

WIND ENERGY

Wind farm

KØBENHAVN

(Denmark)

Wind energy is not the energy source that immediately comes to mind when thinking about renewable energy in cities. Few cities have enough space within their area to build large wind farms. You may rather find small wind turbines on suitable locations within the city's area or see cities doing feasibility studies on this subject. The city of København has recently taken part in a large offshore wind farm project, two kilometres from the city's coastline. The project is based on a partnership between the municipality and local shareholders.

THE CITY

The capital of Denmark, København, (469,000 inhabitants in the municipality, 1.3 million with the outer suburbs) is situated on the very east of Sjælland, being by far the biggest city of Denmark. It lies on the west bank of Øresund, a major access route to the Baltic Sea and the Baltic countries. The history of København goes back to just after the Viking period (1167 AC), where the Archbishop Absalon made it the capital of the Kingdom of Denmark.

Climatic Data:

Mean wind speed (off shore): 7.2 m/sec
Annual mean temperature: 8.0 °C



CONTEXT

Today, more than 100 000 Danish families are members of wind energy cooperatives, who have installed 86% of all Danish wind turbines. Until recently, the cooperatives were a very important and dominant factor in the development of the Danish wind energy sector. Since then, single person ownership has by far superseded the importance of the cooperatives. In the coming years, the utilities are expected to play an increasing role in the establishment of large-scale offshore wind farms. The program of the Danish utilities alone will have a total power of 750 MW in the next 8 years.

In the project of the city of København, of the 20 wind turbines that the wind farm has, 10 turbines are owned by the Co-operative, and 10 turbines are owned by the local utility Copenhagen Energy. The whole project has been developed in part by the Cooperative, in part by the Copenhagen Energy. The cooperative's part will consist of 40,500 shares, one share representing a production of 1,000 kWh/year, sold for 567 euros (4,250 DKK). This project has obtained planning permissions in May 1999, and formal political approval from the Danish Energy Agency in December 1999. Contracts with the turbine manufacturer and the foundations and grid contractors have been signed in December 1999.

An ongoing restructuring and liberalization of the Danish energy market, including new regulation mechanisms for the renewable energy sector, has complicated the realisation of the project.

The realisation of the project was not an easy task due to the three public hearings that it needed to pass. First, in 1997, the resistance of the authorities and interest groups brought about a downgrading of the size of the farm, which went from the originally proposed 27 turbines to 20. Secondly, this new modified project was exposed to a new hearing, focusing on the visual impression. The last hearing concerned the analysis of the environmental impact.

At the beginning, only people from the municipal area could buy shares. A novelty of the year 2000 was that everyone, even from outside Denmark, could buy this renewable energy under certain conditions. By October 2000, 100% of the private shares were sold. By now, more than 8500 people have joined the cooperative.

EXPERIENCE OF KØBENHAVN

The Middelgrunden project is an offshore wind farm with a rated power capacity of 40 MW. The project, consisting of 20 wind turbines of 2 MW each, is situated just 2 km outside the København harbour, in shallow water (3-5 meters deep).

The wind resource is limited, but due to the near shore sitting capital, the cost is as low as 1.2 million euro per MW, including grid connection. The cost of electricity is 5.3 euro per kWh, including operation and maintenance. The total investment in the project was nearly 45 million euro (340 million of DKK).

The Danish Energy Agency granted 680 000 euro (5.1million DKK) to investigate the technical and environmental aspects of offshore wind power. This study analysed the following issues:

- The risk of leaking debris and metal contamination from the former dumpsite (3-4 sites were contaminated by heavy metals and to overcome this problem, the sediment needs to be handled as little as possible during the dredging work).
- The noise propagation (it is not supposed to cause any problems as the distance to populated areas is more than 2 km).
- Influence on the free flow of water in Oeresund (the wind farm will only reduce the water flow in the belt between Denmark and Sweden by 0.0012 %; to compensate the decrease of water flow, a removal of some 4000 m³ of deposits, from an appropriate location on the ocean floor, is being debated).
- The risk of collision with vessels.
- The impact on the flora and fauna.
- The risk of finding shipwrecks and deposits from the Stone Age of archaeological interest.



Technical data of the wind farm

The wind farm is placed 2 km offshore the Port of Copenhagen. The wind farm consists of a slightly curved line of 20 turbines, each with a rotor diameter of 76 m and a generator-size of 2 MW. The chart and the image below express the location and the technical specifications of the wind farm.



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|--------------------------------------|----------------------|
| Turbine manufacturer | Bonus Energy |
| Foundations manufacturer | Monderberg & Thorsen |
| Responsible Grid Connection. | NKT |
| Number of wind turbines | 20 |
| Size of one wind turbine | 2 MW |
| Height of hub | 64 m |
| Mean wind speed (at hub height 64m). | 7.1 m/s |
| Total height. | 102 m |
| Rotor radius. | 38 m |
| Estimated power output. | 89 GWh |
| Park efficiency. | 93% |

Geographical layout

Technical specifications

During the construction of the wind farm, particular considerations were to be taken with regard to fatigue strength; combination of waves, wind and ice loads and the turbulence caused by the relatively short distance between the wind turbines. And only little experience was available about these subjects.

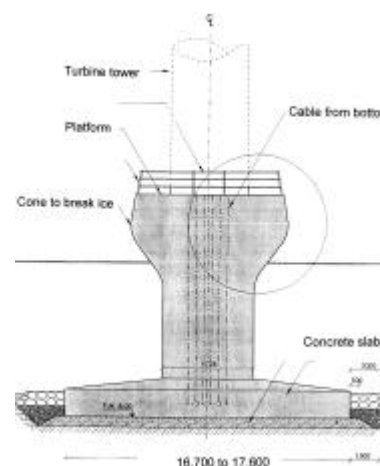
One very important technical issue had been to develop the most appropriate foundations, considering the seabed lies between 2.5 and 5 metres under sea level. Two types of foundations were initially examined:

- A standard gravity caisson foundation used for wind turbines on land, set down on steel or concrete. (Although the steel caisson type cannot compete with concrete in shallow water, even with very low prices of steelwork).
- A monopile solution. (It was not feasible for the actual site, due to the presence of a special type of limestone).

In the end, the gravity caisson foundations, set down on concrete, were the solution chosen.

The internal grid connection in the wind farm consists of 30 kV pex-cables dug into the ground. This installation does not use a central transformer station; instead, each turbine contains a 690V/30 kV transformer at the bottom of the tower.

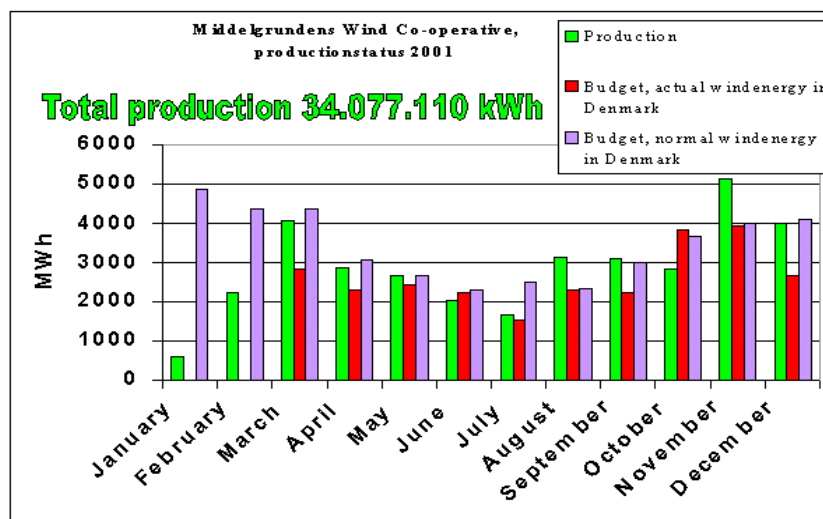
The inauguration of the Middelgrunden Offshore Wind Farm took place in Copenhagen at the Langelinie quay, May 6th 2001. Around 10,000 people participated in the event. Close to 1,300 people joined the boat trip and had a closer look at the wind turbines. It has now developed a web site (www.middelgrund.com) where you can follow the production from this Wind Farm online. The actual production is updated every 10 minutes.



EVALUATION AND OUTLOOK

Together with Vindeby (established in 1991) and Tunoe (established in 1995), the Middelgrunden offshore wind farm represents the first step in a planned large-scale extension of the electricity production from offshore wind turbines in Denmark. Within the next 5-8 years, 5 even larger offshore wind farms will be established. The total power of each of these farms will be 150 MW. A smaller offshore wind farm outside the island of Samsøe with a power of 22 MW is planned for 2001-2002 (www.samsøe.com).

In the graphic, we can see the progress of the production at the Middelgrunden Wind Farm during the year 2001. The turbines were in the test phase from January to April so a normal production can only be expected from April. The budget in the diagram has been calculated based on a standard wind year. Therefore, it is only an indication of the expected production.



The potential for offshore wind farms in Danish waters has been estimated to 2250 MW for the 2000-2015 period, and additional 1750 MW for the next 15 years. These estimates are based on the wind power technologies, which were known a few years ago.

As a result of the offshore power to be produced in the coming years, 50% of the Danish electricity consumption will be produced by offshore wind power parks by 2030 (Danish Ministry of Environment and Energy, 1996; The offshore Wind-farm Working Group, 1997). In this sense, the Middelgrunden project has been a pilot project that can be of considerable value for future projects, in the coming large-scale extension of the Danish offshore wind power production.

FURTHER INFORMATION

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