

Danish wind power – a personal view ©
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Background

Denmark (population c. 5.4 million) is a leading pioneer in renewable energy. Since 1985 it has set up about 3,100 MW of wind capacity. Of this 420 MW are sited offshore (Nielsen, 2004), and more is planned for the near future (Bendtsen and Hedegaard, 2004). Over the same period many small gas- or bio-fuelled CHP plants were deployed, primarily for local district heating but also to produce electricity. Interest in solar power is also considerable.

Economic aspects

This development was strongly supported by a statutory obligation on Transmission System Operators (and indirectly on electricity consumers) to buy the total output of power from wind and local CHP sources at prices fixed by Government. In addition, direct subsidies were paid for renewable energy produced under obligatory purchase or free market conditions. These have amounted to DKK 3.40-3.85 billion per annum since the end of 2000 (Bendtsen, 2003), although some claim that consumers are annually paying DKK 8-10 billion more in capital and operational costs for the combined conventional + renewable energy package than would be the case if Denmark had stayed with its highly efficient conventional power plants (Krogsgaard, 2001). One consequence is that householders pay the equivalent of up to 14 p/kWh for electricity (about twice the current UK price). Another is that wind stations and local CHP plants have produced expensive electricity, even when demand is low. To promote a smoother-running supply market, the Government recently decided to abandon the obligatory purchase scheme (Andersen, 2004b), though owners of existing wind turbines and local CHP plants will continue to receive subsidy (Nielsen, 2004). Annual subsidy costs are predicted to fall to about DKK 2.80 billion in 2008 (Bendtsen, 2003).

The Danish Wind Turbine Industry is important to the economy of this small country, currently supplying about 40% of the world market and employing about 20,000 Danes (Nielsen, 2004). Since 1985, the size and number of individual wind turbines has grown steadily with a view to improving their output, economy, and efficiency. According to one long-term prediction, 20 MW wind turbines as high as the Eiffel Tower are feasible and may be a reality by 2015 (Andersen, 2001). In this context, a subsidised 're-powering' scheme recently encouraged the displacement of 1,200 small turbines (< 150 kW) by 300 bigger machines (Nielsen, 2004), and under a similar arrangement a further 900 turbines of under 450 kW capacity will soon be displaced by 175 larger ones (Sandøe, 2004a). Most of the turbines scrapped to date operated for less than 16 years (Bülow, 2002), so it difficult to assess the effective lifespan and economy of modern wind turbines.

Western Denmark

Denmark operates two unconnected regional grid systems, located east and west of the Great Belt, respectively. Each region benefits from having large, long-established inter-connectors to neighbouring countries, which facilitates the international exchange of power on the open market. In years of normal rainfall the balance of electricity flow is usually in a southerly direction, but in 2003 drought conditions in Norway and Sweden encouraged a net movement the opposite way.

The western region of Denmark (comprising principally Jutland and Funen; population c. 2.7 million) is of particular interest because its wind conditions are comparable to those of the UK (Troen & Petersen, 1989). Moreover, three-quarters of the country's wind turbine capacity is located there. The concentration of wind turbines in this region is such that there are few areas in its rather flat or gently rolling countryside where they are not visible (Sharman, 2003) – despite local regulations that prohibit their deployment on hill tops.

Electricity production

In the western region, electrical power is currently generated by c. 4,156 wind turbines (2,374 MW i.c.), c. 560 CHP plants (1,567 MW i.c.) and c. 11 primary power units (3,516 MW i.c.) (Eltra, 2004). During 2003, the output of renewable energy (mainly wind power) was numerically equivalent to about 21% of local power demand, (i.e. similar to UK aspirations for the year 2020), but possibly 84% of this was exported to Norway, Sweden and / or Germany, primarily to maintain stability in the domestic grid (White, 2004). There is a close relationship between Western Denmark's wind power production and its net exports of electricity (Nissen, 2004). The technical necessity to export wind electricity (often at low or even give-away prices) is a major weakness of the system and has been estimated to cost Danish consumers close to DKK 1 billion a year.

Exports and imports

Security of supply and stability of frequency and voltage are essential to modern power production. Except for the water reserves used with hydro generators, however, no facilities currently exist for the large-scale storage of wind electricity. Western Denmark copes with massive fluctuations in wind and CHP power production by virtue of its fortuitous geographical location, and big inter-connectors (c.2,750 MW; equivalent to its installed capacity of wind power) to the grids of neighbouring countries. Norway is almost entirely supplied by hydro electricity, whereas Sweden produces both hydro and nuclear power. Both can absorb Danish wind power by reducing their output of hydro electricity or using it to pump water to elevated reservoirs for the later generation of hydro electricity (White, 2004).

The transfer option (available to the UK to only a limited extent) not only enables Western Denmark to dispose of large amounts of

power in windy conditions, but also allows it to import hydro-, nuclear- or coal-based electrical backup (often at premium prices) whenever the weather is becalmed. Lesser amounts of wind power are absorbed into the domestic supply system, where it is supported by fossil-fuelled plant, part of which operates sub-optimally as backup for much of the time.

Jutland and Germany exchange power in roughly equal quantities, but difficulties have recently been encountered with Danish exports because of competition from wind power synchronously produced on the southern side of the border (Sandøe, 2003a). This has focused attention on future options for storing or disposing of excess wind electricity within the region's borders. An experiment involving a massive fuel cell was recently abandoned (Bülöw, 2004), but proposals have been made to use wind power to heat the water of local heating plants in the near future (Sandøe, 2003b), despite the limited benefit derived during periods of warm weather. The production of hydrogen by electrolysis is being seriously examined for the longer term (Sandøe, 2004b), although many technical and economic problems must be overcome before this approach can be applied (Andersen, 2004c).

Load factors

The overall load / capacity factor (i.e. the percentage of installed capacity actually produced over a year) of Western Denmark's wind turbines can be estimated from their annual output of electricity and the mean of the capacity of installed wind turbines at the beginning and end of the year in question. Over the last five years, it has hovered between about 20 and 24% (estimated from Eltra 2004 data). Such values are lower than those predicted by some for the UK (28-40%), but higher than figures of c. 15% calculated for Germany's larger number of wind turbines over the same period (see Reuters, 2004). The reason for these lower values is not clear, but wind speeds, location, turbulence, midge or salt accumulations on blades, and breakdowns may all be implicated. Serious problems recently experienced with wind turbine transformers at the new offshore Horns Rev site will not have helped (Andersen, 2004a).

Only time will tell whether current UK predictions of load factor will apply once the prime deployment sites have been occupied. If this factor turns out to resemble that of Western Denmark, the power output and financial returns of many planned UK wind turbines will be considerably lower than currently projected. Furthermore, the amount of installed wind capacity needed to achieve UK government goals is likely to be seriously under-understated. The implications for power supply, landscape and wildlife habitats could be very serious.

Carbon emissions

The primary incentive for developing sustainable sources of power is the dwindling reserves or inaccessibility of oil and gas. Climate change is a useful tool with which to convince the public of the need for renewables. Those who consider man-made carbon emissions to be the main driving force behind 'global warming' (rather than just one of a plethora of interacting factors) argue that the use of renewable energy sources will decrease emissions by reducing the need to burn fossil fuels.

This is so for mini wind turbines, solar panels, and other sources that by-pass the national grid and directly feed electricity to appliances or water-storage containers on an intermittent 'catch-as-catch-can' basis. However, it does not apply in any meaningful way to the mega wind turbines that feed power into the Danish grid. To sustain the integrity of this grid, Western Denmark's domestic use of wind power requires the continuous (and less efficient) operation of backup from carbon-emitting coal/gas-burning stations, and much (usually most) of its exports of wind electricity simply displaces 'green' hydro or nuclear electricity produced in neighbouring countries. In addition, the need for massive concrete foundations, access roads, pylons and / or associated plant negates much of the emission-saving benefits claimed for wind turbines. For all these reasons the argument can be made that Denmark's wind power resources may have little, if any, effect on the country's carbon emissions (Nissen, 2004), which have recently been rising (Sharman, 2003).

Conclusions

For many, the proliferation of wind turbines in Western Denmark has seriously detracted from the former charm and beauty of its natural land and seascapes, and has had a detrimental impact on human and wildlife habitats. A recent statement from Government Ministers can be interpreted to confirm this (Bendtsen & Hedegaard, 2004).

In its present form, Danish wind power still relies heavily on public subsidies. Some have argued that Denmark's investment in renewable energy could have been far better spent improving the environment by less obtrusive and more effective means - for example, by funding radiator valves for Eastern European countries (Abilgaard, 2001). The current production of renewable energy in Western Denmark corresponds numerically to 21% of local demand, but most of this power has to be disposed of in neighbouring countries at considerable cost to the Danish electricity consumer.

The output of wind power has little if any beneficial effect on carbon emissions, because its unpredictable pattern of production can destabilise the grid unless supported by readily accessible fossil-fuelled backup and the option to displace 'green' (mainly hydro or nuclear electricity) or conventional power in neighbouring countries.

With wind conditions similar to those of the UK, annual load factors for Western Denmark's carpet of wind turbines (20-24%) sound a warning. Unless much greater and sustained production can somehow be achieved under UK conditions, consumers and investors will not enjoy the technical and economic benefits suggested by current efficiency predictions.

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