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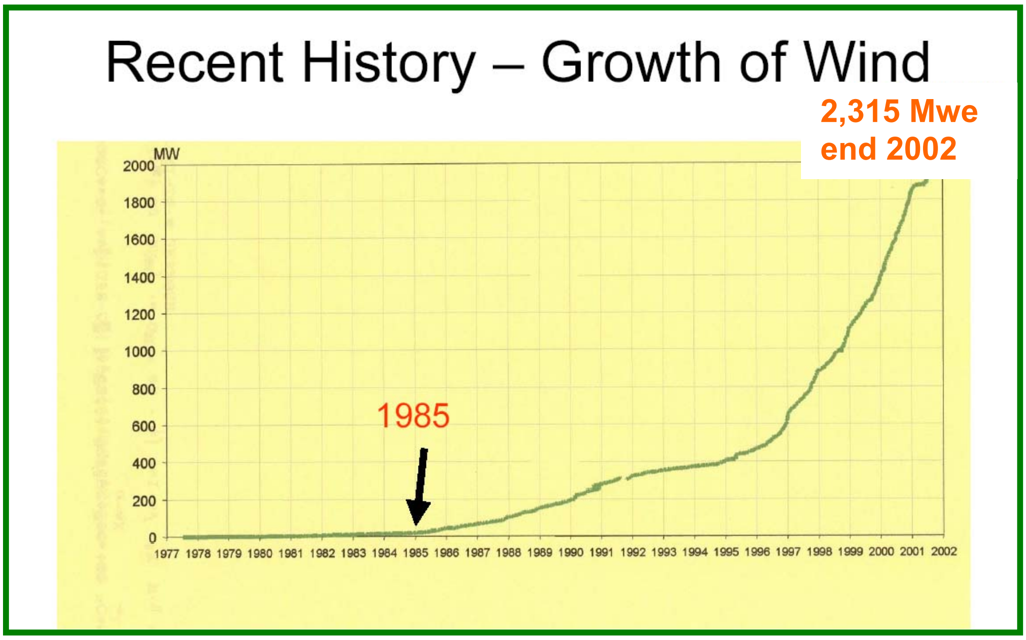
The Dash for Wind
West Denmark's Experience and UK's Energy Aspirations

Background

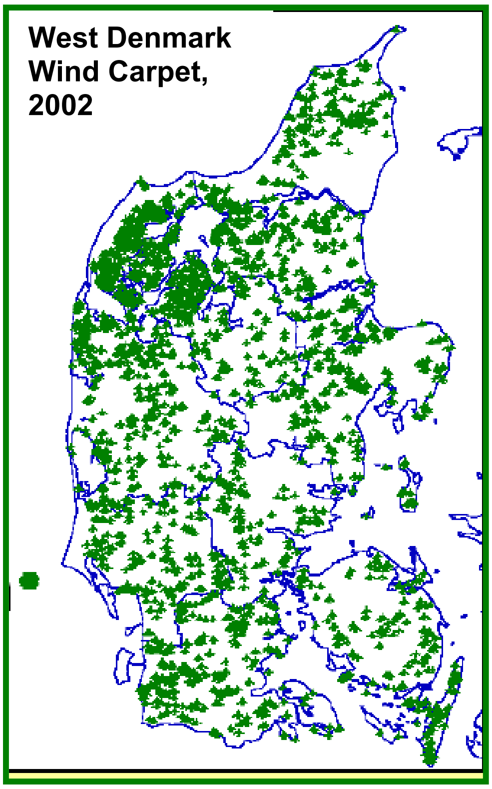
There are two, unconnected, electricity systems in Denmark, being that of East Denmark (Transmission System Operator, or TSO ELKRAFT) and West Denmark (TSO ELTRA), although each system is strongly interconnected with neighboring countries.

During the 1990s, West Denmark experienced a revolution in its generating capacity.



Wind capacity grew from almost nothing in the mid-1980s to more than 60% of peak, local consumption in 2002. Similarly, the electricity generating capacity of smaller, decentralized CHP grew from very small beginnings in the late 1980s to almost 50% of the six, central CHP power plants that supply all the major towns with district heating.

In a single decade, the nominal generating capacity of West Denmark more or less doubled. In 2002, renewable, mostly wind energy supplied the equivalent of roughly 19% of West Denmark's consumption. This will increase to 21%, or so, during 2003.



There are about 2.7 million residents in West Denmark, so the number of wind generators per head of population is 1.74 machines per 1000 people. In the UK, this would amount to about 100,000.

West Denmark is therefore the most intensely wind mill populated land on the planet.

In 2002, there were about 4,700 wind generators with a total, nominal capacity of 2,315 MWe (according to TSO ELTRA).

These cover the landscape so that there are rarely parts of West Denmark, a flat, at most gently rolling, countryside, when they are out of sight.

The physical extent of West Denmark (Jutland and Fyn) runs from 55° N at the German border to 57° 37' at the tip, Skagen. Thus, from South to North, West Denmark occupies the same latitudes as the UK does from Sunderland to the Moray Firth.

The climatic conditions and land use of West Denmark and the UK are similar. As in the UK, the West part of the country is "windier" and the relatively empty northwest is home to the most intense population of wind generators.

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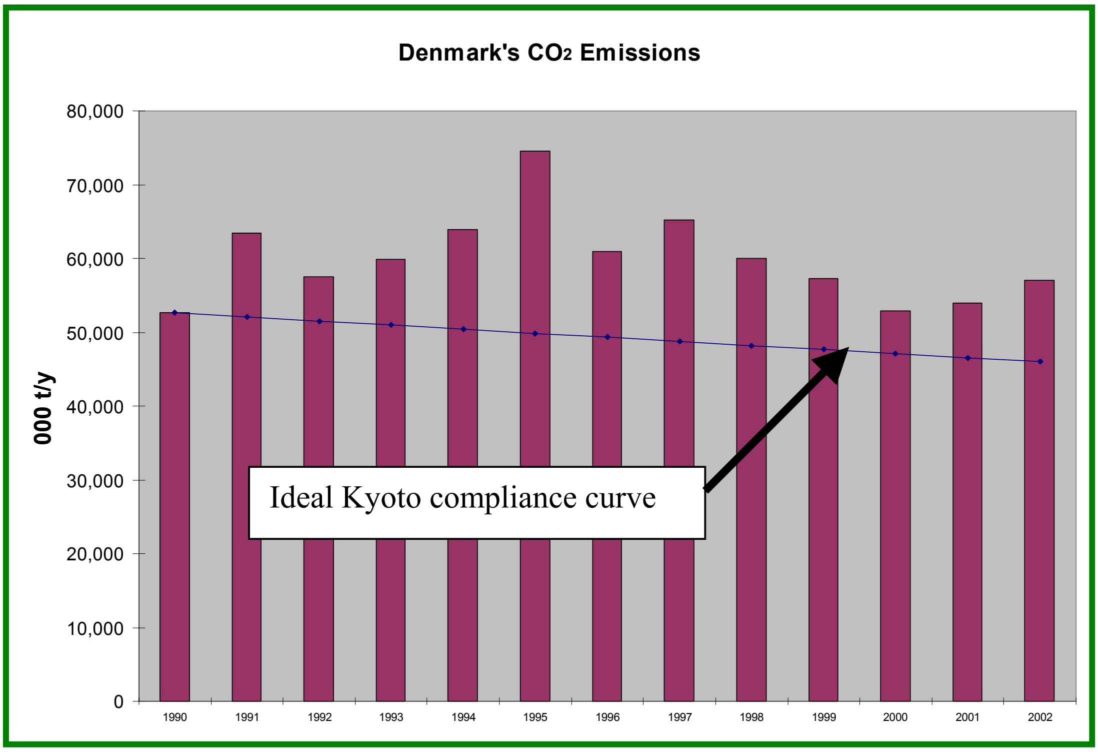
It is the writer's argument that the intense development of wind in Denmark holds lessons for what is now happening in the UK.



Despite its enormous efforts, Denmark's CO_2 emissions, after falling from 1995 thro' 2000, have been rising for the last two years, illustrating how even with best efforts, CO_2 emission reduction remains a stubborn challenge.

The UK Government has mandated that by 2010, 10% of all kWh will be generated from renewable resources and aspires to raise this to 20%, by 2020.

Legislation is in place, which rewards (ie. subsidises) the huge investment, which will be needed to achieve the 2010 objectives, although, after 2010, there is some doubt that "obligations" mean that when they are really "aspirations".

The writer contends that there are so many similarities, if important differences, between Denmark and the UK, that West Denmark's experience provides many important indicators for the UK's renewable energy road map, including its technical and economic feasibility. West Denmark's experience is extraordinarily well documented, so that all the data presented in this article is empirical and trustworthy.

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UK and Denmark, Similarities and Contrasts

Denmark is a prosperous nation and enjoys a high quality of life. In the Western part, six large CHPs provide heat to the district heating of the main towns during the winter. Typically, during the winter CHP ensures an overall fuel utilization of over 90%. Two of these have the distinction of being among the most fuel efficient, coal-fired power plants in the World. Danish houses are well built and fuel-efficient.

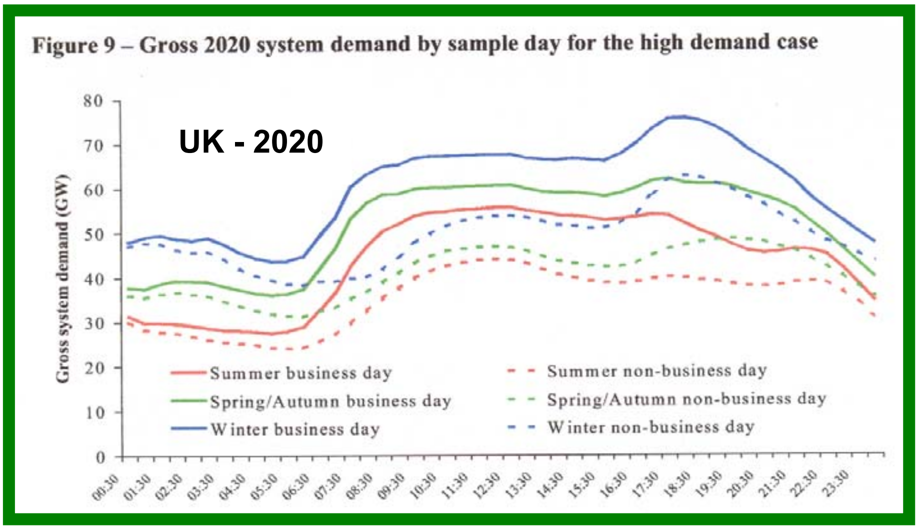
Like the UK, oil and gas from the North Sea has recently made the country independent in hydrocarbons but also vulnerable to the steep decline of production expected to occur during this decade.

In contrast, there are important differences between the two countries.

While both Danish transmission systems are strongly interconnected with their neighbours, Norway, Sweden and Germany, if not to each other, the UK has an ageing, single interconnection with France amounting to a full load capacity of only 2,000 MWe. This means that the UK is, to all practical purposes, an "island" system where generation follows demand. This difference allows the Danish system operators much more flexibility than their UK counterparts.

These differences are important, as we shall see.

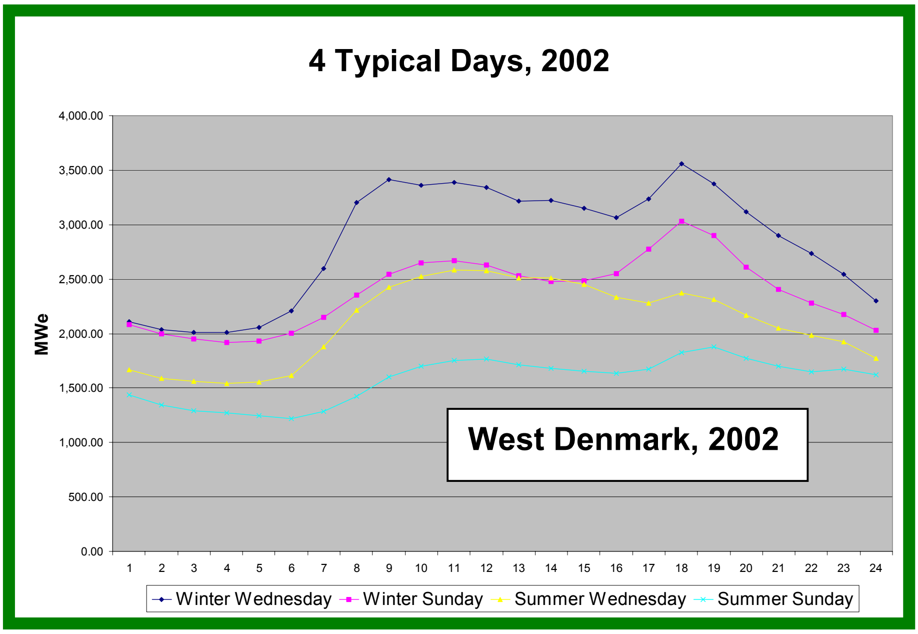
Power Use in UK and West Denmark



This diagram is taken from the report *Quantifying the System Costs of Additional Renewables in 2020*, prepared for the DTI by *ILEX Energy Consultants.* It was published in October, 2002.

The diagram anticipates power demand during 6 typical days in 2020 and is based on the Government's expectations of continued growth in electricity demand.

The ratio between peak demand on a winter, business day and a summer, non-business day is about 2.



This diagram was computed by the author from 4 typical days in West Denmark, during 2002.

Just as in UK, the ratio between peak demand on a typical business day in the winter and that of a typical weekend during the famous Danish summer holiday, is about 2.

The shapes of the curves in UK and Denmark suggest that power use patterns are alike, reflecting similar work and recreation patterns.

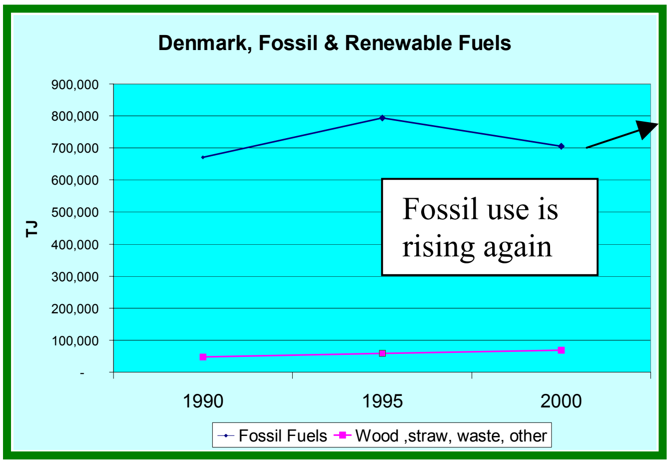
The Danish generating system became grossly "over-built" during the 1990s. There is 6,850 MWe of capacity (including wind) to meet a winter planned peak of 4,100 MWe but an actual peak, during 2002 of only 3,700 MWe. In other words, there is a nominal margin of capacity over peak demand of roughly 3,000 MWe, or 81%. The UK system, by contrast, although generally regarded as "over-built", has a 2002 capacity of 73 GWe and a 2002 peak of roughly 59 GWe. This gives a margin of 24% over peak demand. Recent winter peaks were achieved with no loss of supply but many in the industry considered it a "close run thing".

Because of its interconnectors, and the current lack of generating capacity in Sweden and Norway, caused by a year long drought, Denmark's over capacity is troubling the Danish generators much less than one might expect. During the past six months, everything that can generate power, is running to make up the hydro shortfall. The interconnectors allow some flexibility between domestic consumption and generation. By contrast, the UK's domestic consumption is more or less balanced by its generation.

For all the foregoing reasons, the writer feels able to use the West Denmark demand curve as a reliable indicator for how UK wind will impact the UK system in 2020.

This argument may possibly be over-simplified but at least the Danish evidence is empirical.

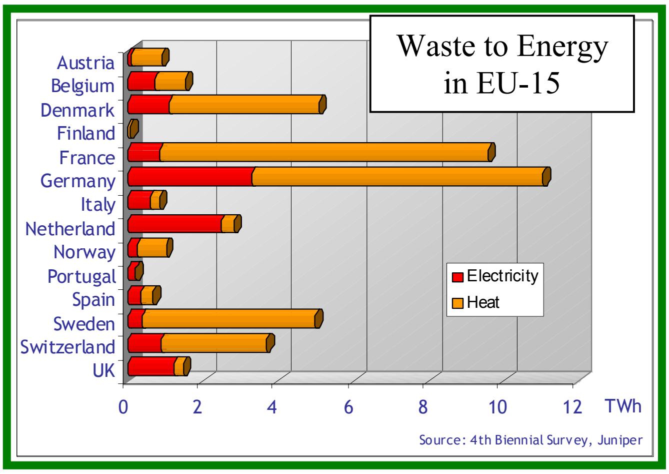
Denmark's Use of Biomass and Waste for Energy



Along with the development of wind energy, Denmark has also poured money and effort into the development of energy based on the use of biomass. A wide range of applications are in use, although applications for heating are in wider use than those for power generation.

The writer's town in North Jutland has been district heated with straw from local farmers since 1986.

The increasing use of biomass during the 1990s had some effect on the use of fossil fuels, as the chart shows. But the drought in Norway and Sweden, resulting in sharply increased exports of electricity since 2000, has resulted in a reversal of this trend.



This chart from Juniper's *European Incineration Profile* (2002) demonstrates that despite being a country of only 5.4 million inhabitants, Denmark has an installed, working capacity of waste to energy plants that is higher, per capita, than any other EU country.

The financial rewards given for the replacement of fossil fuels by such renewable resources is such that currently, it is actually profitable to import dried wood chips from the Baltic countries for combustion in Denmark. This is not only irrational from a total life cycle point of view but also illustrates that little more can be done to raise Danish biomass use for energy without adversely affecting agricultural production or the countryside balance.

In this context, it is worth noting that Denmark is sparcely populated by comparison with Britain so hopes of sourcing as much as 30% of Britain's future energy needs from biomass do not appear to be at all realistic.

Accordingly, it looks as if most of the UK's 2020 aspirations will have to be met from the further development of wind. In view of the well established difficulty of getting popular consent for the building of land based wind farms, most of the wind contribution will have to come from offshore plants.

Tidal stream, wave and other nascent generation technologies, while promising, are not anywhere near commercial as this is being written. These could possibly make a great contribution later in the century but not by 2020.

So this article will now concentrate on the parallels between wind experience in Denmark and what a similar wind contribution will do to the UK transmission, distribution and generation system.

The Energy Contribution of Wind in West Denmark

In West Denmark, during 2002, 3,381 GWhe were produced from about 2,300 MWe of nominal installed wind capacity.

This translates to 0.167 MWhe per year per MWe of installed capacity – or a "power factor" of 16.8%.

This figure is much lower than is generally quoted in the literature but represents the real life experience of the World's most advanced "wind" nation. 1,800 out of 2,315 MWe of the country's wind turbines are prioritized dispatchers of generated kW.

On the other hand, the actual peak wind output in West Denmark, during 2002, was only 1,813 MWe (23 January), despite the nominal capacity being 500 MWe higher. Against this output, peak figure, the load factor of the West Denmark wind carpet rises to a more respectable 21.4%.

This appears to show that an average of 500 MWe of wind capacity was permanently out of service during the whole of 2002. As can be seen, almost the whole of the West Denmark capacity is new and almost no single machine is more than 15 years old. It appears that these machines are less reliable than is often touted. And even the new machines are producing much, much less power than their proponents appear to claim.

Most private and public literature claims that "full load availability" of wind turbines on land in UK is around 30% and for those offshore is around 50%. These optimistic figures may be the reason why the UK's policy planners seem to believe that 27 GWe will provide 20% kWhe in the 2020, 70 GWe peak, system.

But the facts seem to be otherwise. It looks as if the UK will either have to accept that 27GW of wind capacity will likely only provide 12% of kWh, or that the system will require up to 50% more capacity than presently foreseen. If another 15 GW of capacity is to be built, the hitherto, unforeseen capital cost increase of generation alone is in the region of £10 – 15 billion.

The implication of this for private investors is dire. The actual income from wind machines could be up to 50% less than anticipated. This shortfall should also worry the banks that lend to the developers and operators.

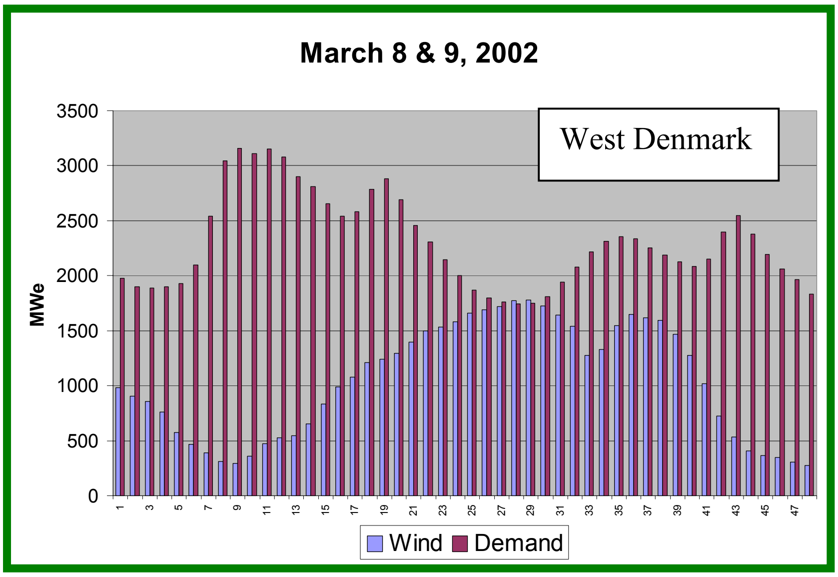
It may be argued that the largest concentration of UK machines will be built offshore, that each machine will be much larger than the average built in Denmark and that the technology will be superior. However, the fact is that in 2003, there is only one substantial offshore wind park in the whole World. This is the Horns Rev wind farm, built by Elsam, 15 km offshore West Denmark. In the Spring of 2003, this is only now being commissioned. It took 6 years of planning and included a delay and considerable cost over-run by the contractor. The commissioning has been far from smooth.

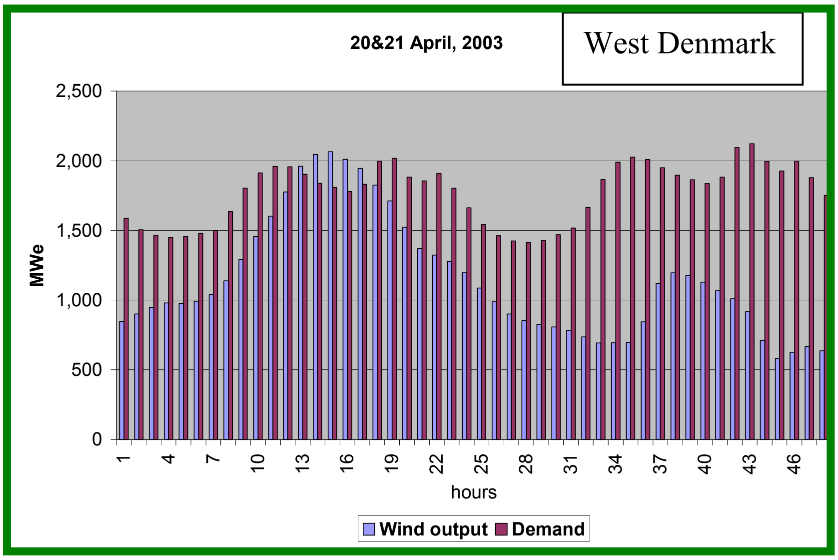
It follows that if (big IF) the full 42 GW gets built, the estimate for system costs, made in the ILEX report, already regarded by some as optimistic, could be under estimated by 50 – 100%. After all, if most of the new capacity is offshore, the national grid, which is built to connect large fossil-fired power plants close to population centres, will need to transmit 40 GW from areas of Britain which are in many cases, connected by tiny transmission lines, if any. A case in point are the huge wind farms mooted for West Scottish islands whose interconnectors today are a few MW at most.

Furthermore, nearly all the UK's experience with wind machines has been on land. The first offshore wind farms are unlikely to be commissioned before 2006. So it might be prudent to take a conservative rather than an optimistic view of how much new capacity might be built, and where and how it is to be integrated into the UK system.

How 42 GW Wind Generation Capacity will Interact with the Rest of the UK System

Challenges for TSOs and Generators





From here on, the writer will assume that by 2020, 42 GWe of wind capacity will be in place and that extrapolated data from West Denmark will provide direct and concrete examples of the types of challenges which are likely to be faced by the UK TSOs and the thermal generators.

The example chosen in this chart is the hourly record of what happened during 8 and 9 March (a Friday and Saturday), 2002.

At between 2 and 4 am, on Saturday morning, wind output exceeded all consumption. This is an extreme but not isolated example.

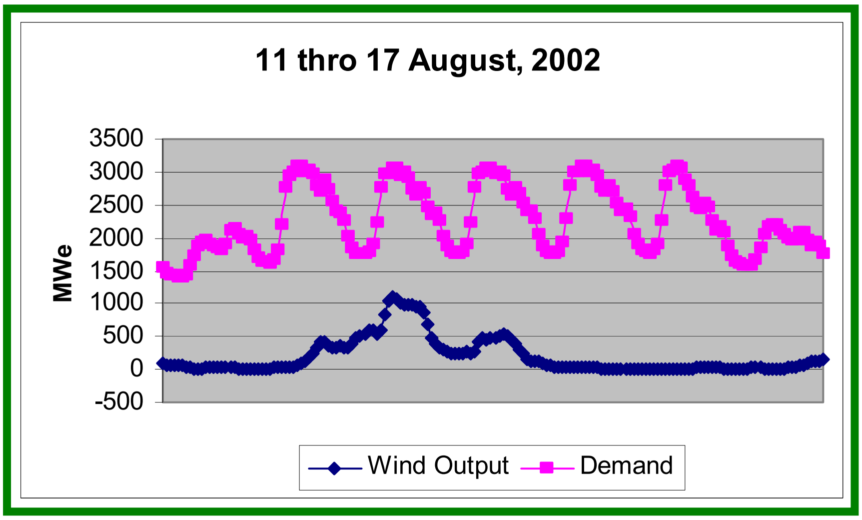
A similar event took place this year (2003) in April.

It is fair to ask how the UK transmission and generation system can be modified in time to meet such a challenge.

The UK's 2003, thermal capacity is composed of nuclear, coal and gas-fired plants, with a sprinkling of CHP. There is a single interconnector of 2,000 MWe, connecting UK to France which has been out of service for much of this year. Even if it were reliable, this amounts to just 3% of UK's 2002 peak load of 59 GWe.

The writer cannot even begin to imagine how such a wind load imposed on today's UK electrical infrastructure might be addressed. Yet from an "infrastructural" point of view, 2020 is just around the corner.

Can Wind Supply any Firm Capacity?

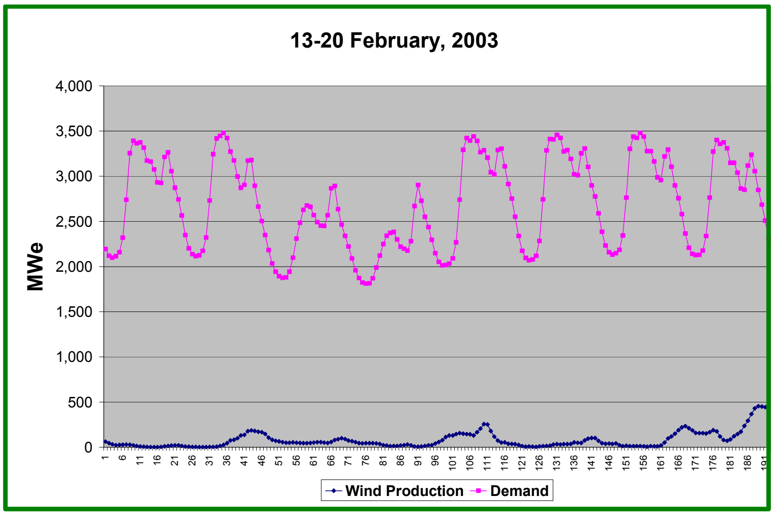


In West Denmark, there were 54 days in 2002 when wind supplied less than 1% of demand.

One day (16 August) there was negative output as the wind power system "steering requirements" exceeded wind output.

The ILEX Report suggested that the UK can expect to obtain some firm demand from a large wind power system, spread over the length and breadth of the UK.

West Denmark is smaller than the UK but, as described in the introduction, still covers



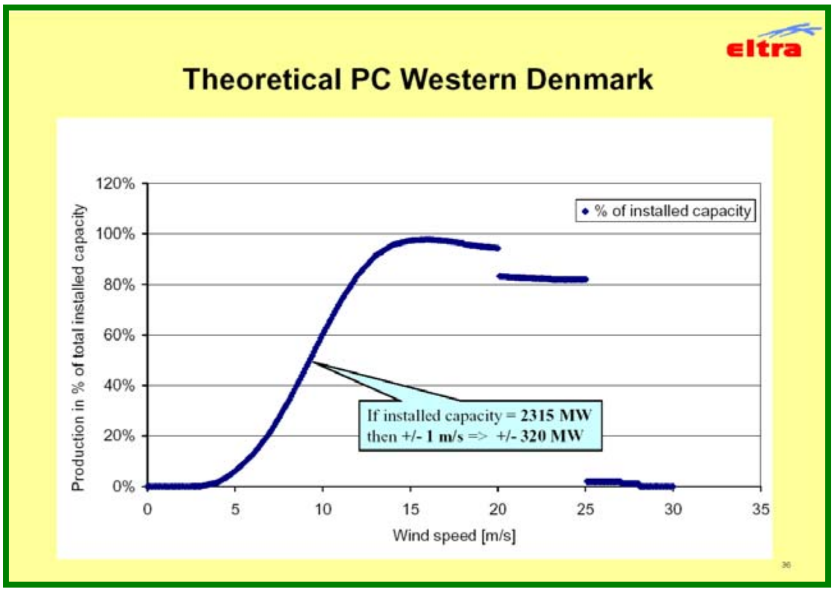
the latitudes from Sunderland to the Moray Firth.

February, 2003, was cold but relatively windless. A whole week went by when virtually no wind power was generated in West Denmark.

So it is probably imprudent, even naïve, to place too much hope in the likelihood that the UK, because of its larger size and more westerly geography, can expect firm demand, even arising from 42 GWe of wind capacity. If the wind does not blow, no power can be generated.

Paradoxically, if it blows too much, no power can be generated.

Does More Wind mean more kWhe?



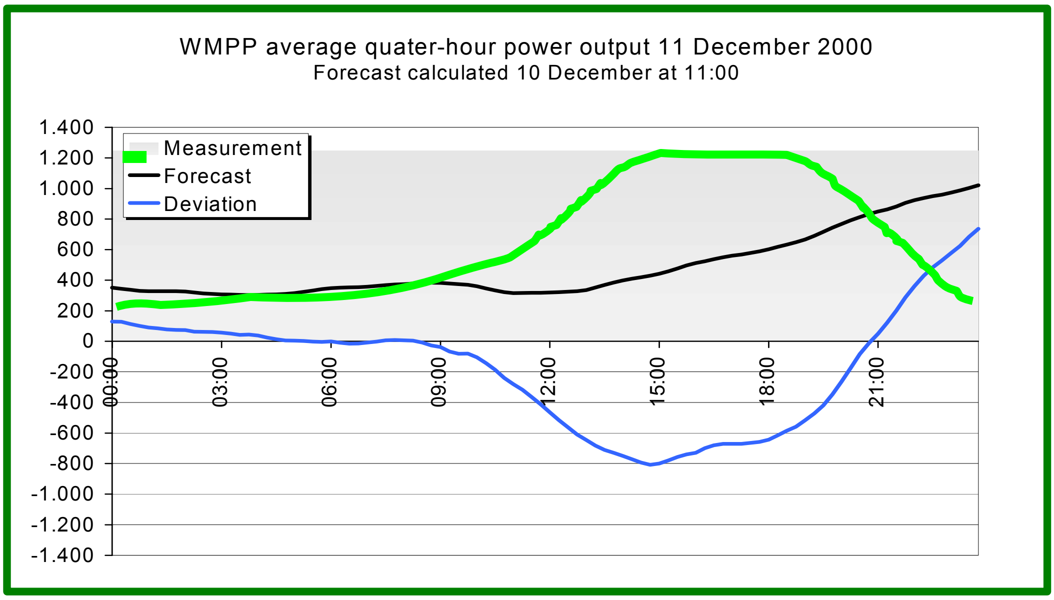
This power curve, by courtesy of ELTRA, illustrates the reality of operating the modern wind machinery on which UK hopes are founded.

Although, the energy in the wind is raised by the third power according to its speed, the actual output of a commercial, production machine is more or less linear between a wind speed of 5 m/s and 13 m/s.

Above this speed, the wind output of the Danish system, of 4,700 machines integrated into the grid, levels off and at 20 m/s (45 mph) stalls altogether for many machines in the system.

Most modern turbines are designed to operate above this speed with a 20% lower output and even these are turned off completely when the wind speed exceeds 25 m/s (56 mph).

Some play is made by the UK wind lobby of the fact that isovents in the UK, particularly in the western and northern parts, reveal Britain as “the richest wind resource in Europe”. What this means is that in the areas where there will be the greatest concentration of wind farms, they are also more likely to be suddenly turned off than in other parts of Europe, raising interesting questions of how thermal plants are supposed to respond!



The difficulty of forecasting the weather is not confined to the UK. In order to accommodate demand, it will be necessary to cycle thermal plant according to wind output.

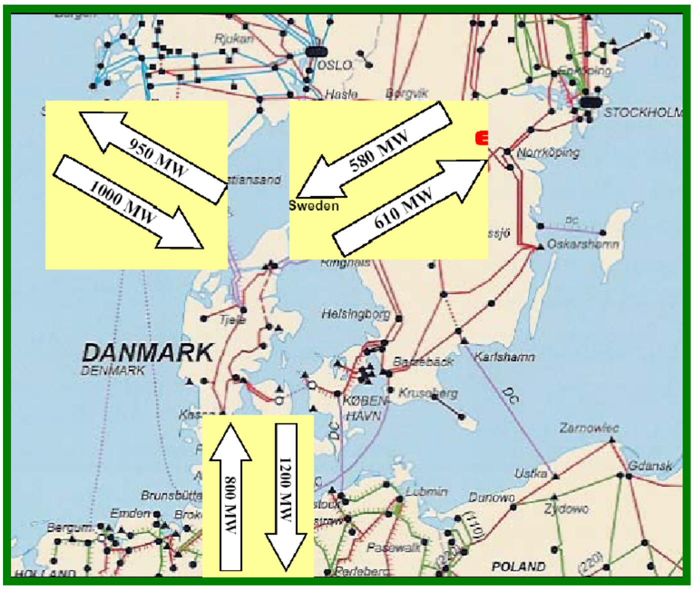
The chart shown here illustrates a "bad" day for Danish weather forecasts. This is not exceptional however.

The chart in the foregoing section indicated that in West Denmark, the small difference in wind speed of just one metre per second amounts to a difference in output (rise or fall) of 320 MWe.

In the UK, 2020 scenario, the change in wind output of one metre per second in a 42 GW wind system would amount to 5.8 GWe, or the rough equivalent output of Drax power station, Europe's largest thermal plant.

The writer respectfully suggests that little thought (given the lack of public debate) has so far been given to the practical implications of controlling such cycling. In Denmark, such differences are balanced with the neighbours. In UK, such cycling must be met by plant simply not designed to cycle.

Location, Location and Location

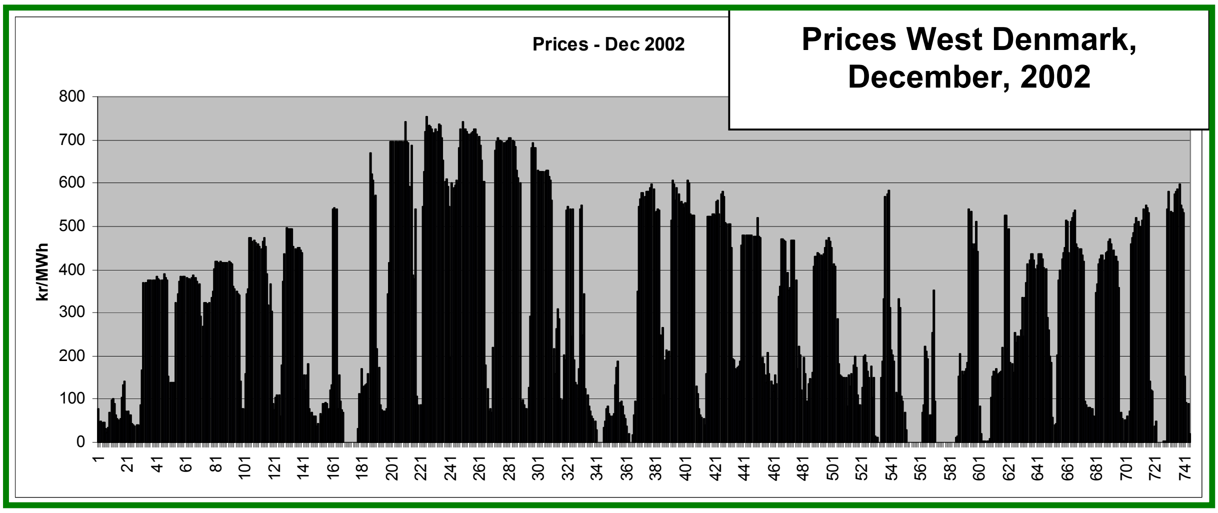


All the power systems around West Denmark are bigger than its own. Wind surges (and still days) are managed by export and imports to and from Germany, Norway and Sweden. The whole of the Norwegian and half the Swedish generation capacity is hydro, so the management of sudden load change is relatively easy.

It may seem that this blissful state of affairs is another example of wonderful Scandinavian foresight. In fact, the interconnectors were already installed when the "dash for wind" started and the ability of the Danes to manage their over capacity, while skilled, is quite fortuitous.

However, the UK (and Ireland) have not the geographical advantage of Denmark.

The huge wind surges characteristic of large wind systems simply can not be accommodated in the UK, island system at the same time as maintaining reliability



The Nordic electricity market consists of Finland, Norway, Sweden and Denmark. It is one of the most liberalized in the World. Thanks to the interconnectors, power flows freely from low cost producers to the market without impediment.

In a system where output can be planned, this works to the theoretical advantage of all.

As the foregoing chart illustrates, during December, 2002, the most "windy" month of the year, the Danish consumers paid for huge amounts of power to be exported to its neighbours at often no cost at all.

The situation is exacerbated by wind arriving at times of least power demand (such as at the weekend, early in the morning) and by the element of "surprise".

ELTRA has used enormous resources to improve the accuracy of wind forecasting so that surprise can be planned out. Nevertheless, wind forecasting poses a real challenge.

It is possible that during the next ten to fifteen years, wind forecasting will cause events like the one shown in this chart to become rare.

Nevertheless, the huge effect wrought on the power system by small, unexpected changes in the weather should be of particular concern to an island TSO and the thermal generation industry that has to live with the effects of more uncertainty.

Conclusions

1. The present UK Government is convinced that present policies will encourage the construction of sufficient new, renewable power capacity to provide 20% of all generated kW in 2020. Based on Danish experience, it is unrealistic to believe that much more than a small fraction of this can be met from biomass. Other new methods (waves, ocean currents, tidal barriers, etc.) are all either at the earliest stages of technical development or themselves carry enormous environmental implications. Against the evidence, it believes that this demand can be supplied by about 27 GWe of new, wind capacity. The evidence of West Denmark suggests the 20% target requires up to 42 GWe of new wind capacity. This is equivalent to 21,000 giant, 2 MWe turbines. The foreseen investment shortfall for generation only is up to £15 billion.
2. It follows that the UK has not properly estimated the technical realities, visual implications and financial cost of tying this large, new capacity, mostly to be built on the Western fringe of the UK, to the bulk of electricity consumers in England's South East and Midlands.
3. Even if built, this huge investment is unlikely to provide any firm capacity. Each kWe of wind energy will require a kWe of firm, conventional capacity to be built. The costs of doing this do not seem to be accounted for in the Country's plans.
4. If built, the absence of adequate interconnectors to other industrial countries, 42 GWe of new wind capacity will pose enormous challenges to the existing thermal and nuclear generators, for which there is no obvious solution.

5. The extra wind available in Western areas of the UK is as likely as not to result in sudden shut-downs as in extra production, posing additional challenges to the transmission system and the operators of conventional generation equipment.
6. 42 GWe of prioritized, subsidized, wind power will impose deep uncertainties into a power trading system that is already bankrupting many generators, unable to cope with relatively conventional challenges.
7. Despite the subsidies, many investors and their banks are likely to lose money as the generators produce many fewer MWh than their forecasters are telling them.

The 20% renewables target for 2020 is seen as a milepost towards a much more ambitious, 2050 scenario, where the even more widespread use of renewables should result in a 60% reduction of CO_2 emissions. The experience of West Denmark seems to suggest that it may be timely to review all such figures against the most likely realities, only a few of which have been raised in this article.

Not mentioned in this article is the disillusion felt by many Danes with the tiny benefits brought by wind against the irreparable desecration of a landscape of dunes, heath and heather, at enormous, un-retrievable cost. Where is there space in the UK to build 21,000 monsters where that space must also be in a “premium” wind site? What happens beyond 2020?

Would it not be cheaper and practically more feasible to legislate for saving power? Power is essential for tasks like lighting and machinery use, but huge savings are technically possible in this area already. Is it not old fashioned to use electricity for space and water heating? Saving power consumption for vital tasks would lower the awesome investment targets for 2010 and 2020, while reducing CO_2 emissions simultaneously.

Should there not be legislation to encourage investment in energy storage systems? If these existed on a Nation-wide scale, wind surges and the like, highlighted by West Denmark’s current experience could be absorbed without damaging market price.

Even with a reduction in wind targets, a crash programme of interconnecting, sea cables with France, Netherlands, Germany and the Nordic countries needs to be implemented, so as to improve whole system reliability while allowing more flexibility in an island system where intermittent wind surges could otherwise impose irresolvable problems for the thermal (read reliable) sector.

The writer is no enthusiast for nuclear power but no serious research of this technology has taken place in the UK during recent years. Despite their problems, the investment in working nuclear reactors is sunk capital and these supply 25% of today’s MW, with hardly any emissions of CO_2. It is unwise in the extreme to jettison this technology for the foolish reasons advanced by many “environmentalists”.

In short, before much more damage can be done to the UK landscape, old fashioned, British pragmatism should take over from the fevered debate taking place. There is an energy crisis ahead for the UK. But facile chat about how renewable energy can address this will make this, when it arrives, much, much worse, not better.

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The Author

Hugh Sharman was educated at Howardian High School, Cardiff and Imperial College, London (Civil Engineering, 1959 – 1962). His early professional experience was gained in offshore construction. This included a stint in the Persian Gulf, during the 1960s when he became aware of the finite nature of fossil energy resources. He has also lived and worked in UK, France, the Caribbean and South America. He is owner and director of an independent energy consultancy, specialised in the energy and environment sector and has been resident in Denmark since 1986.

During the 1970s he became involved, disastrously, with renewable energy exploitation and has followed this sector with interest, ever since

Most of Incoteco's work is done for and with large energy companies, seeking innovative environmental solutions to practical problems.

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