NoordzeeWind

# Operations Report 2007

***Document No:*** ***OWEZ_R_000_20081023***

***Date:*** ***October 2008***

***Internet:*** ***www.noordzeewind.nl***

# Table of Contents

# Summary

In January 2007 the offshore windfarm Egmond aan Zee went into operation. This first Dutch offshore windfarm is a government demonstration project, that is developed, owned and operated by NoordzeeWind, a joint venture of Shell and Nuon. The windfarm comprises 36 Vestas V90 3 MW wind turbines, a 115 meter tall offshore meteorological mast, and an onshore transformer substation.

All turbines have become operational, and with just over 330 GWh in the year 2007 delivered enough electricity for approximately 100,000 homes to the Dutch grid. Challenges arose due to technical problems with the gearboxes, which are similar to those reported on comparable windfarms elsewhere. A maintenance campaign has been started to contain the problem, and this has been successful in keeping the problem under control.

There were no injuries or incidents to report. As of the end of the year, the plant had worked the full year (365 days) without any injury or incident. Total man-hours spent at site was over 60,000 for the year.

An extensive monitoring programme is being carried out to better understand the behaviour of the windfarm and its effects on the environment. This report describes the general performance of the windfarm in the first operating year 2007, and summarizes the results of the monitoring program so far. This report is itself part of the monitoring programme. Further results of the monitoring programme will be published separately.

This and other reports can be downloaded from http://www.noordzeewind.nl or from http://www.senternovem.nl/offshorewindenergy .

Acknowledgement:

The Offshore windfarm Egmond aan Zee has a subsidy of the Ministry of Economic Affairs under the $CO_2$ Reduction Plan of the Netherlands.

# 1 Introduction

In relation to emerging concerns on climate change and sustainable energy provision, the Dutch government identified offshore wind power as the largest feasible renewable energy resource in the country. In order to explore the viability of this technology, a feasibility study was carried out in 1997 on the development and construction of a 100 MW offshore windfarm. The report was issued in September 1997 by Novem (now SenterNovem) and concluded that such a windfarm would be technically and economically viable, provided that appropriate subsidies were granted. Subsequently, the government (through the department of economic affairs) initiated a demonstration project for a 100 MW offshore wind farm and acted in a lead role for site identification. This was the start of what is now the Offshore Windfarm Egmond aan Zee (OWEZ). In mid-2002 the site concession was awarded after public tender to NoordzeeWind (NZW), a joint venture between energy company Shell and utility Nuon. NoordzeeWind subsequently developed the windfarm, including obtaining all permits, grid connection, and securing the necessary contracts. After final investment decision in Q2 2005, NZW and Bouwcombinatie Egmond (BCE), a joint venture of Vestas and Ballast Nedam, signed the contract for the realisation of the windfarm.

The windfarm comprises 36 Vestas V90 wind turbines, associated support systems and an offshore meteorological measurement mast. The project is located in Dutch territorial waters of the North Sea, between 10 and 18 km from the coast. Each wind turbine is connected by a transition piece to a steel monopile foundation, piled to a penetration depth of about 30 m into sandy/silty seabed. The power is transmitted through three 34 kV cables to shore, which land north of IJmuiden harbour near Wijk aan Zee. A substation transforms the voltage from 34 kV to 150 kV and connects the plant to the national grid. The windfarm went into operation on 1 January 2007.

Part of the project is a Monitoring and Evaluation Program aiming to generate knowledge that will be beneficial to the development of offshore wind energy in The Netherlands. The program outline is defined by the Dutch government and covers two main areas:

- Environment, including public opinion;
- Technology & economics.

Design, construction and commissioning of the windfarm was reported previously[1]. This Operations Report 2007 covers the first operating year, i.e. the period 1 January 2007 until 31 December 2007.

[1] OWEZ_R_141_20080206 General report.pdf. This and other reports can be downloaded from http://www.noordzeewind.nl/ or http://www.senternovem.nl/offshorewindenergy/.

# 2 Overview

The wind farm has been designed, constructed and commissioned by the Bouwcombinatie Egmond (BCE), a project joint venture of turbine supplier Vestas and Dutch civil and offshore contractor Ballast Nedam. Offshore construction took place in a single season in 2006, starting in early spring. As a result, commissioning activities had to be completed during the autumn and winter. After the windfarm went into operation on 1 January 2007, initial performance was hampered by adverse weather preventing access to the site. After startup problems were resolved, the first months of operation went smoothly, with the official inauguration of the wind farm on 18 April by His Royal Highness Prince Willem Alexander as a real highlight.

Throughout the year management attention was focused on achieving good safety performance, as well as on wider HSSE (health, safety, security and environmental) matters. As a result of concerted efforts of everybody working on the project, the target of “no incidents” was achieved during the year.

In the second half of 2007, a problem in one of the gearboxes showed up. To prevent damage, the wind turbine was stopped to a safe position and the gearbox replaced. Unfortunately, the problem recurred in a further 13 out of 36 gearboxes over the year. The problem was traced to the design of some parts of the gearbox, which meant that all gearboxes would have to be replaced. A gearbox exchange program was subsequently set up by the contractor to manage the issue, which will last into 2009.

Performance did suffer due to these problems. Overall production over the year delivered to the grid was 330 GWh, which is satisfactory. The resulting capacity factor is 35 %.

Throughout the year, the project attracted a lot of attention from the public and media. The public “Infocentrum NoordzeeWind” in Egmond aan Zee is meeting a need, and welcomed over 50,000 visitors since its opening in April.

Public opinion is slowly warming to the windfarm, too. In line with general experiences of operating windfarms, the opinion of visitors of Egmond aan Zee and inhabitants is showing an upward trend. Although the esthetics are not always appreciated, most people understand the need for large-scale windpower and can therefore tolerate the windfarm in their area.

From the construction phase a number of so-called “punch list items” (open items from the construction phase) remained, which needed to be resolved during the operations phase. Although good progress was made during the year, at the end of 2007 some work was still ongoing. Close-out of all punch list items is expected during 2008.

# 3 Performance

## *3.1 Availability*

The good wind resource in 2007 had an adverse effect on the number of workable days. A statistically normal year would show a bathtub-like graph of unworkable days (i.e. days with bad weather preventing offshore access, see chapter 5 for weather limits), with high numbers in autumn and winter, and low numbers in spring and summer. The actual number of unworkable days shows a remarkable zig-zag pattern in 2007, see graph below. May, July and September were stormy months, and February and October were unexpectedly calm. This posed a challenge for maintenance planning with consequences for availability.

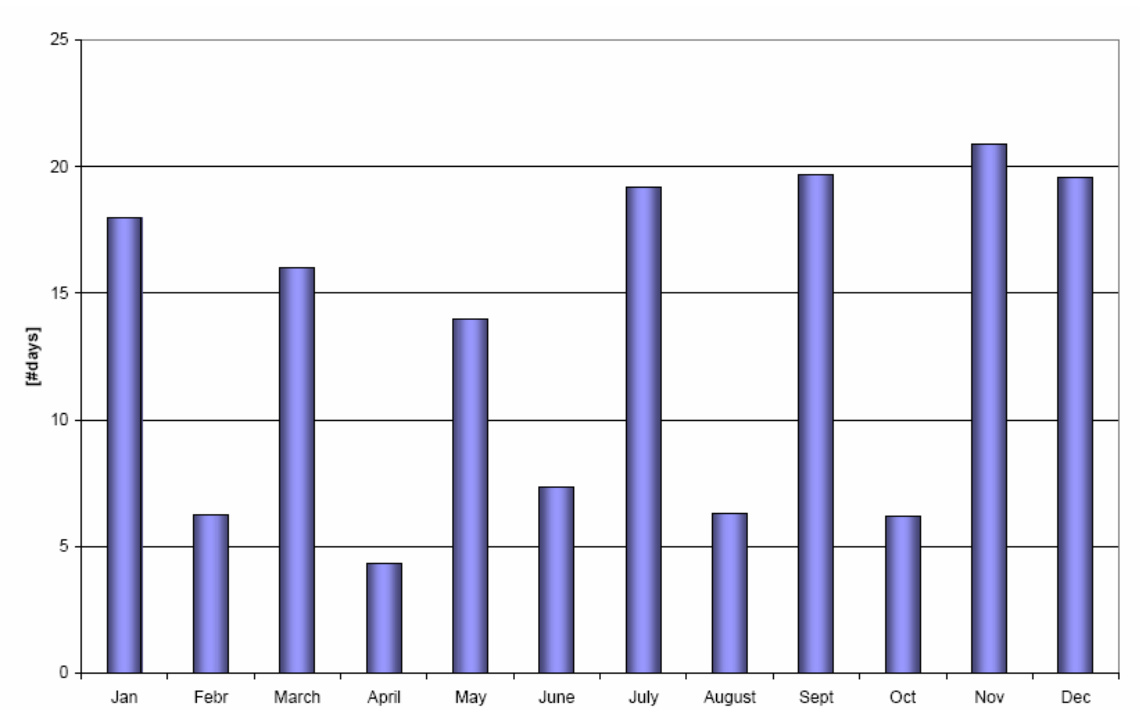


Figure: number of unworkable days for each month in 2007

During July, the remote control system on one of the turbines showed a so-called “swarf” alert, implying that there was a higher than expected metal content in the lubrication oil of the gearbox. After onsite inspection, it was decided to take the wind turbine out of operation as a precaution to prevent damage. During the following months, thirteen more wind turbines followed the same pattern. After thorough analysis by the manufacturer, the immediate cause appeared to be anomalous wear that was occurring in some parts of the gearbox. It was decided to exchange those gearboxes in which the “swarf” alert showed up.

The exchange program had a good start mid October, but was hampered by high winds in November and December. Because a jack-up crane vessel is required to carry out the operation, and engineers need to access the turbine to disconnect the old gearbox and reconnect the replaced one, the exchange is weather sensitive. Ultimo 2007, ten gearboxes had been exchanged and five of those were back on line. As a result the overall wind farm availability suffered a decrease in the same period. Monthly availability is shown in the graph below. The average availability for the year is 81.4%.

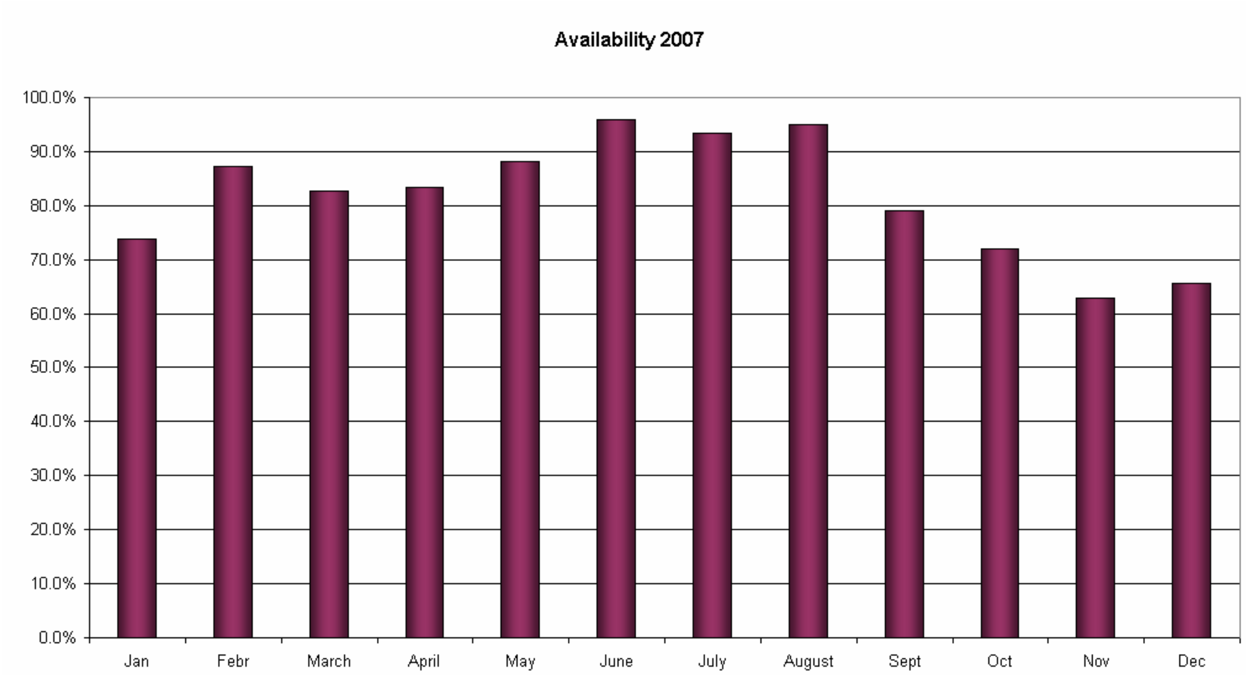



Figure: wind farm availability for each month in 2007

## 3.2 Production

Prior to construction of the project, the expected wind resource at the site was determined from a number of sources, including a correlation between long-term wind data of Meetpost Noordwijk, data from the offshore wind buoy[2] that operated at the site during 2002 and 2003 and measurements of the onsite meteomast of NoordzeeWind.

The actual wind resource in 2007 fluctuated significantly over the year, as already mentioned in paragraph 3.1. On average, the wind resource was slightly below expectation (1.3% below). The following table and shows the actual versus expected average wind speed, metered production delivered to the grid, and availability per month.

[2] E. Holtslag et al.: Offshore measurements: validation of buoy versus met mast. Poster for EWEC 2004 conference.

| Performance | Expected wind speed | Actual wind speed | Output | Availability |
|---|---|---|---|---|
| | (m/s) | (m/s) | (MWh) | (%) |
| Jan | 10.6 | 13.9 | 42,285 | 71.8 |
| Feb | 10.4 | 9.2 | 29,436 | 88.7 |
| Mar | 9.2 | 9.9 | 36,289 | 82.7 |
| Apr | 8.4 | 6.9 | 19,306 | 83.4 |
| May | 8.0 | 7.7 | 27,918 | 88.0 |
| Jun | 8.1 | 6.8 | 20,469 | 95.6 |
| Jul | 7.8 | 9.1 | 32,490 | 93.1 |
| Aug | 7.6 | 6.8 | 22,050 | 95.0 |
| Sep | 8.8 | 8.8 | 27,743 | 79.0 |
| Oct | 10.2 | 8.4 | 16,458 | 71.7 |
| Nov | 10.0 | 10.3 | 27,378 | 62.1 |
| Dec | 10.5 | 10.5 | 28,238 | 65.6 |
| Total | 9.1 | 9.0 | 330,060 | 81.4 |

Table: Performance during 2007.

The total metered electricity production over the year was 330.060 MWh. The actual and expected monthly production is shown below. Remarkably, in January 2007 record production was achieved even though availability was only about 74%. This underlines that this was the windiest month on record in the Netherlands from a wind power production perspective. Also, the very high production in July 2007 is noticeable and attests to the stormy summer weather. At the end of the year, production declined due to lower technical availability caused by the gearbox problems discussed above.

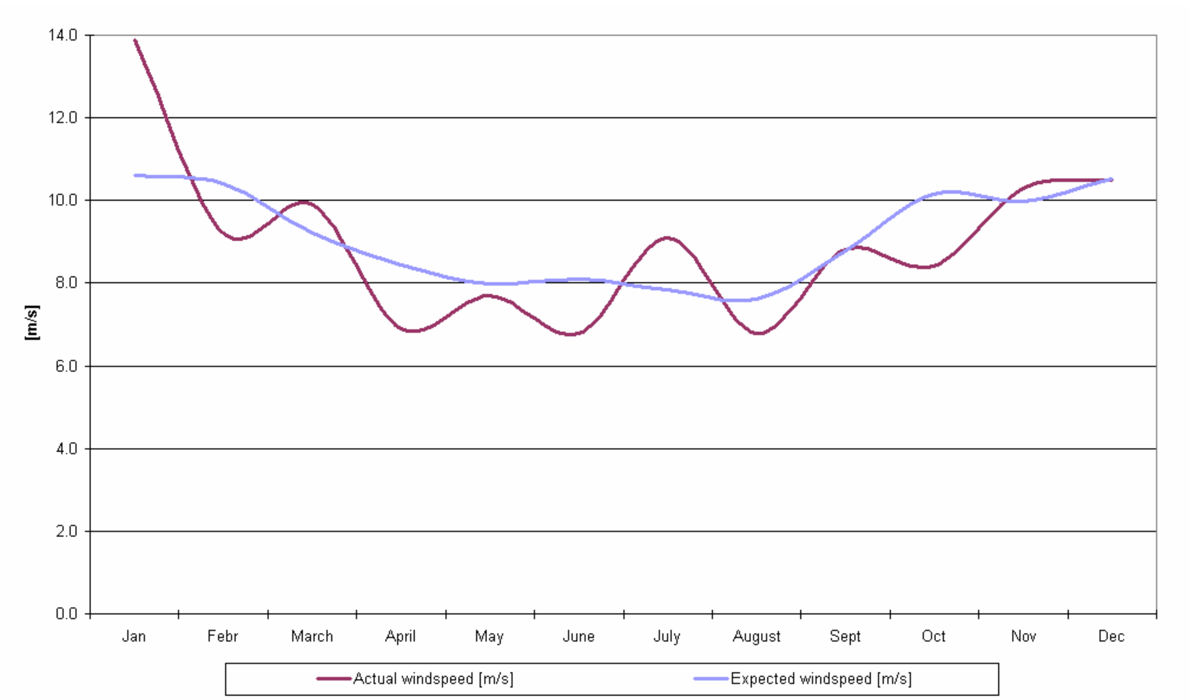



Figure: actual versus expected wind speed

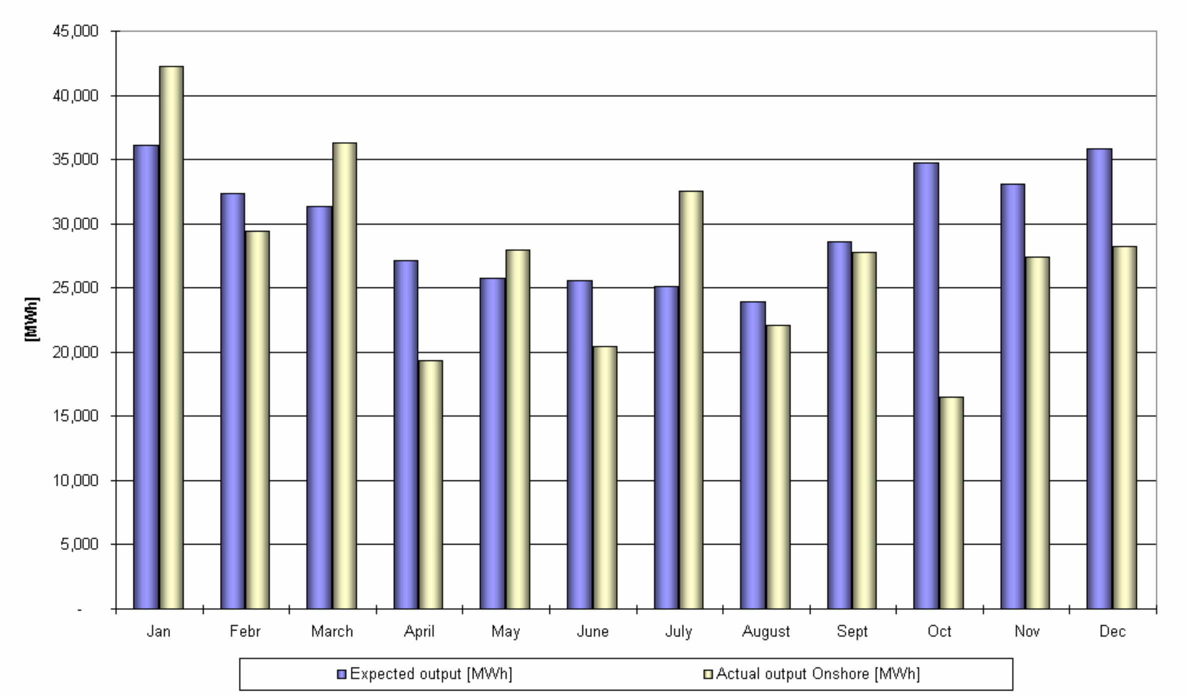



Figure: actual versus expected output

## 3.3 *Downtime per subsystem*

Windfarm performance is remotely monitored by a Supervisory Control And Data Analysis (SCADA) system, that allows access over a secure internet connection to a wide range of sensors installed in the turbines. These track a large number of operating parameters for the various subsystems in the turbines. To analyze the causes of reduced availability, the downtime of the windfarm has been split up into different categories for the main subsystems:

Ambient – All stops as a result of ambient conditions (e.g. wind speed, wind direction, temperature, lightning) being outside design limits.

Blade system – All stops as a result of failures in the blades and blade bearings.

Brake system – All stops as a result of failures in the main brake and auxiliaries.

Control system – All stops as a result of failures in the main controller and associated equipment (like sensors etc.), including remote communication system.

Converter – All stops as a result of failures in the generator power converter.

Electrical – All stops as a result of failures in the wind farm cabling, turbine transformers, substation etc.

Gearbox – All stops as a result of failures in the gearbox including its lubrication systems.

Generator – All stops as a result of failures in the generator including its cooling systems.

Pitch system – All stops as a result of failures in the blade pitch system including hydraulic controls.

Scheduled service – All stops as a result planned\scheduled service (including punch list work).

Yaw system – All stops as a result of failures in the yaw system (including yaw motors, yaw brakes and controls).

Structure – All stops as a result of failures in the support structure (foundations, transition pieces and towers).

Grid – All stops as a result of failures in the public grid.

The overview of the totals for 2007 can be found in the table below.

| Category | Lost MWh | % Lost MWh | # Stops | % Stops | Downtime (hrs) |
|---|---|---|---|---|---|
| **Ambient** | 181 | 0,2% | 148 | 1,7% | 249 |
| **Blade system** | 57 | 0,1% | 22 | 0,3% | 40 |
| **Brake system** | 120 | 0,2% | 7 | 0,1% | 65 |
| **Control system** | 10.098 | 13,5% | 3262 | 38,3% | 6673 |
| **Converter** | 9.694 | 13,0% | 255 | 3,0% | 3762 |
| **Electrical** | 2.906 | 3,9% | 531 | 6,2% | 3231 |
| **Gearbox** | 30.394 | 40,8% | 530 | 6,2% | 29413 |
| **Generator** | 5.688 | 7,6% | 131 | 1,5% | 3090 |
| **Pitch system** | 9.015 | 12,1% | 307 | 3,6% | 5224 |
| **Scheduled service** | 3.848 | 5,2% | 1506 | 17,6% | 4965 |
| **Yaw system** | 2.536 | 3,3% | 1798 | 21,0% | 1174 |
| **Structure** | 46 | 0,1% | 46 | 0,5% | 609 |
| **Grid** | 0 | 0,0% | 0 | 0,0% | 0 |
| **Total** | 74.583 | 100,0% | 8543 | 100,0% | 58495 |

Table: calculated losses and downtime per subsystem

“Lost MWh” is the electricity production that is missed due to the downtime. This is a calculated number that uses actual onsite windspeeds over the period of the downtime as input. Hence, downtime occurring during low wind periods would result in a low number of lost MWh.

“# Stops” is the sum total of the number of stops in the specific downtime category occurring over the year. This figure includes stops on failures, which were automatically reset (this is the majority), remotely reset or locally reset. In the latter case, a site visit was required.

“Downtime” is the amount of time that any windturbine was not working, and is measured in turbine-hours. With 36 turbines * 8760 hours = 315360 turbine-hours in 2007, the total downtime is therefore 58496/315360 = 18.5%.

For the 3 different parameters (# Stops, Lost MWh and Downtime) pie charts (refer to annex 1) show the percentage contribution of each value to the total.

It is clear that the gearbox failure frequency is low but the impact on downtime and losses is high. This is due to the repair procedure which requires a jack up vessel with a crane, working at height, and the gearbox exchange itself, and the work can only be performed at favorable weather conditions (limited wave height, limited wind speed).

The control system has the highest failure frequency. This system has a significant percentage in the electrical losses as well, as some failures (such as failing sensors) could not be reset automatically or remotely. This required local repair, which was subject to weather delays. All failure data are collected by Vestas and fed back to their technology center. Together with data from similar turbines operating worldwide, this allows Vestas to define quality improvements. These are subsequently implemented at the site in a programme of Continuous Improvement Management (CIM), and ultimately should lead to improved reliability and a reduction in the overall number of failures.

The total number of service crew vessel visits in the first year was circa 300. Each crew vessel trip contained a maximum of 6 to 12 persons for performing inspections, scheduled service, unscheduled service and punch list activities. These visits were carried out by service technicians visiting the windfarm by boat, and then transferring from the boat to the turbine. On average nine people are on board of a crew tender and on average 1.5 wind turbines are visited during each trip. This results in a total number of offshore transfers in the year of 8100.

Picture: Windcat at foundation pile

# 4 Remaining construction items

With the construction works substantially completed by the end of 2006, windfarm operations started in January 2007. The remaining construction items didn't affect the safe operation of the windfarm and had to be completed during the operations phase. This included additional rock dumping around the foundation of wind turbine #22, repair of paint damages, and the completion of the burial of the shore connection cables to their design depth. Also, concrete mattresses were laid during 2007 at each of the turbine foundations where the cables enter the seabed, to prevent any cable exposure at the seabed. The cable burial proved more challenging than expected, especially in the surf zone, because there is only limited equipment available that can work in very shallow waters; moreover, very calm weather conditions are required to complete the work. Similarly, weather circumstances prevented the rock dumping to be finalized during 2006. Most of the paint damage was caused during construction by vessels (boat landings) and by the equipment required to pull the cable through the J tubes (lower part of the towers and platforms). Although good progress was made during 2007, at the end of the year some work was still ongoing, in particular the burial of the shore connection cables. Close-out of all remaining items is expected during 2008.

# 5 Monitoring program

Part of the project is a Monitoring and Evaluation Program aiming to generate knowledge that will be beneficial to the development of offshore wind energy. The program outline is defined by the Dutch government and covers two areas:

- Environment including public opinion;
- Technology & economics.

The environmental research program comprises field surveys on birds, marine mammals, fish, benthos and a public opinion survey during the summer season. The program was started prior to construction in order to obtain good baseline data and will last for several years.

The public opinion program consists of opinion polls conducted along the shores from where the windfarm is visible. Since the first public opinion survey back in 2005 before start of construction, the public opinion shows a continuous upward trend.

Black backed gull in the wind farm (photo: M. Poot, Bureau Waardenburg)

Under the technology research program a lot of meteo data, sea state data and operational data were gathered and special measurements were carried out. All data are brought together in a relational database with a synchronous time stamp as common parameter for all signals.

Results of the program that are available in the public domain are reported separately, and can be found on the websites of NoordzeeWind and SenterNovem[3]. A summary of the work carried out in 2007 is provided below.

[3] This and other reports can be downloaded from http://www.noordzeewind.nl/ or from http://www.senternovem.nl/offshorewindenergy/.

## *5.1 Environmental research and public opinion*

The aim of the environmental research programme is to determine the impact of the wind farm on the (living) environment, such as birds, marine mammals, fish, benthos (life within and on the seabed) and also the perception of the windfarm by people visiting the beaches and living or working in the area. The environment at site may be influenced not only by the presence of turbines and the obstacle they present to e.g. birds, but also by operating turbines causing noise, as well as by human activities connected to the wind farm such as maintenance and repair. To get a comprehensive picture a wide range of field surveys are being carried out.
To support coordination of all onsite research activities, a map was developed with all research areas (Annex 3).

### 5.1.1 Local birds

A comparatively large area, of about 885 $km^2$, with the windfarm more or less at its centre was selected for the study of local birds. The windfarm itself covers circa 27 $km^2$. Within this area, ten survey lines were drawn that were to be surveyed during each subsequent seabirds survey (A-J from north to south, equidistant), refer to the black dotted lines in Annex 3. During the first full year of seabirds studies after commissioning of the wind farm, six surveys were executed using various survey vessels, see table below.

| **Survey** | **from** | **to** | **Survey vessel** |
|---|---|---|---|
| April 2007 | 9/04 | 12/04 | Vos Baltic |
| June 2007 | 27/06 | 29/06 | Vos Baltic |
| August 2007 | 19/08 | 22/08 | SC41 (Osterems) |
| September 2007 | 24/09 | 27/09 | SC41 (Osterems) |
| November 2007 | 5/11 | 6/11 | Vos Baltic |
| November 2007 | 20/11 | 24/11 | Vos Baltic |
| January 2008 | 14/01 | 18/01 | TX33 (Maarten Cornelis) |

Table: Local bird surveys

Most surveys were hampered by bad weather, particular high winds. The aim was to survey all ten transect lines within the study area twice, keeping watch on both sides of the ship (port and starboard). However, high winds prevented this on many days, and cut some surveys short. Still, during each survey, each transect line was covered at least once, although sometimes with coverage only at the lee-side of the ship.

### 5.1.2 Flying birds, large scale bird movements

To assess the flight paths of birds in the area of the wind farm, visual observations as well as fully automated radar observations and registration of birdcalls are being carried out from the meteo mast in the windfarm. Radar observations include a vertically and a horizontally operating radar, that collect data continuously through an automated detection system.

Bird radar systems on the met mast

Nocturnal bird calls were collected during a night in October, to gain insight in the species composition migrating through the area.
The study period in 2007 ran from February 2007 until the end of December 2007. In this period, visual data were collected on a total of 19 observation days. An overview is given in the table below.

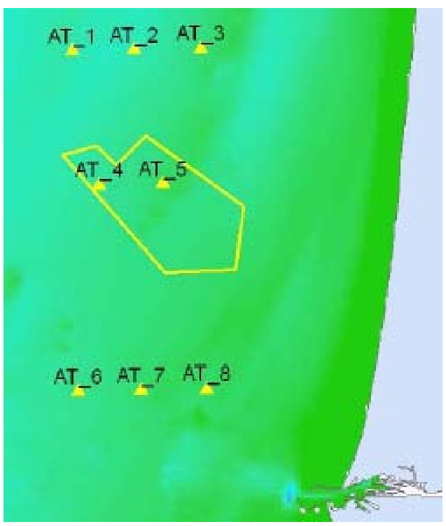
| **date** | **remarks** | **weather conditions** | | | | | |
|---|---|---|---|---|---|---|---|
| | | **wind dir** | **force Bft** | **waves cm** | **visibility km** | **$T_a$** | **clouds/rain** |
| *Winter* | | | | | | | |
| Feb | 21 start-up/installation | SSW | 3-4 | 50-90 | 3 | 10 | cloudy, rain |
| *Spring* | | | | | | | |
| Mar 15 | start-up/installation | SW | 4 | 60 | 5 | 10 | clear, dry |
| Mar 26 | start-up/installation | E | 4 | | 5 | 10 | clear, dry |
| Apr 5 | | W | 3 | | >10 | 12 | partly cloudy, dry |
| Apr 12 | | N | 3 | 80 | >10 | 15 | clear, dry |
| May 25 | | S | 1 | 30 | >10 | 20 | partly cloudy, dry |
| *Summer* | | | | | | | |
| Jun 5 | maintenance | NE | 5 | 90 | | | dry |
| Jun 21 | 1/2 day; thunderstorm | VAR | 3 | 50 | >25 | 18 | partly cloudy, dry |
| Aug 2 | | NW | 4 | 60 | >10 | 18 | partly cloudy, dry |
| Aug 20 | | SSE-NNE | 1-4 | | >15 | 18 | cloudy, few showers |
| *Autumn* | | | | | | | |
| Sep 6 | | NW | 4 | 90 | >10 | 16 | cloudy, dry |
| Sep 13 | | NE-SE | 3-1 | 70 | >10 | 17 | cloudy, dry |
| Oct 2 | night | E | 3-2 | | - | | cloudy, dry |
| Oct 3 | | E | 4-2 | 60 | 2 | 12 | cloudy, showers |
| Oct 10 | | NE | 2-4 | | 4 | 15 | fog / clear |
| Oct 25 | | NE | 4 | | 5 | 10 | cloudy, dry |
| Nov 2 | | NW | 3-2 | | 4-1,5 | 13 | fog, afternoon rain |

| | | | | | |
|---|---|---|---|---|---|
| *Winter* | | | | | |
| Dec 13 | | NE | 2 | >10 | clear |
| Dec 19 | observations &maintenance | NE | 4 | 0,5 | fog |

Table : weather conditions during visual observations on meteo mast

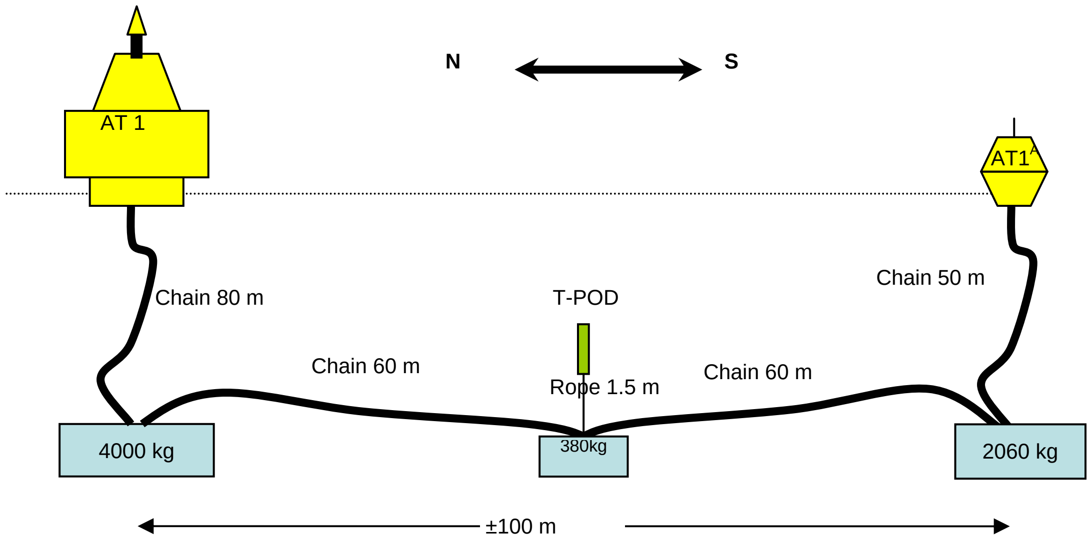
### 5.1.3 Harbour porpoises

In order to observe and quantify the occurrence of porpoises, it is most suitable to use permanent acoustic recording stations such as anchored T-PODs (see below), as well as visual observations which could yield density estimates. T-PODs enable the researchers to record every porpoise encounter within a radius of some hundred meters and, as the stations were operating throughout the year, diurnal variation, seasonality and other variations in occurrence were analysed. Two TPODs were deployed in the windfarm area and six in reference areas to the South and North, see map.




Nine locations of T-POD stations; AT_4 and AT_5 are in the windfarm area.

The mooring used for the T-PODs was designed using robust material. Where in other areas T-PODs are usually attached to small anchor blocks and small buoys, this study uses very heavy equipment for anchoring the T-PODs due to the risk of collision with trawlers in the area. Approximately 15 tonnes of buoys, chain and concrete were used for securely anchoring a single T-POD. The acoustic sensor itself, together with batteries, control electronics and data logger, is contained in a small buoyant submersed unit. The T-POD needs to be serviced at regular intervals for exchange of batteries and offloading of data.




Schematic setup of the T-POD mooring. The large buoy is lit at night.

Each T-POD is deployed between two large buoys, the larger being equipped with a yellow navigation warning light. Due to a number of losses, probably because of some heavy storms, the actual attachments of the T-PODs were changed during the December survey. The attachment is made of a Kevlar cable surrounded with rubber tubing. To add buoyancy a small buoy is attached to the upper part of the T-POD.

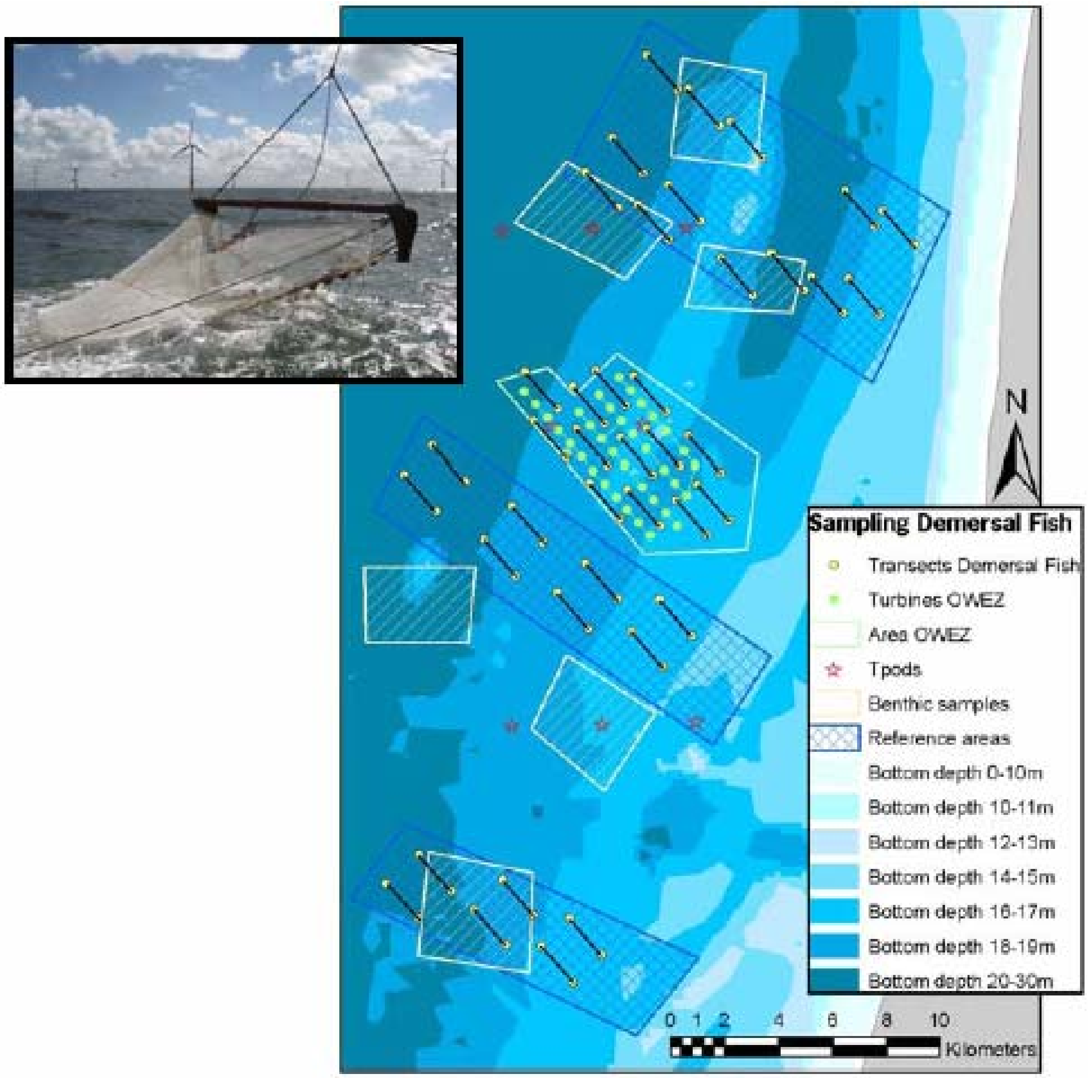

The new T-POD attachment. Kevlar cable with rubber tubing (1) and buoy (2) for additional buoyancy.

The TPODs were recovered and deployed again four times during 2007. Three units had disappeared, and had to be replaced.

### 5.1.4 Fish

*Demersal fish*

The monitoring program is designed to quantify the possible effects of the windfarm on the occurrence, density, population structure and migration patterns of the demersal fish community, i.e. those fish that dwell near the seabed. The sampling scheme has been designed to sample the variation in depth, grain size and distance offshore within the windfarm representatively and to replicate this scheme in the three reference areas. The sampling was executed in July and comprised 40 transects divided amongst three reference areas and the windfarm area. One third of the samples was be taken in the windfarm area, one third to the North and one third to the South, refer to the figure below.




Demersal fish sampling areas

*Pelagic fish*

The monitoring program is designed to quantify the possible effects of the windfarm on the occurrence, density, population structure and migration patterns of the pelagic fish community, i.e. those fish dwelling in the water column. The sampling scheme has been designed to sample the variation in fish density in wind farm and to replicate this scheme in the two reference areas. Long North/South transects were surveyed to sample seasonal variability in the overall coastal area. The sampling scheme comprises a high resolution coverage of the windfarm area and its two reference areas as well in a low resolution coastal coverage. Acoustic techniques were used to sample fish abundance whereas trawl sampling was used to get species specific information such as age structure of the population, refer to the figure on the next page. Sampling was carried out in April 2007.

Pelagic fish acoustic sampling transects (trawl stations are indicated as blue dots).

### 5.1.5 Benthos

Fieldwork was carried out in March and October 2007 on board of the research vessels Pelagia and Poseidon. The field programme consisted of collecting benthic fauna samples within the area of the windfarm as well as in control areas. Three of these areas were chosen North of the windfarm and the other three to the South. The benthic macrofauna was sampled with a boxcorer and a Triple-D benthic dredge. The dredge was adjusted to a sampling distance of 80 m, so each sample represented the fauna present under a 16 $m^2$ surface area. The boxcorer is used to sample the small (generally 1 to 10 mm) more or less abundant fauna species. The dredge is used to sample the less abundant and larger species, which cannot be sampled quantitatively by the boxcorer. Boxcores were collected at 30 stations (refer to purple C marked dots in Annex 3) within the area of the turbines, one boxcore per station. The stations were arranged along transects running parallel to the windmill rows. In each of the control areas 15 boxcore samples were taken on three parallel transects. On board the boxcores were washed through a 1 mm mesh sieve and the residue was preserved in a 6% neutralized formaldehyde solution for later analysis in the laboratory. Dredge hauls were made along 14 transects in the area of the windmills, and along two transects in each of the control areas. Submerged landers were used to deploy instruments and in situ experimental settings (mesocosms) for a period of 8 months at the seabed to collect high resolution environmental data and samples of benthic larvae settled at different types of sediment.

A benthos lander being deployed

### 5.1.6 Public opinion

Even though the nearest wind turbine is more than 10 km offshore, the wind farm is frequently visible from the beach and continues to raise interest. A public opinion poll was held in the summer to assess appreciation of the windfarm[4]. This was the third survey, following the baseline 0-measurement in 2005 and the 1-measurement in 2006, in a series of four surveys that track stakeholders' appreciation. The final survey will be held in the summer of 2008. The interviews were conducted by an independent agency by means of the Internet with a number of residents of coastal towns, local businesses, Dutch holidaymakers, and German holidaymakers – being the largest group of foreign visitors. The purpose of the surveys is to record the development of the perception of the windfarm in the context of experience with and perception of the sea, the beach, and wind energy. The general finding is that approximately three in ten respondents consider the view of the windfarm disruptive. Across all groups, the appreciation has changed in a positive sense over the period 2005 to 2007.

[4] OWEZ_R_24_T2_20071101 public opinion.pdf

Key findings were:

- Approximately three-fifths of the residents, the business people and the Dutch holidaymakers think that a visible sea-based windfarm would have a negative impact on their perception of the sea and the beach, this group is however more positive about this than a year ago.
- All in all, approximately seven in ten respondents found the view of the windfarm not to only slightly disruptive.
- In 2006, it showed that the respondents had become slightly more positive about every aspect of the windfarm in the period 2005-2006. Now that the construction of the windfarm has been completed, this positive development seems to have continued at an accelerated rate. In particular, the difference among the German holidaymakers is remarkable: from being the most negative of all the study groups in 2005, they now have the most positive attitude towards the windfarm.
- Across all groups, appreciation has changed in a positive sense over the period 2005 to 2007.
- The majority of all visitors said that the Information Center (see below) had lived up to their expectations.

### 5.1.7 Information center

To facilitate information demand of visitors to Egmond aan Zee and other interested parties, a dedicated information center was established in close collaboration with the local tourist office, VVV. This “Infocentrum NoordzeeWind” offers an exhibition on the windfarm and the monitoring program, and is operated by the tourist office. In the first year 2007, some 60,000 visitors were welcomed specifically to the windfarm exhibition. The combination with the tourist office has proven very effective in reaching a larger group of stakeholders than would have been possible with a stand-alone visitor center. A typical comment from the guest book captures the debate very well: “I find them ugly things but because they don’t emit $CO_2$ more people should use clean power from windmills (2 Aug 2007)”.

Interior of the Infocenter NoordzeeWind in Egmond aan Zee

## *5.2 Technology research*

The aim of the technology research program is to support cost reduction for future off shore wind energy projects. For this purpose, many different data signals are collected from the windfarm and stored in a relational database with 10 minute time stamp as time base for all data. In addition, data are stored from two turbines (#7 and #8) equipped with strain gauges for dynamic measurements, and the data from the meteo mast. The formal start of the data collection program was 1 April 2007, though some data are available for the preceding period as well. The datasets are complemented by reports based on the measurements, and relevant design documents. In many cases the data are accessible to third parties, please refer to section 5.2.3.

### 5.2.1 Database

The database contains: meteorological data (from the meteo mast, and wind speed of all 36 wind turbines), oceanographic data measured at the meteo mast, wind turbine production figures, failure ("event") data, operational status of all 36 wind turbines, detailed scada data of wind turbines #7 and #8, measured load measurements at wind turbine #7 and #8, power quality data and cable temperatures measured in the shore connection cables. The following table summarizes the content of the database.

| Parameter | Number of signals | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Winddata metmast | 50 | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| Metocean data | 8 | | | | | | | | | | **X** | **X** | **X** |
| PV data wind turbines | 72 | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| Event data | 252 | | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| Operation status all WT's | 684 | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| Detailed Scada data WT7&8 | 12 | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| Loads WT7&8 | 108 | | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| Power quality | 6 | | | | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| SCC Cable temperature | 3 | | | | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |

Table: overview of contents of database, note **X** indicates that data is present in the database, in general data availability for the month is between 80 and 100%.

The wind and metocean data are available in zipped Excel XLS files for downloading per month, on either http://www.noordzeewind.nl/ or http://www.senternovem.nl/offshorewindenergy/. Other data are available on request, please refer to section 5.2.3.

### 5.2.2 Reports and documents

Reports were published on the long term wind resource, the licensing process, the construction of the windfarm, power forecasting, as well as a user manual for the meteo data files. Please refer to the table below.

| Title report | Topic | Report reference |
| --- | --- | --- |
| Pre-survey of marine fouling on turbine support structures of the Offshore Windfarm Egmond aan Zee | Biofouling | OWEZ_R_112_20060725.pdf |
| Meteorological Measurements OWEZ<br>Half year report 01-07-2005 - 31-12-2005 | Wind resource | OWEZ_R_121_20050701-20051231_wind_resource_2005_2.pdf |
| Meteorological Measurements OWEZ<br>Half year report 01-01-2006 - 30-06-2006 | Wind resource | OWEZ_R_121_20060101-20060630_wind_resource_2006_1.pdf |
| Meteorological Measurements OWEZ<br>Half year report 01-07-2006 - 31-12-2006 | Wind resource | OWEZ_R_121_20060701-20061231_wind_resource_2006_2.pdf |
| Meteorological Measurements OWEZ<br>Half year report 01-01-2007 - 30-06-2007 | Wind resource | OWEZ_R_121_20070101-20070630_wind_resource_2007_1.pdf |
| Off Shore Wind farm Egmond aan Zee General Report. | Construction of OWEZ | OWEZ_R_141_20080215 General Report. pdf |
| Short-term output prediction OWEZ<br>Wind forecasting<br>Reporting period 2004-06-01 - 2006-05-31 | Power forecasting | OWEZ_R_172_20040601-20060531.pdf |
| Surrounding obstacles influencing the OWEZ meteo mast measurements | Wind measurements | OWEZ_R_181_T0_20070821 undisturbed wind.pdf |
| User manual data files meteorological mast NoordzeeWind | Wind measurements | NZW-16-S-4-R03 Manual data files meteo mast NoordzeeWind.pdf |
| Rapportage<br>Proces vergunningverlening<br>Offshore Windpark Egmond aan Zee (in Dutch only) | Licensing process OWEZ | OWEZ_R_192_20070820 vergunningen |
| Maritime and marine<br>risk assessment of calamitous (oil) spills | Safety risks for shipping | OWEZ_R_280_20060720.pdf |

Table: reports and documents, published in 2007

These reports can be downloaded from http://www.noordzeewind.nl/ or from http://www.senternovem.nl/offshorewindenergy/ .

The database contains relevant design, inspection, and operational reports as well. Subjects include foundation design, corrosion protection, scour protection, and electrical infrastructure. In the course of 2008 a more detailed overview will be published on the web sites mentioned above.

### 5.2.3 Accessing data and reports

NoordzeeWind is committed to making as much information as possible available into the public domain, subject to restrictions of prevailing commercial interests of any of the project partners. Several of the data and reports resulting from the technology program are (temporarily) confidential. Data that are freely available can be downloaded from the website; confidential data may be available upon signing of a non-disclosure agreement.

# 6 Operations management

Operations management is built on a foundation of management of health, safety, security and the environment – abbreviated HSSE. All activities related to the performance of the wind farm asset, the electrical infrastructure and substation, as well as all surveying and monitoring activities are carried out in a structured fashion. HSSE is a core line management responsibility, built on a policy that is shared between all parties working on the project. The key aspects of this policy are:

- No harm to people;
- Protect the environment;
- Use materials and energy efficiently;
- Play a leading role in promoting best practices in our industry;
- Manage HSSE matters as any other critical business activity;
- Promote a culture in which all persons working on the project share this commitment.

## *6.1 HSSE aspects of operational strategy*

Day-to-day operations are carried out by the main contractor BCE in accordance with criteria defined in the Operations and Maintenance agreement with the owner, NZW. All work is covered under a HSSE management system. This management system stipulates a pro-active way of working which includes the following.

**Method statements**
Method statements and risk assessments are developed for all on- and offshore activities. Frequently this is done by collaboration between (sub)contractors and the owner using “hazard identification” workshops. This provides an efficient forum for exchange of expertise, and fosters alignment between owner and contractor aspirations.

**Safety reporting**
All incidents, near-misses, unsafe situation and unsafe acts are reported, are regularly reviewed at project board level, and remedial actions defined and taken.

**Offshore competence**
Minimum offshore competence requirements have been defined for all project staff (i.e. owner, contractors, and subcontractors). Depending on the type of activities, these can be 3 day or 1 day offshore survival training, tower climbing training, and rescue from heights training.

**Offshore site control**
Access to the offshore site is strictly limited, as the entire area including a safety zone of 500 m around the the windfarm perimeter is an exclusion zone to all vessels except those that are required for the operation of the windfarm. A Work Vessel Control procedure has been established to control and coordinate all vessel movements at the offshore site, and issue work permits. This has been done in close liaison with the authorities.

**Work permits**
Work permits are required for all non-routine activities and for all vessel activities. These are issued by the main contractor, BCE. See below for more details.

**Regular meetings and toolbox talks**
HSSE is discussed in all regular meetings including the toolbox talks held before the start of activities. Findings are systematically tracked and closed out.

**Weather limits**
Carefully maintained limits have been set to weather conditions for working offshore. Working at site is only allowed below a sea state of 1.5 meters of significant wave height, clear visibility and no lightning. Specific tasks (e.g. lifting at height) can also be limited by wind speed. Working at night is not encouraged but allowed in principle, provided sufficient precautions are taken.

**Offshore transfer**
Transferring from an access boat to the fixed structure of a wind turbine is one of the more hazardous activities in the project, due to the movement of the boat compared to the structure. Strict procedures apply as outlined in the section below.

**Stopping work**
All people working on site have the power and obligation to stop any unsafe activity. Work can only be resumed when the unsafe situation is resolved adequately. If such a safety stop occurs it is immediately reported to senior project management.

**Emergency response**
An emergency response plan is in place, which has been developed together with the authorities and emergency services. The plan forms part of the operating permit.

## *6.2 Work permits*

A key step in managing safety is that for all non-routine and high-risk activities a work permit is required, called Permit To Work (PTW). In general, a PTW is needed for entry of the restricted area of the wind farm by work vessels, any work involving high voltage, hot work (welding etc), and any non-routine activities. In line with common practice a PTW has a validity of one activity. Each PTW is issued as the final step of a process:

1: a method statement\risk assessment to be made by the contractor;
2: approval by BCE of the method statement\risk assessment;
3: audit by BCE of the vessels used (if applicable);
4: site induction of the captain of the vessel(s) (if applicable);
5: evidence of adequate training of staff involved in the job;
6: coordination of jobs by BCE;
7: a request of the job leader to the BCE operations manager for a PTW;
8: Issue of the PTW by BCE after successfully concluded steps 1-7.

A method statement is required for each activity at site requiring vessels or non-routine activities. The statement at least states:

- The activity to be carried out (the more complex, the more detail will be required);
- The vessel(s) to be used;
- Required staff;
- A risk assessment including mitigating measures.

Vessels have to meet minimum requirements and are audited prior to being approved to work on the project. The vessel audit comprised general safety on board, presence of formal paperwork, compliance with legally obliged environmental and safety requirements, and a general introduction to the NoordzeeWind project.

## *6.3 Working at site, go/no go decisions*

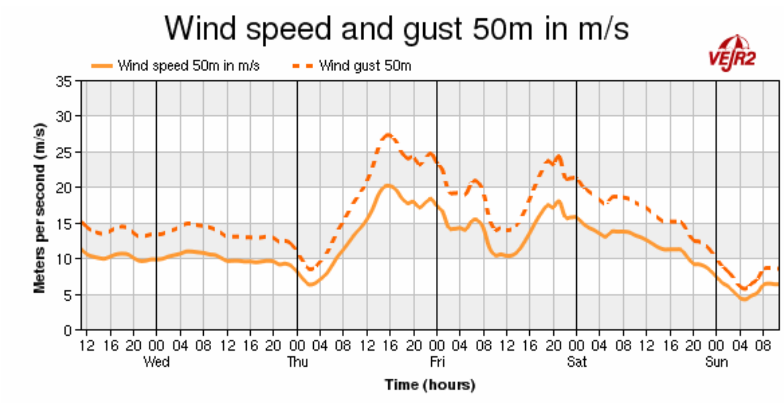
Access of the wind turbines is by vessel, operating out of the port of IJmuiden. Different crew transfer vessels have been used during the first operating year, like Windcat

Photo: Windcat crew tender

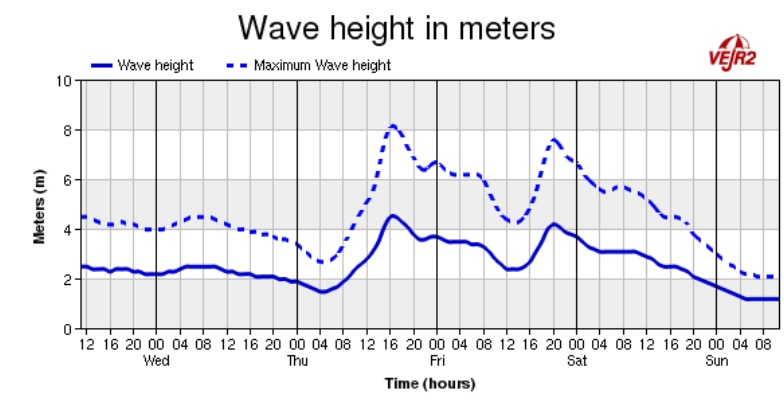
and similar vessels, refer for other examples to Annex 4. Typical dimensions are an overall length of about 15 - 25 meters, width 6 meters, transporting capacity of 10 - 15 people and a speed up to 30 knots. For all these vessels the limitations of the suitable weather window are about the same, which in practice means 1.3 - 1.5 meter significant wave height. The vessels can operate in higher seas, but transfer of people from the vessel to the wind turbines and vice versa is considered to be unsafe under these conditions. Swell and currents may also have an impact on accessibility, as strong currents may occur which make docking at the turbines difficult. Strict procedures are in place for transfer from the vessel to the turbines, and back. These procedures include requirements on weather conditions, training of personnel, protective equipment, and safety devices such as mandatory use of immersion suits whenever the sea water temperature is 12 deg Celsius or lower, and the use of crew finder beacons.

In case the forecasts and on line data (refer to next page) show marginal conditions, and there is doubt on the actual situation on site, the decision is usually taken to sail out and assess the local situation. In those cases the initial decision is with the captain of the crew vessel to allow or refuse the transfer, as is common practice in the offshore industry. In case the captain decides that access can be safely allowed, still any individual engineer has the full right to refuse transfer if he/she feels uncomfortable.

Different sources for weather forecasts have been used to obtain wind and wave predictions, typically for 1-5 days ahead. Initially the information from Ditvejr was used (http://www.ditvejr.dk/), but later on a shift was made to the information from Metoffice (http://www.metoffice.gov.uk/). Examples of prediction graphs by Ditvejr are shown below.

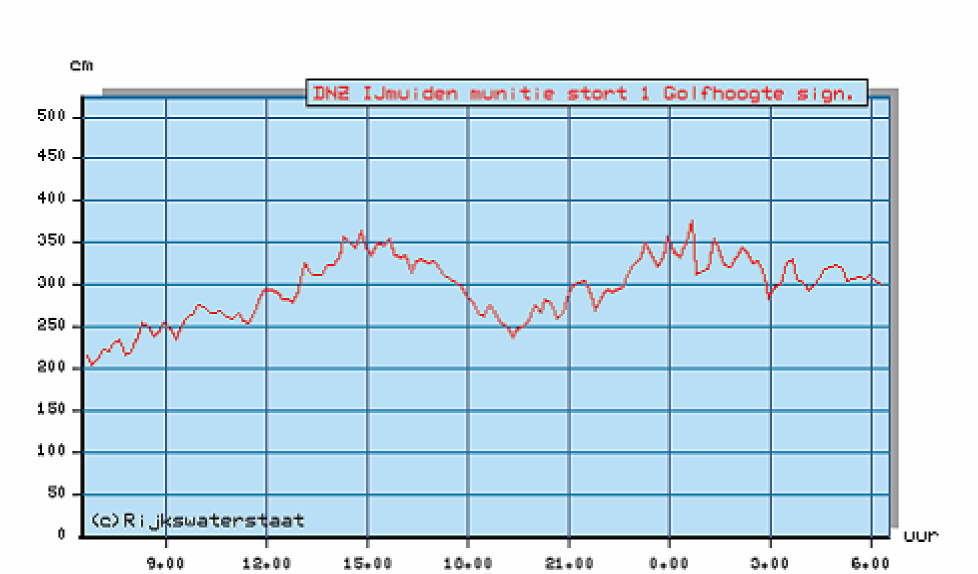



Graph: example of wind prediction by Ditvejr

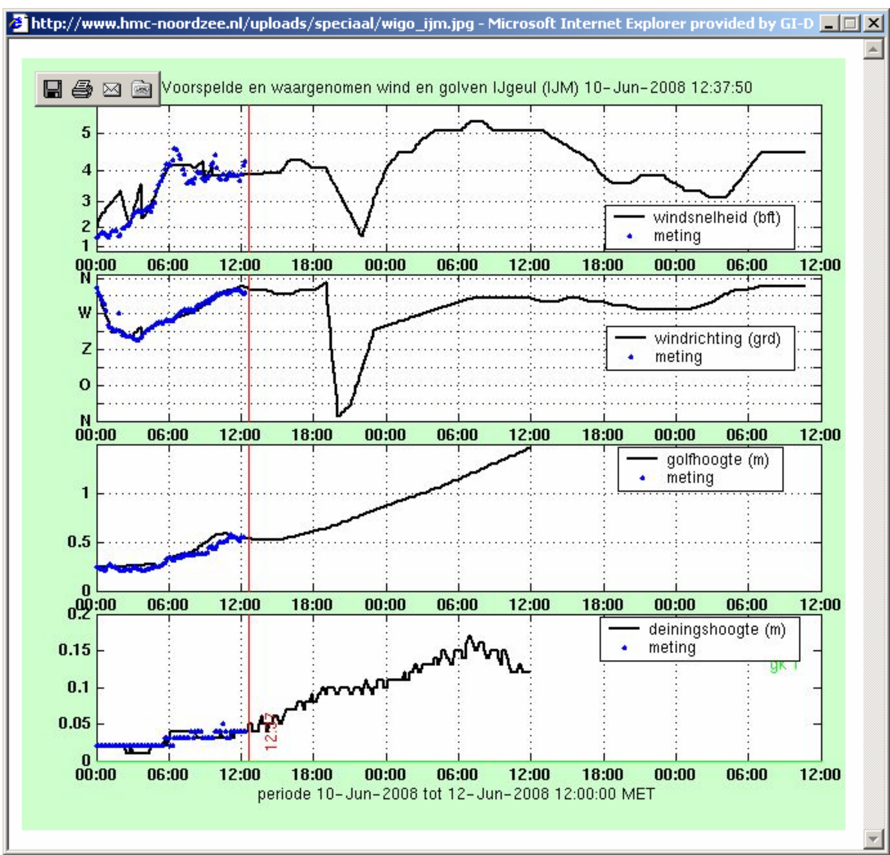



Graph: example of wave prediction by Ditvejr

The actual sea state is also monitored via http://www.actuelewaterdata.nl/golfgegevens/ and http://www.hmc-noordzee.nl/ , public web sites of Rijkswaterstaat that provide the last 24h of data and show measurements from various metocean stations in the vicinity of the project site. See typical graphs at the next page. This combination of weather forecasts turned out to be sufficiently accurate, and was used for operations planning purposes.



Graph: example of actual water data as published by Rijkswaterstaat




Graph: example of actual and predicted wind and water data as published by Rijkswaterstaat

### *6.4 Man hour recording and incident reporting*

The total number of man hours spent at the project site was over 60,000 for the year. Helped by the joint efforts from all staff working on the project, including contractors, subcontractors, and owner representatives, there were no injuries or incidents to report.

# 7 Conclusion and outlook

The offshore windfarm at Egmond aan Zee successfully completed its first year of operation. All turbines have become operational, and with just over 330 GWh together delivered enough electricity for approximately 100,000 homes to the Dutch grid. Challenges arose due to technical problems with the gearboxes, which are similar to those reported on comparable wind farms elsewhere. A maintenance campaign has been started to contain the problem, and this has been successful in keeping the problem under control although availability suffered as a result. Aside from this, performance of the plant has been quite good, and the outlook for 2008 is positive.

# Annex 1: Pie charts operations 2007

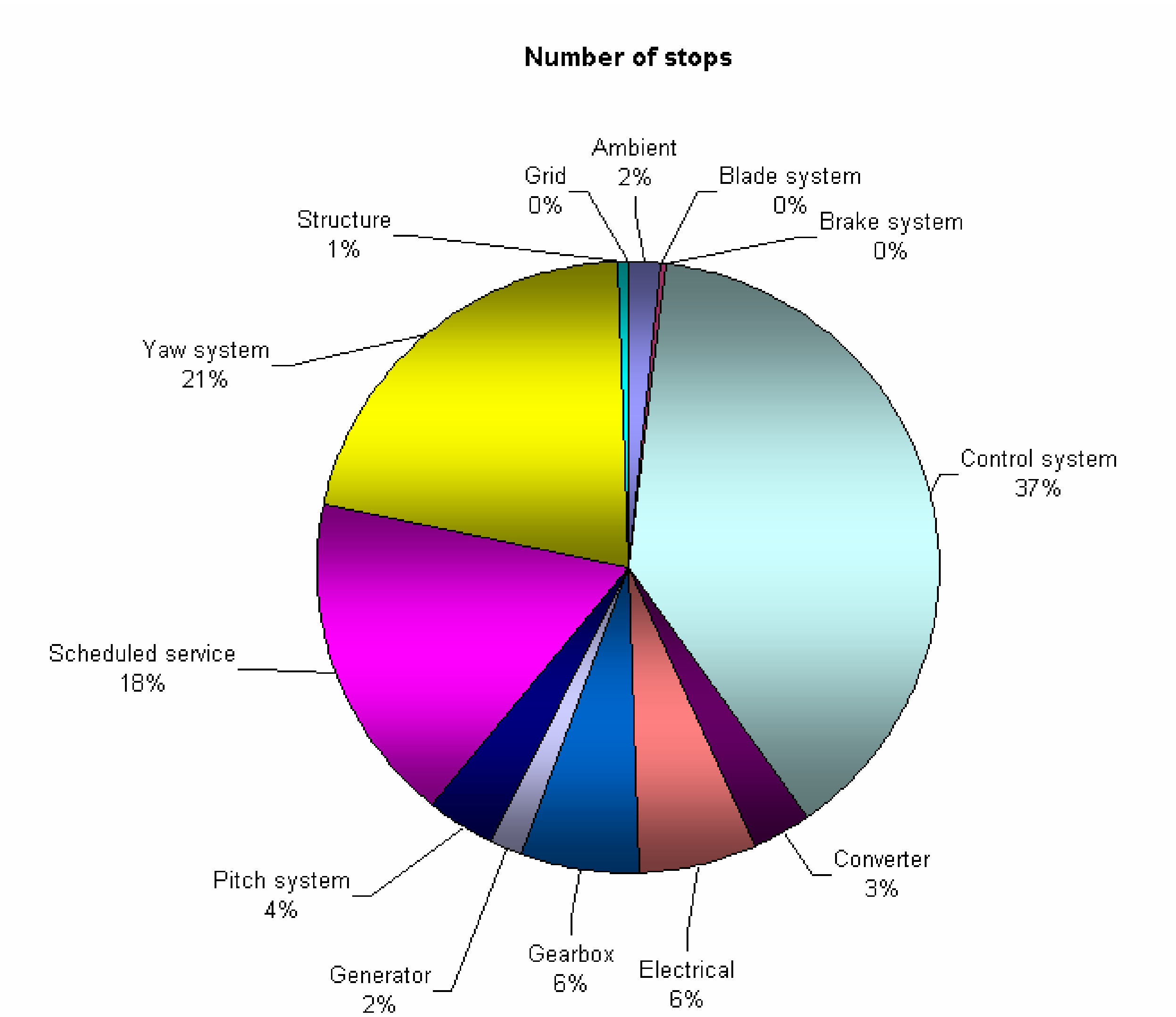



Figure: distribution of stops per subsystem

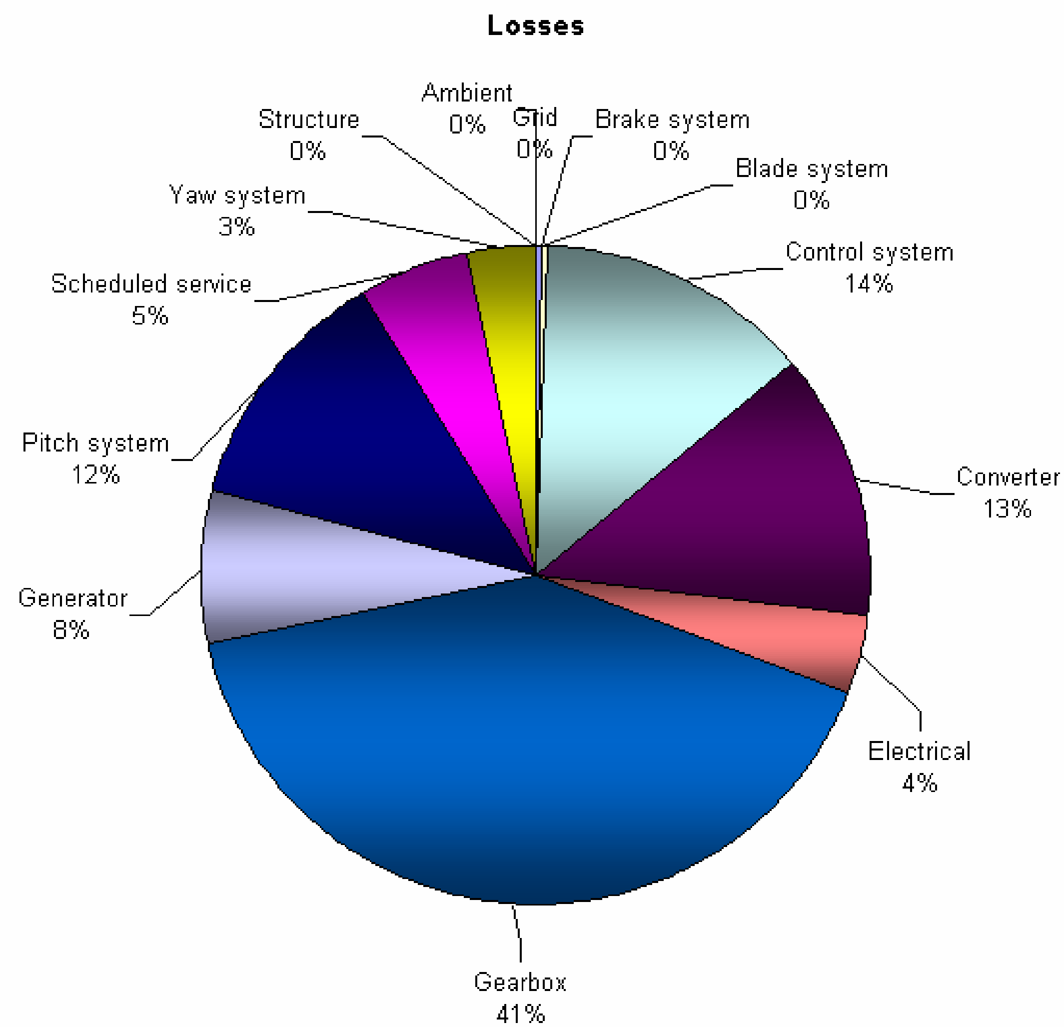



Figure: losses as function of failures of subsystems

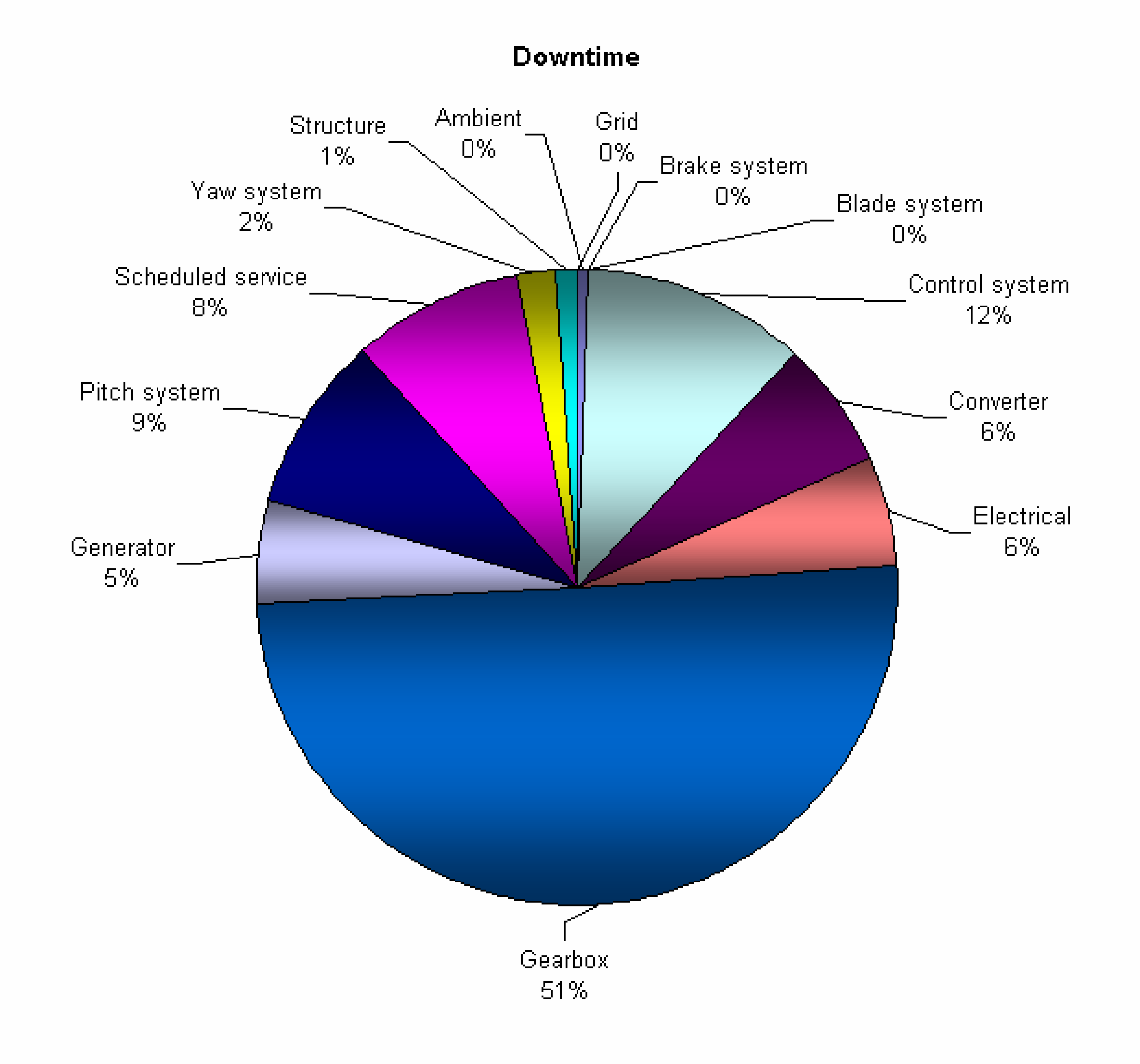
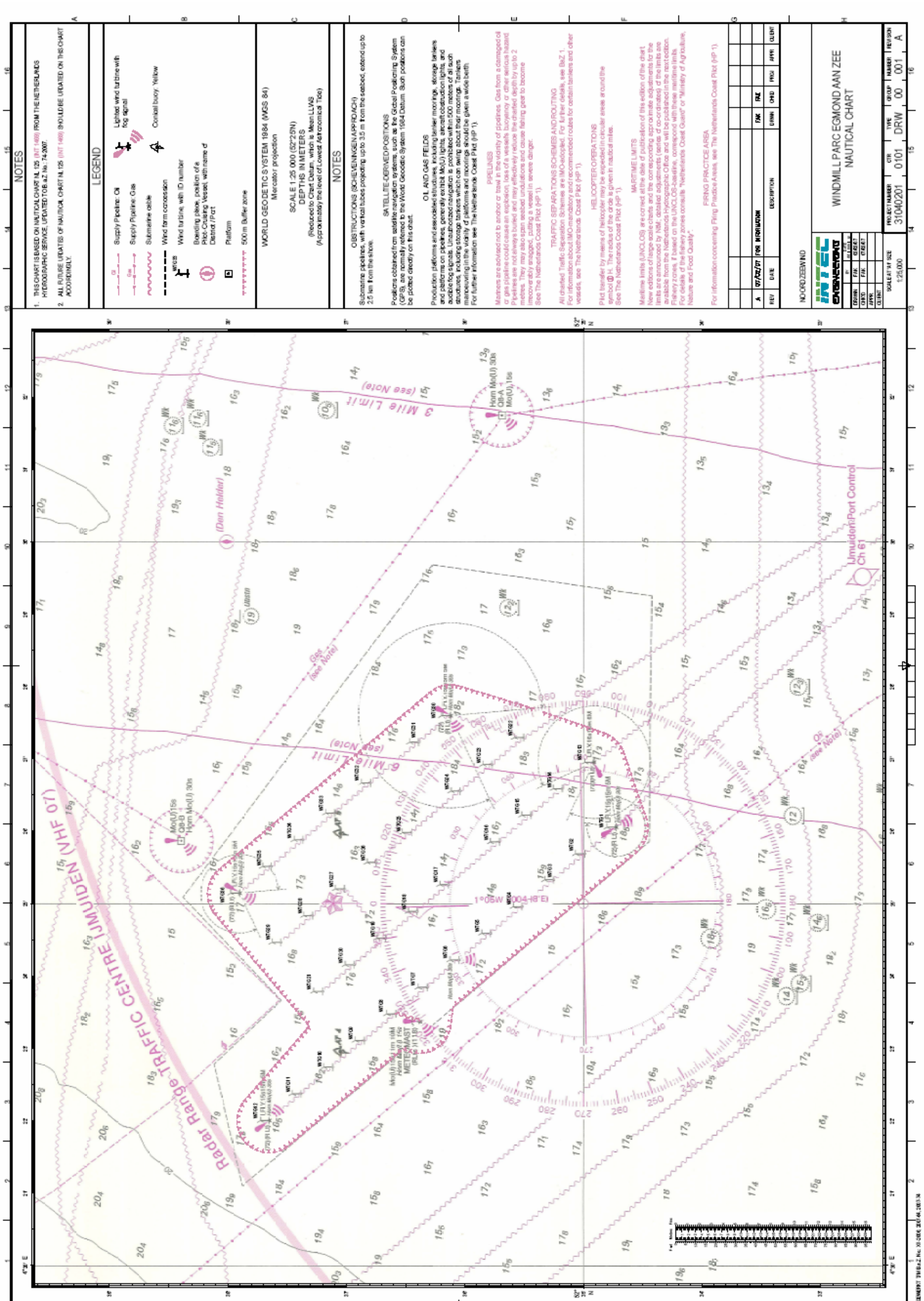
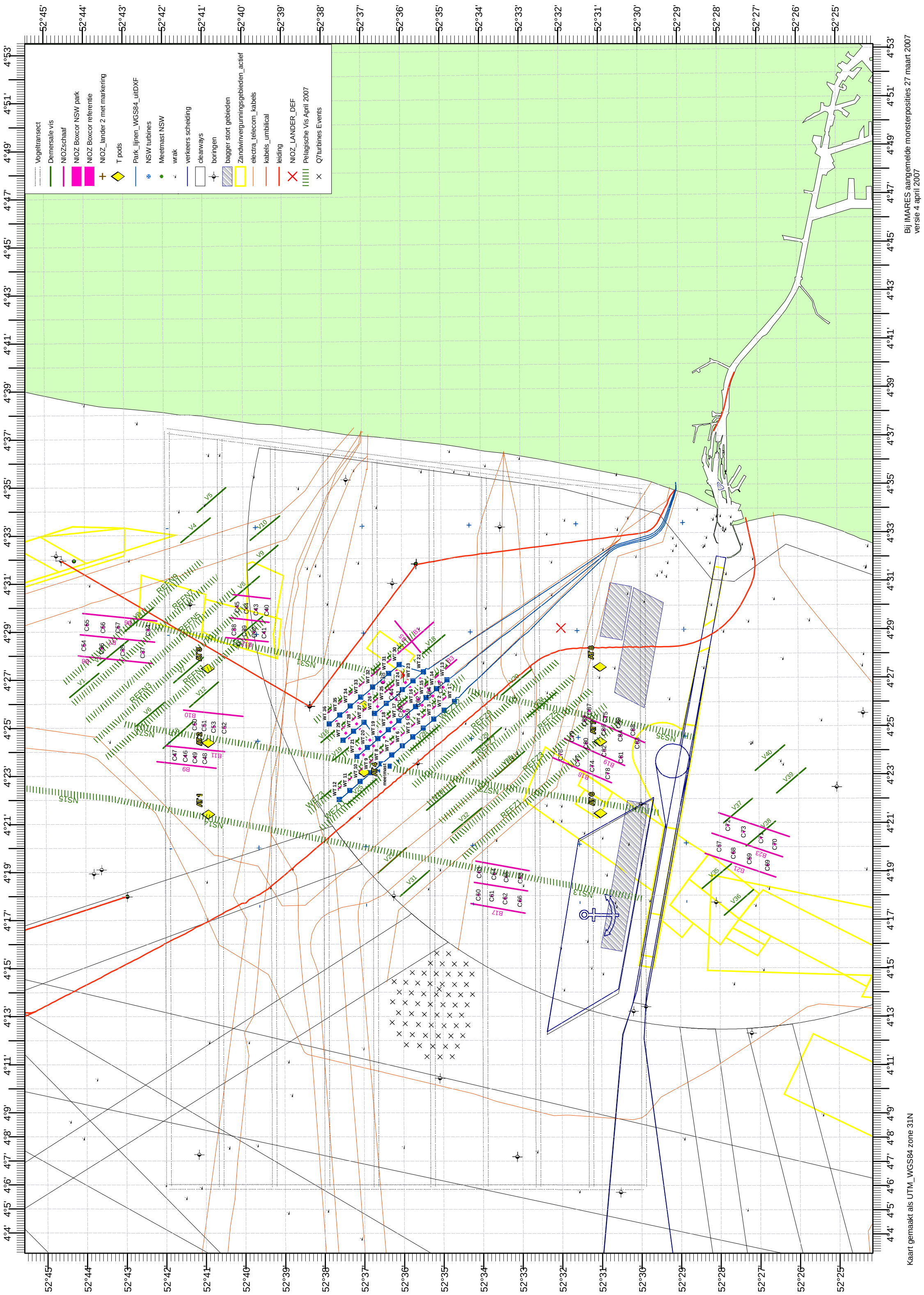



Figure: downtime as function of failures of subsystems

# Annex 2 Nautical map



# Annex 3: Research area map



# Annex 4: Examples of used crew tenders

Picture: FOB Lady in the port of IJmuiden (source: Internet)


Picture: Purpose-built trimaran wind turbine service vessel FOB Trim (source: Internet)