in the possibilities for use by the civilian sector could make infrastructural facilities available that until recently were not.

Without support services even the best infrastructure is useless. Section 4 draws up an inventory of the products and services of principal importance to the offshore industry in the Kop van Noord-Holland. Besides the services provided by private companies in the region, the Navy's maintenance arm, the Marinebedrijf, also has various services of interest to the offshore wind sector. Co-use by civilian companies increases the chances of the marketing of the products and services the Navy can provide.

Finally, Section 5 considers the infrastructure and services that are available in the Kop van Noord-Holland and those that are required, producing a picture that the region can use as a basis for positioning itself in the market for offshore wind farm maintenance.

2 Requisite infrastructure and services

The most important infrastructure for the offshore wind industry is already present in most ports. A distinction does, however, need to be drawn between the infrastructure required for the construction, corrective/preventive maintenance and major maintenance of offshore wind farms. Construction and major maintenance requires infrastructure of a higher level than corrective/preventive maintenance. As the Kop van Noord-Holland is primarily targeting corrective and preventive maintenance, the infrastructure relevant in this context will be discussed.

For the time being, use will be made of existing resources as much as is possible for the maintenance of the near- and offshore wind farms. Where necessary, relatively minor modifications will be made to these resources, e.g. adding a system for transferring people and equipment to an offshore wind turbine. These systems are easy to place on the existing supply boats, and the development of special ships for maintenance is not expected in the near future. In practice, this means that supply boats from the fleet currently used to supply and maintain drilling rigs and platforms in the North Sea will be used for maintenance purposes. There is no standard size for these ships, but in general they are not more than 50-60 metres in length. It is estimated that up to 2010 about 6 boats will be needed for maintenance. In 2020 this number will increase to about 16 boats, but inefficient use of these could mean the number of ships will in practice be higher.

Experiments have been carried out in Denmark, among other countries, in hoisting maintenance crews onto offshore wind turbines by helicopter. This method of transferring personnel proved very time-consuming and in some instances even dangerous, because the turbine has to be positioned in a specific way from shore to allow a helicopter to approach. It is not always possible to guarantee that the turbine will indeed be in the right position. If there is any uncertainty, flights will not be carried out and a boat will be sent. An added disadvantage of the use of helicopters for transporting maintenance crews to the turbines is the limited capacity for equipment. Also, the use of helicopters is very expensive. Expectations are that little or no use will be made of helicopters for offshore wind farm maintenance in the Netherlands. Helicopters could be used, if necessary, to fly specialist maintenance personnel swiftly to a maintenance vessel. It is impossible to predict how often this will be necessary.

Supply boats will be used to take parts/spare parts to the offshore wind farms. How the parts will be brought in to the port of supply will depend on their size. Small parts, where appropriate packed in containers, can be brought to the port either by road or rail, or by inland vessel. In practice, transport by road will in most cases be the favoured option. If the products are too large to be carried by road or rail, they will be brought in by ship. Therefore, good road and water links as well as good transshipment facilities are a must for the port of landing. The table below shows the maximum dimensions of the largest components of a wind turbine.

	Blade	Nacelle	Tower	Other components
Maximum size	70 metres	25 mx7 mx7 m	140 metres	
Maximum weight	25 tons	440 tons	250 tons	60 tons

Table 1: Overview of dimensions of largest turbine components

The activities in the port from which maintenance will be organised needs to be concentrated on the provision of a wide range of services. The majority are the same as the services customarily required for the offshore oil and gas industry. These include, for example, provisioning ships, transshipment of parts, temporary storage of goods, ship-related services, etc. In addition to these general port-related services, the maintenance of offshore wind farms also requires a number of more specific services, e.g. the maintenance of the electrical infrastructure and supporting structures. The maintenance and inspection of the electrical infrastructure is expected to be necessary about once every five years. Specialist companies already performing similar work will be used for this. The supporting structures will probably be inspected by divers at most once every three years.

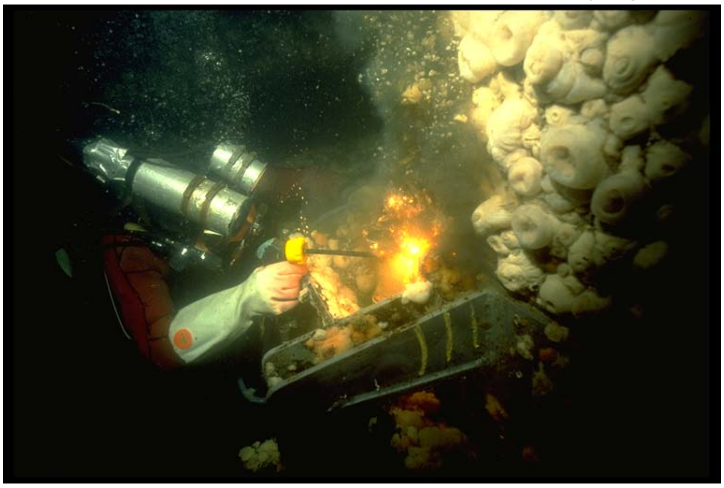

Figure 1: Subsea inspection and maintenance

Besides the products and services that will be supplied direct to the offshore wind companies, there is also a need for support products and services. These could comprise training programmes and/or know-how in the field of maritime technology, maritime safety or test facilities for equipment used. In particular, know-how in respect of maritime safety in the widest sense of the word will become increasingly important. As the offshore wind turbines will be used in a marine environment, extremely high demands need to be met by coatings, lubricants, seals, etc. Knowledge and research in this field is therefore of great importance. A great deal of knowledge is already available within the offshore wind market, but knowledge from other sectors affords clear added value.

3 Infrastructure in the Kop van Noord-Holland

Den Helder

The port of Den Helder is the most important seaport in the Kop van Noord-Holland region. The port affords year-round open access to the sea, even in the most extreme weather conditions. Den Helder is strategically located in respect of the North Sea, the oil and gas fields on the continental shelf and the planned offshore wind farms. Many offshore oil and gas companies have acknowledged this and make intensive use of the port. Because of the port's open character, there is no need to allow for waiting times; most services can be handled without passing locks or a bridge.

Den Helder port is multifunctional and currently performs many important functions for the region, e.g.: *Offshore Port, Fishing Port, Navy Port.* In the context of the project 'Region strong contender for offshore wind farm maintenance' its function as a port for the offshore sector is of principal importance, and to a lesser extent its function as a Navy port. Its function as a port for the offshore industry means the infrastructure and business community concentrate on providing services to offshore vessels. The step from offshore oil and gas vessels to vessels for the maintenance of offshore wind farms is, if there is one, minimal.

The relationship between the Navy port and offshore wind power is equivocal and perhaps not immediately obvious. In the first place there is infrastructure in place on Navy property that could increase the capacity of Den Helder port. In the second place, some of the know-how and services of the Marinebedrijf could be put to very good use for the offshore wind industry.

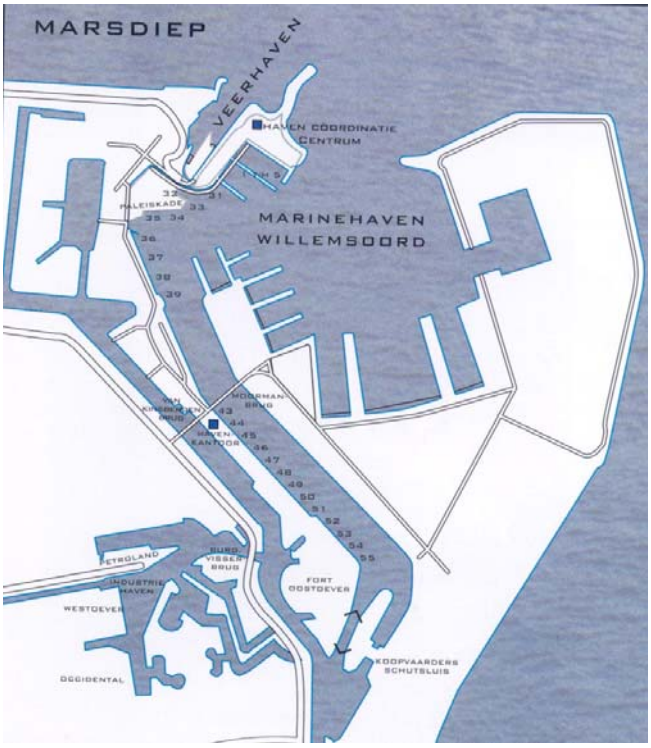

Figure 2: Seaport Den Helder

Besides its open seaport, Den Helder also affords opportunities for water-related activities. Opportunities are currently confined to the industrial port, but a regional port-related industrial estate will be developed in the short term that will complement the Kooypunt industrial estate. This site has direct access to the North Holland canal and offers excellent opportunities for builders of complex installations, whose size means that they can only be transported by water, to establish their business.

Quays	Total length	Maximum jetty length	Maximum draught	Main function/suitable for	Quay capacities maximum
Het Nieuwe Diep					
*Jetties 31-35**	200 metres	170 metres	12.5 metres	Offshore	4,000 kg/m^2 **
Jetties 36-38	230 metres	100 metres	7.5 metres	Offshore	2,000 kg/m^2
Jetties 40-47	840 metres	60 metres	5.5 metres	Fishing	2,000 kg/m^2
Jetties 52-55	270 metres	70 metres	5.5 metres	Offshore	4,000 kg/m^2
Industrial port					
Westoever	620 metres		4.6 metres	Offshore	
	310 metres		4.6 metres	Inland shipping	
Unloading quay					
Oostoeverweg	225 metres		3.0 metres	Inland shipping	

* New Paleiskade (will be completed in 2004)

**As an additional facility a reinforced platform with a floor load of 600 KN/m^2 is available

Table 2: List of port facilities in Den Helder civilian port

The above data could create the impression that the port of Den Helder is capable of berthing ships up to 170 meters. Although this is theoretically possible, there are however a number of restrictions as regards the length and draught of vessels. In principle, ships up to 160 metres can use the port, above that things get tight. The maximum draught of 12.5 metres for the new Paleiskade does not mean in practice that ships with this draught can sail into Den Helder port. The navigable channels giving access to the port permit a maximum draught of around 10.5 metres. This depends on the tide and is subject to changes caused by shifting sand on the sea bottom.

Jetties 52-55 are accessible for ships with a draught of 5.5 metres. Also, the maximum dimensions for passing the Moorman bridge also need to be taken into account. These are 85 metres for the length and 18 metres for the width of the vessel.

The vessels that will be used for offshore wind farm maintenance will not be affected by the restrictions of Den Helder seaport. Most of the supply ships will fall well within these maximum dimensions. Only the vessels that will be used for the construction and major maintenance of the offshore wind farms could in a number of cases be too large to be received in the port of Den Helder. As this is not the primary aim of the Kop van Noord-Holland, this will be no problem.

Figure 3: Blade under construction

In addition to the above infrastructure already in place, the regional port-related industrial estate Kop van Noord-Holland is being developed close to the Kooypunt industrial park. The 1st phase will comprise 40 issuable hectares gross, 17.5 hectares net of which will be port-related and 13.5 hectares net port-dependent. There is an additional possibility of continuing the development up to 90 hectares gross. Thanks to its excellent road, rail, air and water links and the vicinity of the Kooypunt Industrial Park, where various offshore service companies are established, this estate affords excellent opportunities for offshore wind-related companies. Large components can be transported in and out by water. It is connected by water to Den Helder seaport via the Koopvaarderschutsluis locks. Vessels up to 85 metres in length and 18 metres wide can pass through these locks. The maximum draught is 4.6 metres. Looking back at the maximum dimensions of the parts as formulated in section 2, all components - with the exception of the tower - could in principle be transported via this route.

Figure 4: Koopvaarderschutsluis and Den Helder port

If the opportunities for civilian use of naval facilities were enlarged, the effective capacity of Den Helder seaport could be increased. The major part of the port is currently being used exclusively by the Royal Netherlands Navy. If a decision were taken to grant businesses limited access to the Navy's facilities (on a call-off basis if necessary), any peaks or vessels of extraordinary dimensions could still be accommodated in the port. Take, for example, a sudden rush of supply boats due to bad weather conditions or, as already happens, because dockworkers in Denmark are on strike.

Besides accessibility via the sea, accessibility via other transport means is also of importance. Although helicopters will only be used in extraordinary circumstances for carrying out maintenance on offshore wind turbines, the presence of Den Helder Airport is still of importance. The airport concentrates largely on providing services to the offshore oil and gas industry, but if necessary the businesses there could easily make the jump to providing support for offshore wind-related activities.

A potential bottleneck for Den Helder seaport is its accessibility by road. From Alkmaar, Den Helder can be reached by the N9 trunk road. This could present difficulties for large or exceptionally large transports when passing through the villages. A second possible route is via the A7 motorway and the N99 trunk road. In the future, a branch of the A7 may be constructed, linking Den Helder direct to the motorway network. At present, there is hardly any congestion on the road network in the region, but in the near future it is something that will need to be taken into account on a number of points. Boosted by the opening of the nautical theme park in Den Helder and the delivery of the new, larger Texel ferry, peak traffic on the road network will increase sharply, especially around the entrance to the theme part and at the ferry terminal. This does not present immediate problems for the port's accessibility, as it can be reached easily via the Kinsbergen bridge. Only in busy periods like the long weekend around Ascension Day and Whitsun is it possible that the port will be less easily accessible.

Figure 5: Accessibility by road

The bottlenecks on the road for exceptionally large transports can be easily avoided as inland vessels can reach Den Helder easily via the North Holland canal. A direct link to the IJsselmeer may be added in the future through the creation of the planned Wieringerrandmeer, a lake bordering the former island of Wieringen. Large transports can therefore be easily handled via the waterways.

Oudeschild/Den Oever

The two ports of Oudeschild and Den Oever can also be considered to be seaports. Due to their specific location they will probably only play a support role in the organisation of offshore wind farm maintenance in the region. Oudeschild is located on the island of Texel and is primarily used as a fishing port, recreational port and transshipment port for agricultural products, building materials and fuels. Bringing in goods by road, via the Texel ferry, is by definition time-consuming and possibilities for transshipment are limited. Access to the port of Den Oever is via the Wadden Sea. The navigable channels are relatively narrow and shallow, which can hamper larger vessels. The port of Den Oever is primarily in use by the fishing sector and recreational shipping. For the sake of completeness, the tables below give the data for both ports.

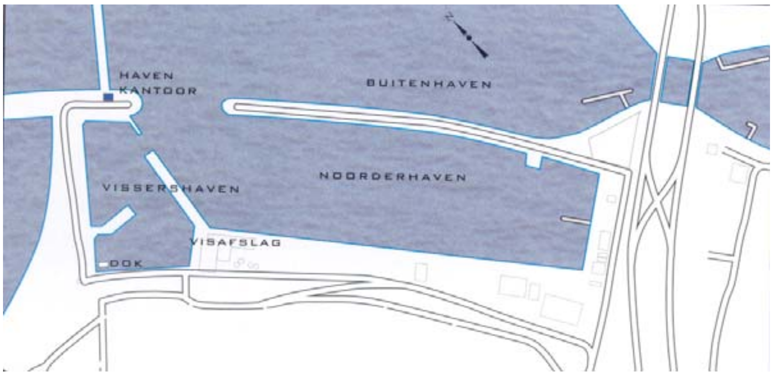

Figure 6: Port of Den Oever

Quays	Total length	Maximum draught	Main function/suitable for
Noorderhaven	500 m	4.0 m	Fishing / recreation / transshipment
Vissershaven	300 m	4.0 m	Fishing / recreation
Waddenhaven*	80 m	3.30 m	Fishing / recreation

Table 3: Port of Den Oever

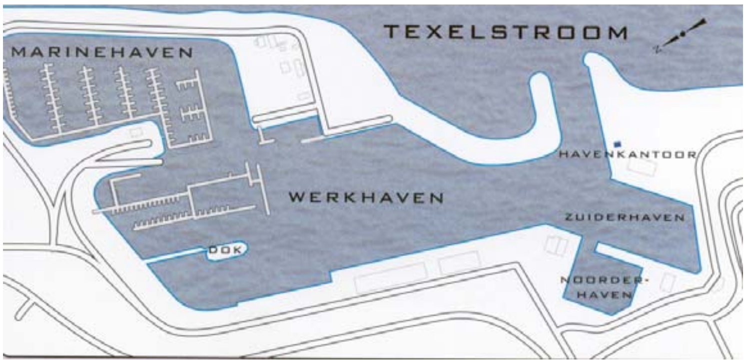

Figure 7: Port of Oudeschild

Quays	Total length	Maximum draught	Main function/suitable for
Zuiderhaven	275 m	5.0 m	Offshore / recreation / fishing / transshipment
Working port	485 m	5.5 m	Fishing / recreation
Noorderhaven	240 m	4.5 m	Sports fishing / work vessels
Port entrance	95 m	5.5 m	Miscellaneous

Table 4: Data port of Oudeschild

4 Offshore products and services in the Kop van Noord-Holland

As emerged in section 2, there is in principle little difference between the services required by the offshore oil and gas industry and those required for the offshore wind industry. This section will therefore give a general overview of the principal offshore-related services in the Kop van Noord-Holland.

There is a large number of offshore-related businesses active in the Kop van Noord-Holland region. The regional development agency keeps a digital file of these, which it publishes on the Internet. A complete overview of these companies can be found on ***http://www.gasandoil.com/den-helder/*** and ***www.networkedcommunity.nl***. Some of these companies have already been involved in the manufacture of wind turbines or have provided services to wind turbine manufacturers. The companies operating in the region can easily take up the provisioning of vessels involved in offshore wind farm maintenance. Existing companies can carry goods and parts for shipment as well as load the ships. The companies that currently supply (complex) metal constructions to the offshore industry can also supply goods and services to the offshore wind industry. In Den Helder there are in any event a number of companies that are active in this market. Warranty provisions mean that, initially, suppliers will carry out the maintenance and overhaul work on turbine components themselves.


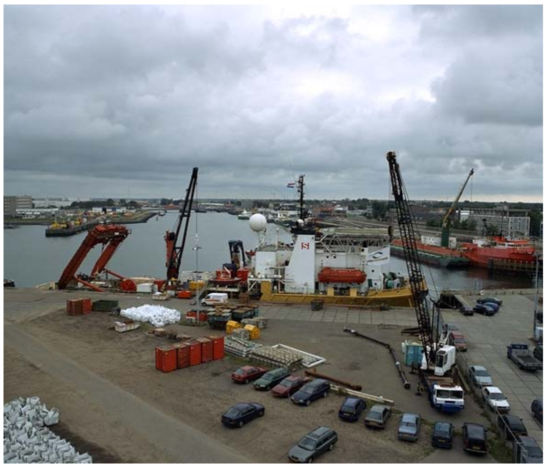

Figure 8: Transshipment and provisioning in the port of Den Helder

Although there will be no direct demand for the use of helicopters from the offshore wind market, the presence of the regional airport, Den Helder Airport, is most certainly a point to the region's advantage, as the service it provides already focuses to a large extent specifically on the offshore market. Den Helder Airport is *the* national airport for the offshore industry. The switch to products for the offshore wind market is not great and can easily be made if so desired. Moreover, if necessary specialists can be flown in, whereupon they can be dropped by helicopter swiftly on a supply vessel, for example.

An important aspect in the sphere of safety is the commissioning of a rescue helicopter specially for the offshore industry. This helicopter is under the control of the Coastguard and can in an emergency pick up 25 drowning people. The helicopter is also equipped with infrared equipment so that it can also work in the dark. The deployment of this helicopter is an initiative of the Dutch offshore industry and will continue until 2007. In 2007, the government itself is expected to be able to guarantee the required rescue capacity. These "safety" services do not afford absolute advantages for the establishment of offshore wind-related activities, but they do play a part in projecting the region as an offshore centre. At present there are plans at European level to concentrate rescue, salvage and environmental cleanup vessels in a number of centrally located ports. Den Helder could play a part in this, which would enable it to project itself as an “offshore emergency services” port.

The presence of DHTC and ROC affords big advantages, as they offer training courses and programmes in the field of maritime safety. In future, the syllabus can be expanded to include courses focusing especially on the offshore wind market. The Netherlands Organisation for Applied Scientific

Research (TNO), the Royal Netherlands Naval College (KIM) and the Netherlands Institute for Sea Research (NIOZ) are the principal knowledge centres in the region in the maritime and marine spheres. Their knowledge touches in many aspects on offshore wind power. The Netherlands Energy Research Centre (ECN) and the test centre for wind power in the Wieringermeer have at their disposal knowledge and facilities that can be directly applied.

The Navy's maintenance arm has a complete package of products and services for maintaining the Navy fleet. Many of these products and services can also be applied directly to the offshore wind market. Take, for example, the overhaul of machine parts, paint spraying, electrotechnology, test facilities for a wide range of equipment, etc. The reduction in the size of the fleet will result in a substantial overcapacity in terms of production infrastructure. It is not yet clear to what extent this capacity can be used in the future for activities in the private sector. Although the government is investigating the extent to which the civil sector can also make use of Navy facilities, no concrete promises have as yet been made.

5 Conclusion

It can be concluded from the preceding sections that both the infrastructure and the range of companies in the Kop van Noord-Holland tie in perfectly with the requirements of the offshore wind market. The wet infrastructure in the region does not require immediate modification to provide services to the possibly increasing number of supply boats that will put into Den Helder. By extending the Paleiskade, larger vessels can be accommodated in the port. Construction of the regional port-dependent industrial estate Kop van Noord-Holland also means an increase in the potential for the building and maintenance of large constructions. If the opportunity arises in the future for civilian companies also to make use of Navy facilities, the capacity and possibilities afforded by the port will further increase.

The existing companies can easily take advantage of the larger, new markets that will emerge from the offshore wind market. There are a large number of businesses established in the region which specialise in providing services or making products for the offshore industry. Most of these products and services can easily be adapted to the offshore wind market.

Given the possibility the region affords for maintaining offshore wind farms, it will be necessary to vigorously project the region’s attractions in this respect. Especially now there is broad support from the authorities for attracting offshore wind power to the region, the Kop van Noord-Holland will need to seize on the opportunity. To give an impression of the requisite input, you will find in the appendix a proposal for marketing Den Helder and the Kop van Noord-Holland, with offshore wind as the focal point. The process will in as far as possible be a joint venture together with other maritime and port-related organisations.

