Danish Wind Turbines: An Industrial Success Story

By Soren Krohn, Managing Director, Danish Wind Industry Association, February 2002

Danish wind turbine companies have a market share of half the world market with a turnover of some 20-22 billion DKK = 3 billion EUR (2001) out of a total world market of 6 billion EUR[1].

The global wind industry has been growing at a rate of above 40 per cent per annum during the past five years, and growth rates around 20 per cent per year are foreseen for the first decade of the new century[2].

In 2001, the Danish wind turbine companies supplied turbines with a rated capacity of more than 3,000 Megawatts (MW), equivalent to the rated power of three large nuclear or coal-fired power stations per year[3].

Wind turbine manufacturing, maintenance, installation and consultancy services account for some 16,000 jobs in Denmark, while component supplies and installation of these Danish turbines currently create another 8,000 jobs worldwide[4].

The global job creation of Danish wind turbine companies are substantially larger than these figures indicate:

Only about 9 billion DKK (1.2 billion EUR) is due to turbines manufactured in Denmark. The rest are manufactured in Germany, Spain, India, Italy, and the U.S., i.e in countries where there is a substantial home market. There is no wind turbine manufacturing in countries without a substantial market: Wind turbines are heavy equipment, so it simply does not make economic sense to manufacture them anywhere but where the market is, despite low labour costs in some other countries. Component manufacturers and service suppliers are spread all over Europe.

Wind energy employs some 60,000 people worldwide, and 45,000 in the European Union (2001).

1 The Danish Wind Pioneers

1.1 Poul la Cour

The use of wind energy for electricity generation is 100 years old. In the 1890s Poul la Cour a Danish meteorologist, inventor, and folk high school principal, started experiments converting classical windmills to DC electricity generation.

In aerodynamics la Cour pioneered the use of an electrically operated wind tunnel.

He also patented a mechanical device to stabilise the torque (power output) of wind turbines.

VINDMØLLEINDUSTRIEN
Vester Voldgade 106
DK 1552 København V

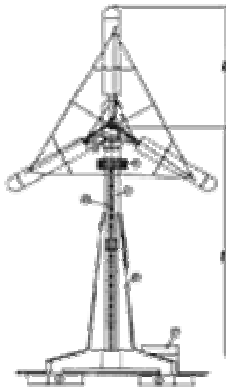
Tel : +45 3373 0330
Fax : +45 3373 0333
E-mail : danish@windpower.org
Internet : http://www.windpower.org

Finally, la Cour used electrolysis to store energy in the form of hydrogen for lighting his school. The electrolysis system, however, had problems with small amounts of oxygen being mixed with the hydrogen. The accounts of the school show several bills for replacing the windows of the buildings involved in the hydrogen lighting experiments!

La Cour gave courses in wind energy for Danish "wind electricians". Some old students later built a number of both two- and three-bladed pitch- and stall controlled wind turbines for the F.L. Smidth engineering company, mostly during World War II.

1.2 Johannes Juul

After world war II the Danish interest in wind energy waned. But in the early 1950s a chief engineer for a power company, Johannes Juul, who was reaching retirement age took up his old interest in wind energy acquired during one of la Cour's courses in 1903. Juul built a number of experimental machines and was the first to connect a wind turbine with an (asynchronous) AC generator to the electrical grid. Around 1956 Juul built the Gedser wind turbine which became a pioneering design for modern wind turbines.



For many years the 200 kW Gedser Turbine remained the largest in the world. Among the inventions on the Gedser turbine were the aerodynamic tip brakes on the rotor blades which were released automatically (using the centrifugal force) in case of over speed of the turbine.

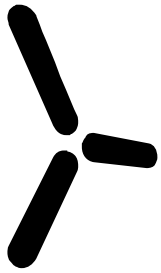
The Gedser machine ran without any major maintenance for 11 years, but was not repaired when a bearing failed in the late 1960s. In the mid 1970s, however, the machine was refurbished at the request of NASA which needed measurement results for a new ambitious U.S. programme for the construction of large wind turbines. The Gedser machine subsequently ran for another 3 years. After decommissioning it became a museum piece in the Danish Electricity Museum in Bjerringbro, Denmark.

2 The Globalisation of the Wind Energy Market

The Danish wind turbine industry had a rather humble infancy in the 1970s. The energy supply crises in the early 1970s created new interest in wind energy in several quarters:

2.1 Amateurs at work

Most wind energy projects in the 1970s began as private projects, largely pioneered by technically interested people, who based their designs on scaled-down versions of the Gedser machine. The maximum power output was some 10 to 15 kilowatts.



There was considerable interest in these designs, so one of the pioneers, Christian Riisager eventually managed to build a series of some 30 machines.

Meanwhile, a number of innovative designs of small machines appeared, and politicians began to take interest in the new development, partly in light of the energy supply crisis, partly as a reaction to popular opposition to nuclear power in Denmark.

Since the power purchasing policies of the local utilities varied wildly (offering prices between zero and the retail price of low voltage electricity), Parliament legislated a purchasing price of 85 per cent of the retail price of electricity.

An incentives programme in the form of capital grants for installation of wind turbines was established in the late 1970s. The scheme was finally abolished in 1989, when a (then 10 per cent) capital grant was dropped.

2.2 Scientists at Work

In order to ensure that Government supported turbines also had a certain quality and safety, legislation on type approval for wind turbines was established. The type approval job was given to the Risø National Laboratory which was originally established to do research on nuclear power.

While most nuclear research has since been abandoned by Risø, the institution today has an important research department in wind energy, with some 100 scientists and engineers employed in research on aerodynamics, meteorology and wind assessment, structural dynamics, advanced materials etc.

There has been considerable interaction between Risø and the wind energy community worldwide. Risø's work on turbine safety has been important in ensuring the reliability of modern wind turbines.

Danish turbine manufacturers guarantee a 95 per cent availability rate for their turbines, and statistics show that the availability rate in practice is around 99 per cent.

2.3 Power Companies at Work

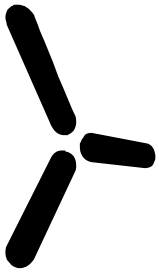
Danish power companies at a fairly early stage took an interest in wind energy. The Gedser wind turbine itself was built and financed by a power company, SEAS.

In the early 1980s, however, the Danish power companies became interested in large wind turbines and built two experimental machines, one pitch regulated and one stall regulated, of 630 kW each.

For their time these machines were very large compared with the conventional 10 to 25 kW commercial designs. They were nowhere near the size of the megawatt designs being developed in Sweden, Germany and the U.S., however.

Although these electricity company designs generated some interesting measurement results, they were neither successful commercially, nor were they intended to be commercial. The cost of energy from the large turbines was so high that series manufacturing was not even envisaged.

The manufacturers' development of commercial machines therefore was largely unrelated to the work on the large machines. Later 2 and 1 MW designs suffered much the same fate as their predecessors.



2.4 Manufacturers

Having noticed the success of companies like Riisager's, some manufacturers of agricultural machinery (e.g. Vestas, Nordtank, Bonus, Nordex, and later Micon) quickly realised the commercial possibilities of the rapidly growing turbine manufacturing sector.

With their superior engineering knowledge, these companies quickly came to dominate the Danish wind turbine market, and later the world market. Today, these companies are all on the "top ten" list of manufacturers worldwide.

2.5 The California Wind Rush

The great luck of the Danish wind turbine manufacturers was the fact that the State of California in the early 1980s began a programme of support to wind energy development. Danish manufacturers had the longest track record, having already developed several generations of successively larger machines in small series.

The California market expanded dramatically, allowing volume production of wind turbines unheard of previously. The benefits of this learning process were colossal.

It involved one risk, however: Manufacturers became dependent on a single market. When the California wind programme ended in 1985-86, a large number of the 20-odd manufacturers went bankrupt, having few alternative markets for their products. At the same time, virtually the entire manufacturing base of the U.S. disappeared.

Thus began a long, tough haul for the remaining (subsequently merged) manufacturers, who very consciously began to broaden their market base to include several countries.

2.6 New markets

Today, some 40 countries are export markets for Danish wind turbines, the largest being Germany, Spain, the United States, and Italy.

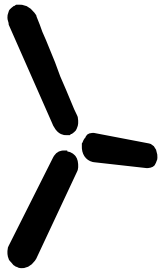
3 Technology

The background of the Danish turbine manufacturers was different from wind power companies in the U.S., Sweden, or Germany. Names like Boeing, Lockheed, Westinghouse, MBB, and Siemens indicate a strong background in aircraft and generator manufacturing.

Interestingly, however, practically all of today's remaining larger wind turbine manufacturers have a machinery manufacturing background rather than an aircraft background. Although modern wind turbine technology resembles helicopter technology, the operating requirements are very different.

3.1 A Unique Technology

Wind turbines operate in fluctuating, relatively slowly moving air currents.



This makes it necessary to model aerodynamics in three dimensions rather than the two which are normally used in aircraft design.

Furthermore, most turbines make use of the "stall" effect of airfoils to control the power output from the rotor blades. Aircraft designers, on the contrary, have to avoid the stall effect at all costs to prevent the aircraft from falling like a rock.

Although modern wind turbines have borrowed a number of tools from classical aircraft design, including airfoil profiles, components are gradually becoming more specialised.

The requirements for low noise emission require special design of both rotor blades, gearboxes and other mechanical components.

3.2 The Danish Concept

Most modern wind turbines tend to be three-bladed designs with the rotor position maintained upwind (on the windy side of the tower) using electrical motors. This design is known as the classical Danish concept and tends to be a standard against which other concepts are evaluated.

3.3 Upscaling

Wind turbines have grown dramatically in size and performance during the past 20 years.

The early machines of 25 kW with 10.6 metre rotor diameter may still be found in Denmark.

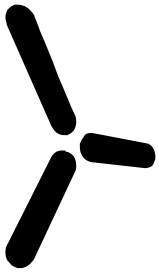
Today the most widely sold turbines have a rated power output of 750-1,300 kW, and a rotor diameter of 48-54 metres. The largest machines commercially available are 2,500 kW machines with 80 metre rotor diameter placed on 70-80 metre towers. Each 2,000 kW machine produces more energy than 200 old 1980 vintage machines. Productivity thus has increased rapidly.

4 Wind Energy Economics

The economics of wind energy has improved tremendously during the past 15 years tumbling with a factor of five. Today, wind energy can compete with coal and nuclear on average kWh costs.

The cost of wind electricity depends heavily on the average wind speed at the turbine site, since the energy content of the wind varies with the third power of the average wind speed. On typical, good sites is the UK and Denmark, the cost per kWh for large wind parks is close to 4 US cents, depending on financing conditions, and infrastructure costs.

Wind turbines have a design lifetime of 20 years, and O&M costs are typically in the region of 3 per cent p.a. of the cost of the turbine.



5 Power From the People

More than 80 per cent of the 6,300 wind turbines in Denmark are owned by wind energy co-operatives, or individual farmers. 150,000 Danish families own wind turbines or shares in wind co-operatives.

The Danish wind turbine owners are organised in the Danish Wind Turbine Owners' Association.

The well-organised Danish wind turbine owners have been a very important driving force for debugging and improving Danish wind technology in its earlier years. Through their magazine they have published statistics on both reliability and production - compared to what they have been promised by the manufacturer - and they have an annual opinion poll on the quality of the service from each manufacturer.

6 Danish Energy Policy

Danish energy policy has indirectly played an important role in fostering the commercial success of the Danish wind industry. This policy is explained in the article Wind Energy Policy in Denmark: Status 2002. The industrial implications of 25 years of public policy for wind power are discussed in the article Wind Energy Policy in Denmark: 25 Years of Success - What Now?
Both articles can be found in the article archive at the website www.windpower.org

1) 20 billion DKK is the (global) group turnover of Danish wind turbine manufacturing companies Bonus, Vestas, NEG-Micon and Nordex. These companies account for more than 99.9% of wind turbine manufacturing in Denmark, the remaining part was manufactured by Wincon. Nordex is 93% German-owned and is often quoted as a German company in German statistics. The sales of components to foreign turbine manufacturers, primarily rotor blades from LM Glasfiber, controllers from Mita, brakes and hydraulics from Svendborg Brakes etc. account for somewhere between 1 and 2 billion DKK. The 20 billion DKK does not include turbines manufactured under license or in companies where the owner has less than 50% of the shares, thus companies like Gamesa and RRB Vestas India are not included in the figures. Gamesa was the world's second largest turbine manufacturer in 2001.

2) BTM Consult, Ringkøbing, Denmark: World Market Update 2000.

3) Annual energy output will be about half of that of a similarly rated conventional or nuclear power station. This difference in capacity factor has nothing to do with efficiency factors. Wind turbines are optimised with roughly twice as large generators as other power stations as explained on our web page on capacity factors: http://www.windpower.org/en/tour/wres/annu.htm

4) The data is based on input-output analysis as explained on the web page on employment; http://www.windpower.org/en/tour/econ/empl.htm