

West Danish wind power – lessons for the UK ©

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Background

Denmark (pop. 5.4 million) is a leading pioneer in the field of renewable energy. Since 1985 it has erected about 3,100 MW of wind turbine 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 for local district heating and/or electricity production. Interest in solar power is also considerable. The Danish Wind Turbine Industry is particularly important to the economy of this small country, currently supplying about 40% of the world market and employing about 20,000 Danes (Nielsen, 2004).

This development has been 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 district heating sources at elevated 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 there is a 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 almost double the UK price for electricity. Another is that wind stations and local district heating plants have produced excessive amounts of electricity, even when demand was 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 district heating plants will continue to receive subsidy (Nielsen, 2004).

Since 1985, the size and number of these turbines has grown steadily with a view to improving their output, economy, and efficiency. According to one 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.

West Denmark

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

West Denmark (comprising principally Jutland and Funen; pop. 2.9 million) is an interesting model for study because its wind conditions are comparable to those of the UK (see Troen & Petersen, 1989). Moreover, three-quarters of the country's wind turbine capacity is located there. The concentration of installed wind power in this region (819 MW per million of population) is amongst the highest in the world, and approximately 64 times that of the UK at the present time. There are few areas in its rather flat or gently rolling countryside where wind turbines are not visible (Sharman, 2003) – despite local regulations that prohibit their deployment on hill tops. For many people, the proliferation of onshore wind turbines has

seriously detracted from the former charm and beauty of the natural countryside. It has also had a detrimental impact on both human and wildlife habitats: A prominent Danish newspaper has stated: “[It is correct that Denmark has placed itself in a leading position with regard to the utilisation of wind energy, but until now this has certainly occurred at great cost to nature and with considerable public subsidy]” (Jyllands Posten Editorial, 2004).

Electricity production

West Denmark’s electrical power generation is currently accomplished by about 11 primary units (3,516 MW), 4,156 wind turbines (2,374 MW), and 560 district heating plants (1,567 MW (inc. 40 MW bio-boilers) - spread across most towns and villages) (Eltra, 2004).

Of course, wind power is produced when the wind blows, - not necessarily when power is demanded. The annual load / capacity factor (i.e. the percentage of the installed capacity that was actually produced over a year) achieved by West Denmark’s turbines over the last five years has hovered between 20 and 24% (estimated from Eltra data), this being comparable with the 24.1% reported for the comparatively small number of onshore wind turbines in the UK in 2003 (DTI, 2004), but higher than the 15% calculated for Germany over the same period (see Reuters, 2004). The Union for Co-operation on Transmission of Electricity (UCTE) is reported to claim an average load factor of only 20% for its European TSO members (Refocus Weekly, 2004). Clearly, load factors are important measures of efficiency which are influenced by wind speed, location, turbulence, midge or salt accumulations on blades, and breakdowns. Serious problems recently experienced with wind turbine transformers and generators at the new offshore Horns Rev site (Andersen, 2004a; Renewable Energy Access, 2004) will not have helped the Danish cause.

During 2003, the annual production of renewable energy (mainly wind power) in the region was numerically equivalent to about 20.7% of power demand (Bülow, 2004a) (i.e. similar to UK aspirations for 2020). However, at its times of generation, about 84% of the wind power was surplus to local demand (White, 2004; Sharman, 2004) and had to be exported to the much larger power systems of Norway, Sweden and/or Germany, primarily to maintain stability of frequency and voltage in the Danish grid. This implies that over the period of 2003 under 4% of the region’s demand for electrical power was directly provided by wind resources, the bulk of requirements being met by carbon-emitting central and local CHP generators, some of which operated sub-optimally as backup for the wind power for much of the time.

Erratic production

The unpredictable nature of wind power generation is responsible for intermittent and massive fluctuations in Western Denmark’s power supplies. Even in winter its provision can be precarious (Bülow, 2003). Until now, subsidies to the district heating plants have also stimulated their generation of electricity for the Spot Market, even when prices and the demand for power were low (Sandøe, 2004b). Talking to Jyllands Posten newspaper in 2001, the then Chairman of the regional Transmission System Operator, Eltra, stated: “[The consequence of the many wind turbines and decentralised power stations is that during the winter there is regularly produced 1,000 to 2,000 MW more than is needed in our area. This over-production we must dispose of on the open market for considerably less than we have paid.]” (Kongstad, 2001). To surmount these challenges Eltra has had to pay Elsam (the region’s biggest conventional power company) to ramp its production up or down, or alternatively it has had to export or import electricity (Sandøe, 2003a). This erratic provision of electricity is said to put the watch at Eltra’s central control room in a situation that corresponds to “[having to manoeuvre a rapidly moving articulated lorry train without a steering wheel, accelerator, clutch or brakes]” (Andersen, 2003a).

Exports and imports

It is evident that exports currently play a key role in balancing and protecting the West Danish grid against big surges in power generation. More than 60% of all electricity produced in the region is sold on The Nordic Power Exchange (NordPool). In fact, in recent years close relationships have existed between the amount of wind power produced and net exports of electricity (see Nissen, 2004; and Sharman, 2004). These exports have often been sold at low or give-away prices, and have recently been costing Danish consumers about DKK 1 billion a year (Sharman, 2004). The power is exported via inter-connectors (c. 2,760 MW; i.e. capacity equivalent to 73% of peak load in 2003), these being large enough to accommodate most of the total output of the region's current wind carpet. Both Norway and Sweden can absorb Danish wind power by rapidly reducing their output of hydro electricity or using imported power to pump water to elevated reservoirs for the later generation of electricity (White, 2004).

In becalmed periods, large inter-connectors (c. 2,380 MW) allow West Denmark to import hydro-, nuclear- or coal-based electrical backup from these countries and/or northern Germany, often at premium prices. However, limitations in inter-connector capacity also necessitate the purchase of much of the Balance Power from Elsam. Jutland and Germany exchange power in roughly equal quantities, but difficulties have recently been encountered with Danish exports because of direct competition from large amounts of wind power synchronously produced on the southern side of the border (Sandøe, 2003a).

Carbon emissions

The main incentives for developing alternative energy sources are declining reserves or uncertain supplies of particular fossil fuels, and the control of atmospheric pollution. Nevertheless, ignoring many scientific theories on the complex interactions between cosmic and terrestrial factors in climate change, with almost religious fervour many Danish politicians, developers and 'green' organisations insist that man-made carbon dioxide emissions are the principal cause for 'global warming' and should therefore be reduced. No matter what the scientific merits of this latter theory may be, it has the political advantages of introducing an un-resolvable 'fear factor' into the public debate, promoting a lucrative wind industry, and elevating an essential plant food to an easily handled object for trade and taxation.

Whatever the driving forces behind climate change, the level of carbon emissions actually saved by exploiting renewable energy sources depends on the nature and amount of conventional power displaced by them. To date, West Denmark's wind power resources have had little or no beneficial impact on Danish carbon emissions because the turbines depend on the continuous (and less efficient) operation of backup from the region's modern, coal/gas-burning stations, or imported power, to protect the integrity of its domestic grid (Sandøe, 2003a). Furthermore, much or most of the wind power exported simply displaces 'green' hydro or nuclear electricity produced in Norway and Sweden (helping to replenish reservoirs only when wind power is cheap or in dry periods or times of drought). Turbine and electrical plant manufacturing processes and the need to deploy massive concrete foundations, access roads, pylons and associated equipment also help to negate the emission-saving benefits claimed for these machines. Indeed, carbon emissions have recently been rising in the region (Sharman, 2003) due in part to increased exports of subsidised power from local CHP plants to neighbouring countries. Against this background, a leading Elsam expert has intimated that "[Increased development of wind turbines does not reduce Danish CO₂ emissions]" (Nissen, 2004).

From January 2005, the larger district heating plants (> 5-10 MW) will operate under free market conditions. This will reduce their production of 'overflow' power, and may result in the direct replacement of some of their electricity output by wind energy. CHP plants are also

being encouraged to supply regulating power (Bülow, 2004b); and when legislation permits resistance heating, peak wind electricity may displace some of the gas burned at these facilities (Sandøe, 2003b). Such changes should resolve part of the current balance challenge (Andersen, 2003b) and start to lower carbon emissions, but only time will tell which of these options are technically efficient and economically viable.

Lessons for the UK

The present concentration of installed wind power in West Denmark (819 MW per million of population) is amongst the highest in the world. To achieve a comparable level of deployment, the UK would need to install roughly 49,000 MW of wind power (assuming a UK population of 60 million, and similar load factors and power demand per head). This corresponds to a need for approximately 24,500 wind turbines of 2 MW installed capacity.

The problem is that wind stations and their associated infrastructure of buildings, cables and/or pylons and access roads etc. destroy wildlife habitats (including peat bogs and forests) and are known to kill large numbers of birds and bats, as well as cause damage to the habitats of the insects, creatures and plants on which they live (see Mason, 2004). They also require very large areas of operational space, making their cumulative environmental impacts far worse than those of individual stations. A 27-year old Danish rule of thumb stipulates that turbines should be separated by at least seven times their rotor diameter to prevent them taking wind from each other and reducing load factor. The 80 new 2MW off-shore turbines at Horns Rev were thus arranged in lattice pattern, such that the distance between individual turbines and rows is 560 metres (Bonefeld, 2001). Thus, just to provide the levels of power production currently achieved in West Denmark, UK wind turbines (2 MW) and their accoutrements would leave their 'footprint' on close to 7,700 Km² of land or sea (equivalent to one third of the total area of Wales). Assuming a UK land area of 241,950 Km², this would equate to one 350 foot high wind turbine per 10 Km², or a spacing of one turbine per 3 Km (or 2 miles) if equally spaced over the land. However, most of this footprint would inevitably concentrate in some of our most cherished and environmentally sensitive regions, damaging peat-bogs wetlands and fields, and requiring the clear-felling of forest and scrub (i.e. our main land-based carbon reservoirs!) to achieve optimal load factors (see the Cefn Croes Wind Farm website, 2004). The UK would still have to rely on imported natural gas, and invest heavily in large numbers of local CHP plants and large inter-connectors (depending on developments).

A similar study (assuming a load factor of 50% for 3 MW wind turbines) has estimated that about 96,000 units would be required to run all British transport vehicles on hydrogen, these turbines occupying an area greater than that of Wales or, alternatively, a 10 Km strip encircling the entire coastline of the British Isles (Oswald and Oswald, 2004). For onshore turbines, annual load factors are more likely to resemble those of the West Danish wind carpet (20 – 24%), while off-shore they may reach 35%. This suggests that the cumulative impact of wind turbines on UK landscapes, seascapes, recreational areas and wildlife habitats could be considerably worse than that intimated by Oswald and Oswald (2004). West Denmark's present carpet of wind turbines produced about 4.4 TWh of electricity in 2003. Yet production of enough hydrogen fuel to displace today's use of hydrocarbons for transport vehicles would require roughly 40 TWh of electricity (Sharman, 2004).

Conclusions

There can be little doubt that the main success of Denmark's very expensive wind technology policy lies in its establishment of a lucrative domestic and international industry for the production of wind turbines (see Norbye, 1998). However, the holistic technical success of this venture to date is questionable, not least in the context of value for money. In West Denmark, (the windiest region of the country) only a small proportion (under 4% in 2003?) of local power demand is currently being met directly by its massive wind resources, the bulk of

these demands still having to be met by fossil-fuelled generators. The bottom line is that in recent years, there has been little or no saving in the region's carbon emissions.

If carbon emissions are judged to be so very dangerous to climate that they warrant the industrialisation of large areas of precious landscapes and wildlife habitats, one must ask why the UK Government promotes the widening of motorways and the extension of airport runways, - major structures that encourage two of our principal sources of pollution. Why has fuel-rationing not been introduced and why is aviation fuel not taxed? Maximum speed limits of 50 – 60 mph on motorways would make a big difference to fuel consumption, as would an efficient, well-used public transport system. Why isn't local production of essential commodities promoted more aggressively? The environmental absurdity of some world trade practices is striking – for example, New Zealand lamb and Chinese shoes compete side by side with their British counterparts in UK shops. How much energy is wasted in refrigerating and/or transporting these commodities half way round the world? How many UK buildings are properly designed and insulated to conserve energy? Why is the UK Government offering more than £1.5 billion in loans, grants etc. to build fossil-fuelled power stations in several developing countries while almost ignoring this option at home? The questions go on and on! Either carbon emissions are dangerous to society or they are not! Since energy conservation measures alone could reduce UK carbon emissions by 30% (Coppinger, 2003) serious efforts should be made to promote this approach before large swathes of our precious countryside and coastal regions are destroyed. It is high time that our politicians and 'green' organisations were asked to justify their support for the massive economic outlay and potentially horrific environmental impact associated with wind technology in its present form. As a nation we should be investing in predictable, reliable and more environmentally-friendly sources of power.

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