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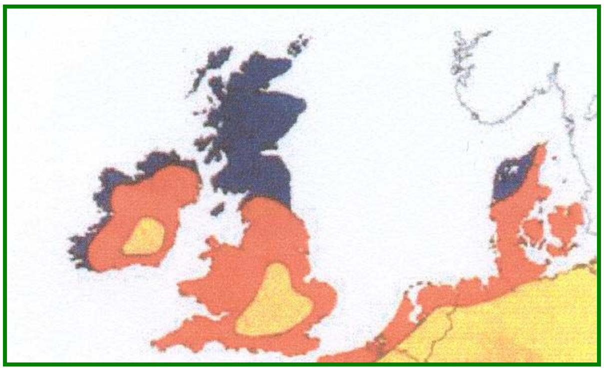
THE PRACTICALITIES OF DEVELOPING RENEWABLE ENERGY IN THE UK – IN THE LIGHT OF DANISH EXPERIENCE

1. Summary

I am a citizen of the UK who lives and works in West Denmark. I am an independent energy developer and consultant.

There are two unconnected electricity systems in Denmark, East and West. West Denmark has a highly developed renewable energy sector. This includes heavy use of biomass and waste and the World's largest, offshore wind farm. It is likely to achieve a "wind output" equivalent to 21% of its local consumption this year, 2003.



West Denmark has therefore, already achieved the goal which the UK aspires to in 2020 and is by far the most "wind power intensive" region on Earth. Its proximity and shared latitudes with the UK and the large contribution that its wind turbine manufacturers will make to the UK's wind energy portfolio, make its experience with wind energy highly relevant to the UK.

Critically, for the arguments advanced in this submission, it would appear that the wind régime in Denmark is broadly similar to that in the UK.

However, it appears to me that with regard to the most crucial issues, being the actual performance of the West Denmark wind carpet, this experience is largely being ignored.

In this article, I argue that H.M.G and its advisers ought to look critically at experience in West Denmark and adjust its plans and expectations in the light of that experience.

These plans are based on the hope that the UK wind carpet, when it is built, will deliver 175 % more energy for each MWe of installed wind capacity, than its Danish equivalent. That is to say, the average, planned load factor (LF) of the UK wind carpet is 35%[1]. LF is only 20% in West Denmark. I therefore find the arguments underlying the UK's technical and economic assumptions about wind optimistic but deeply unconvincing.

From its assumption of high LF, arises an optimistic estimate that only (sic!) 26 GWe of wind power can deliver 80 TWhe per year by 2020, or 20% of the 400 TWhe which planners expect will be consumed in 2020[2]. If I am right, and needed capacity turns out to be closer to 40GWe, there has also been a serious under-estimation of the infrastructural costs needed to support the amount of wind capacity which can actually deliver the Government's aspirations.

It is not the purpose of this paper to replace the estimate for UK LF with my own. But, as an example, I point out that even if the UK wind carpet performs 25% better than its West Denmark equivalent, it will need to build 36 – 37 GWe of wind capacity and strengthen the transmission and distribution network at a cost 50% greater than that which is foreseen by current budgets. The money "missing" is enormous, amounting to a figure between £14 and £20 billion.

I have provided you with a few "snapshots" which show how West Denmark's relatively large wind carpet actually delivers power and go on to demonstrate that total system breakdown in West Denmark is avoided only because the size and strength of its interconnectors with its much larger neighbours.

By contrast, the UK grid system is virtually an "island". So I show how a large UK wind carpet will make it enormously difficult to cope with the "peaky" nature of wind, given the type of generation which provides firm capacity today.

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[1] . If a 1 MWe wind generator produces 8,760 MWhe in a year, its load factor would be 100%. If it produces 4,380 MWhe, its load factor would be 50%. Etc.

[2] . *Quantifying the System Costs of Additional Renewables in 2020*, ILEX Energy Consulting and Goran Strbac, 2001, herein after referred to as "The ILEX Report"

I further show how wind provides no "firm capacity" whatever in Denmark and remain to be convinced that it can do so in the UK, notwithstanding the views of the DTI and its advisers.

I conclude that HMG has over estimated the benefits of wind and grossly under estimated its cost and the technical difficulties of adjusting its existing system to a wind carpet which can deliver on its aspirations. I go on to suggest that if it is serious about wind making a significant contribution to future generation capacity, it will need to find ways of storing and releasing surplus power on a huge scale, hitherto unconsidered. This will require very amounts of money and much more time than currently being considered.

Finally, at the time of formulation of this paper (September, 2003) there are 3,700 days in all, until the 1st January, 2010. Even 13,000 MWe of new wind capacity will require roughly two very large machines to be erected every day, weekends and holidays included, until the end of the decade. This is and always was quite unrealistic. The policy is resulting in an unseemly and impractical rush where other legitimate concerns of citizens are being trampled under foot, and other, realistic energy sources are being ignored.

My summarised recommendations are that HMG should:

1. Urgently and deeply review its plans and budgets for renewable development, in the light of the experience of others
2. Review its apparent desire to abandon nuclear power
3. Pursue carbon sequestration from clean coal-fired power plants, existing and yet to be built.
4. Pursue every possibility of energy conservation, in every energy-consuming arena, so as to reduce the unrealistic requirement for more and more energy consumption
5. Assess and review all possibilities for energy storage
6. Assess and pursue the possibility of strongly interconnecting the UK with its neighbours in Europe at a scale previously considered unthinkable

I am therefore pleased to provide the following, more detailed, analysis of West Denmark's experience and its lessons for the UK, as testimony for your committee's consideration.

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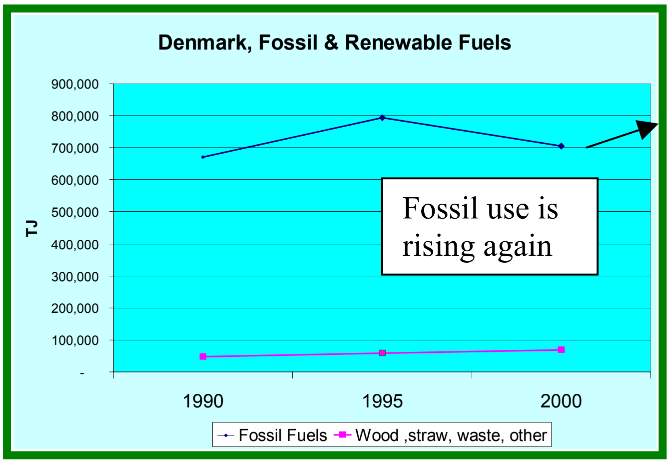
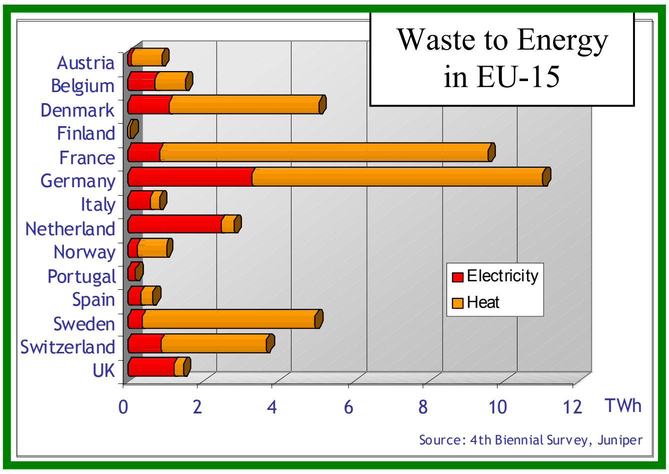
2. What mix of renewables can be relied upon to provide H.M.G.'s targets?

2.1 Denmark's Use of Biomass and Waste for Energy





Along with the development of wind energy, Denmark has poured money and effort into the development of energy based on the use of biomass. A wide range of applications is 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 current drought in Norway, Finland and Sweden, has resulted in sharply increased exports of thermally generated electricity since 2000 and fossil fuel use is rising again.

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.

However, despite this, its contribution of 1 TWhe of power amounts to only 3% of the country's consumption.

The financial rewards given for the replacement of fossil fuels by 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 sparsely populated by comparison with Britain so hopes of sourcing as much as 30% of Britain's future energy needs from biomass, without affecting food production or drastically altering the countryside's fauna and flora do not appear to be at all realistic.

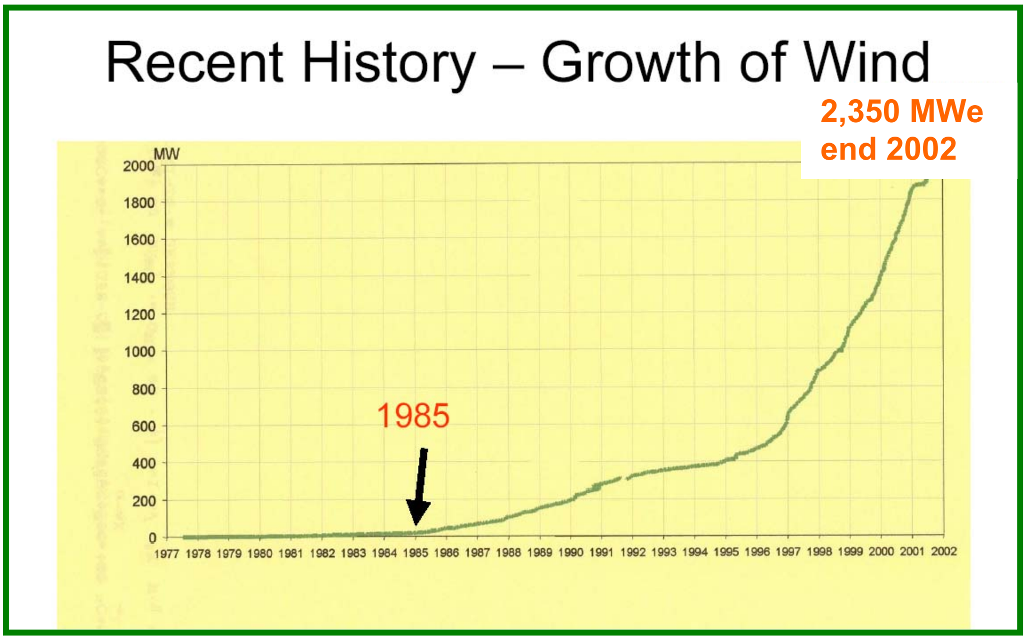
Accordingly, it looks as if most of the UK's 2020 aspirations will have to be met from the further development of wind. In view of the well established difficulty of getting popular consent for the building of land based wind farms, most of the wind contribution will have to come from offshore plants.

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.

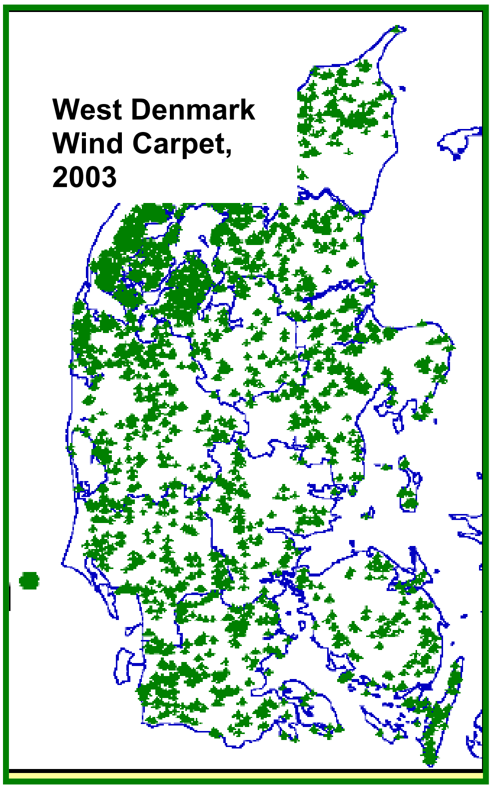
2.2 West Denmark's Existing Wind Carpet & the UK's Future Wind Carpet

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 1500 MWe. This is about 50% of the 3,100 MWe, which can be produced by the six, central CHP power plants that supply 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 looks as if it will increase to 21%, or so, during 2003.



In 2003, there are about 4,700 wind generators with a total, nominal capacity of 2,350 MWe (according to TSO ELTRA).

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. Extrapolated to the UK, this would amount to about 100,000. West Denmark is therefore the most intensely wind mill populated land on the planet.

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.

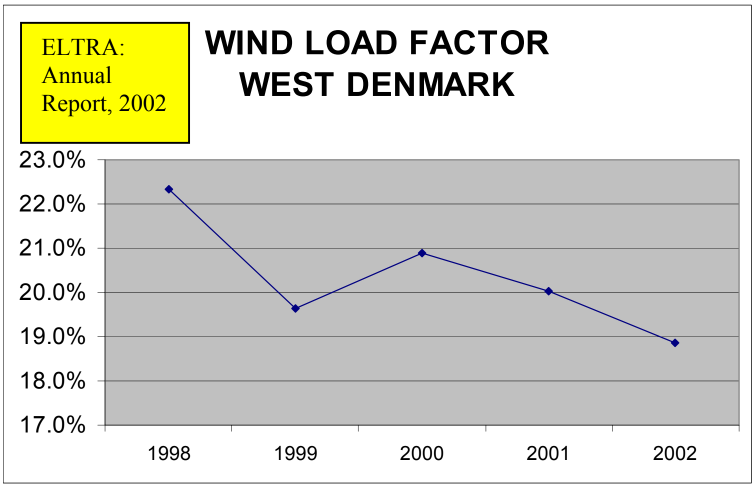
The physical extent of West Denmark (Jutland and Fyn) runs from 55° N at the German border to 57° 37' at the tip, Skagen. Thus, from South to North, West Denmark occupies the same latitudes as the UK does from Sunderland to the Moray Firth.

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

Danish suppliers are already delivering a large fraction of the UK's wind generators. It is therefore reasonable to expect that the performance of the Danish and future, UK, wind carpets will resemble each other.

2.3 Wind carpet Output of UK and Denmark Compared

The "load factor" (LF) is a universally accepted measure of how much power a wind generator will actually deliver in relation to its capacity. It is calculated by dividing actual output (MWhe) by the product of rated output (MWe) and 8760 hours per year.



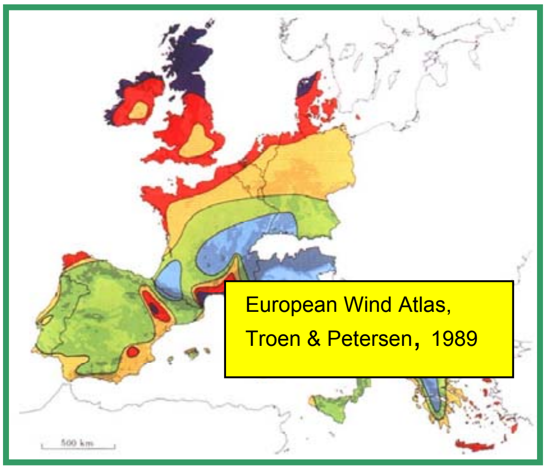
In Western Denmark, LF is hovering around 20%. This is dramatically less than the 35% LF which is used by the UK Government and its advisers. LF is used to calculate how much any installed wind capacity will actually deliver.

The actual experience of West Denmark is based on a statistically significant number of carefully monitored machines, nearly all of which have the highest dispatching priority. This means that if the wind blows and the wind machine is working, the power will be purchased.

By contrast, the statistics gathered from the UK wind farms is from a statistically insignificant number of machines, for a much shorter period and suffers from a lack of rigorous collection. I have been told that many wind operators do not keep the DTI up to date on their actual output, leaving them to guess output.

I have sought to explain the wide disparity between the hard statistics of Denmark and the planning assumptions made for the UK. Obviously, the actual LF achieved will determine how much capacity must be built in order to achieve the UK's targets for a renewables contribution.

Various explanations have been given, among them that the UK is "windier", that the UK wind carpet will have "more efficient" machines and that a high proportion of the UK's wind carpet will be built "offshore" where the load factor should be higher.



It is incontestable that in parts of the United Kingdom, the average wind speed is higher than much of Western Denmark. But it also appears from the wind map that the overall differences should not be significant.

The Wash and Thames Estuary, where the first tranche of large offshore wind parks are planned, are not notably "windy" and it would be surprising if wind output at these locations exceeded the expected output of the Horns Rev wind farm, 15 km offshore from S. W Denmark, where one reading of the expected load factor is 42%[3] and another reading is a bit over 30%[4].

One suspects that these sites have been chosen because of the comparatively benign construction conditions, being shallow water in the lee of the prevailing South West winds. And the proximity of a significant market for the power.

Overall, it looks as if the most fundamental planning assumption of the UK's Renewable programme is deeply flawed. Any deviation under a wind carpet average LF of 35% will increase the risk that estimates for power generation capacity, added transmission, strengthened distribution equipment etc. will be wrong, in direct proportion to the

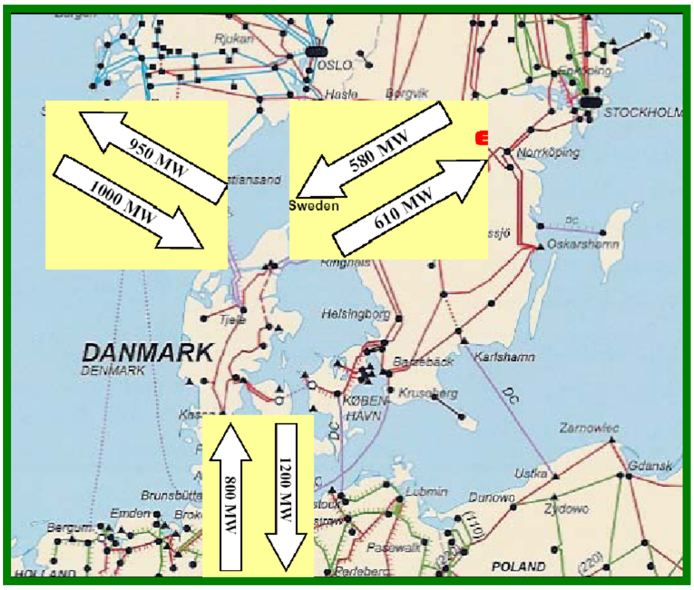
[3] . Elsam hopes that output will be 600 GWh per year from 180 MWe, or 42% LF.
[4] . Average load LF on land is about 20%. Elsam expects offshore wind farms to "produce 50% more power" than onshore installations, i.e. 30%. For both statements, visit www.hornsrev.dk . This wind farm started commercial operation in early 2003, so no statistically significant output data is yet available.

deviation. For example, a figure closer to West Denmark's LF of 20% will require 75 % more expenditure than is currently foreseen.

3. How to Balance the Power Grid?

Unless the transmission system in UK is transformed during the next 17 years, it will remain, to all intents and purposes, the “island” system it is today. Today, load generated track demands in the UK. The small fractions of total load and demand, which are balanced by the 2,000 MW interconnector to France, are “at the margin”. The French interconnector represents only 3.5% of today’s peak load.

An additional complication is the limit on the interconnector between Scotland and England.



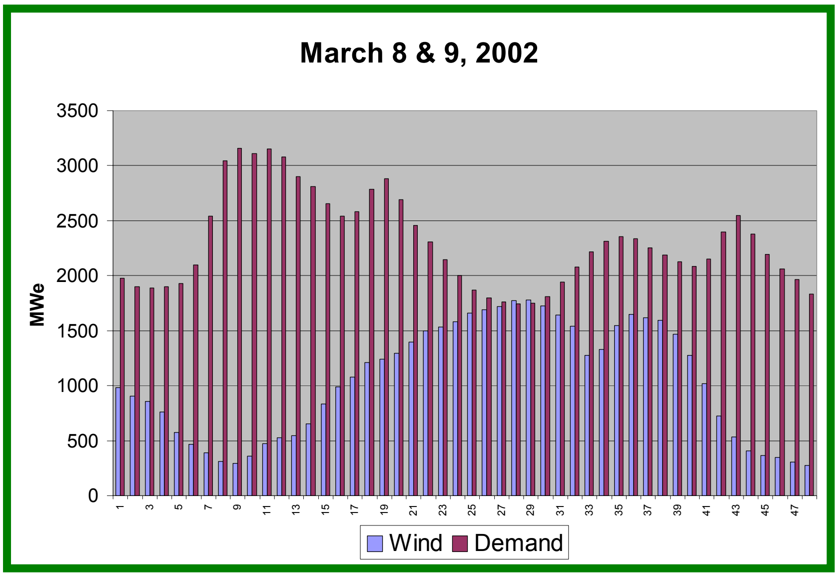
By contrast, Denmark is strongly tied into the much bigger grids of its neighbours in Sweden, Norway and Germany, having a total interconnector capacity of 2,400 MW. This is 2/3 of peak winter demand, or, interestingly, about the same as its wind capacity.

It is as if the UK, today, were blessed with 40 GW of interconnections with France, Netherlands and (say) Norway.

West Denmark’s 3.8 million MWhe of wind power generated during 2003, came from 2,315 MWe of capacity. Thus, wind energy output was equivalent to 18.7 % of power demand. This year, 2003, with the commissioning of the Horns Rev, offshore wind farm, and capacity rising to 2,350 MWe, it is expected that this figure will rise to a shade over 20%.

Thus we see that the wind capacity needed to achieve this number is 62% of peak winter load and 85% of peak summer demand.

The UK Government foresees that in 2020, 26 GWe of wind power will provide 80 TWh of electricity which is 20% of the foreseen demand of 400 TWh. As mentioned, this assumes an LF of 35%. It is my view that this is unrealistic, for the reasons stated. I do not claim to know what actual LF for a UK “wind carpet” is likely to be but suggest, for the purposes of the following argument, that 80 TWh per year could be provided by a capacity of about 37 GWe, at an LF 25%. This is a generous 25% better than West Denmark’s LF of 20% - but still hypothetical.



I argue that the wind that blows over Denmark will blow over the UK in a similar manner. The load-time curves in UK and Denmark are very similar. So it is valid to predict how a similarly large wind capacity will behave within the UK’s “island” grid system. The effect should be, more or less exactly proportionate.

In West Denmark, during the night between 8 and 9 March, 2002, local wind power exceeded local demand for the first time. This happened once more, during 2002[5].

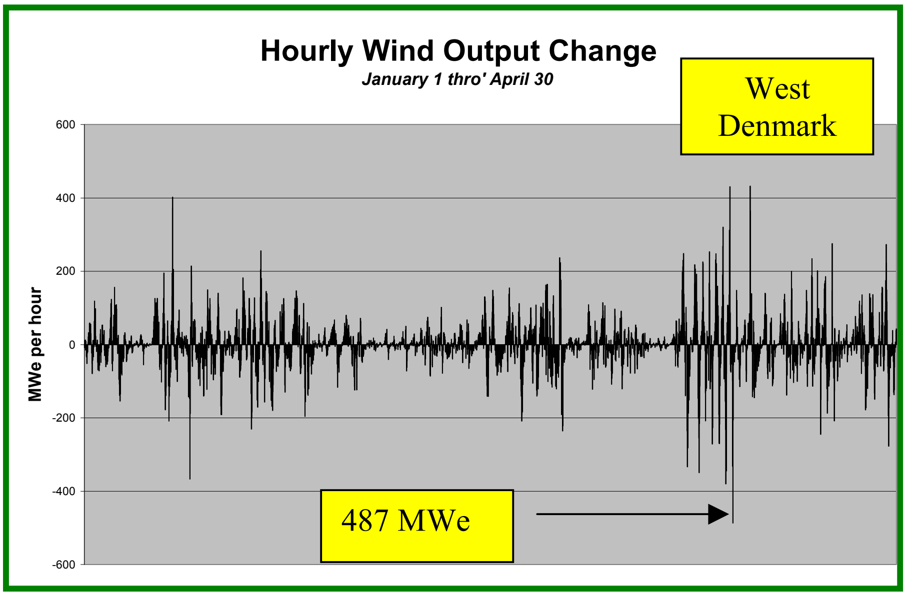
Up to the end of June, 2003, thanks to the small increase of capacity, there were already six such events.

The daily demand patterns in Denmark are very similar to those in the UK.

[5]. More snapshots are provided in Appendix I

Thus, we can see that with a proportionate wind output in the UK, its thermal plant will have to perform heroically in order to maintain grid balance and stability.

It is not merely a question of “heroics”. The key question is whether the UK ‘s generation equipment can, at all, be ramped up and down at the rate of thousands of MW per hour and whether nuclear power plants, for example, can be cycled, stopped and started.



This chart illustrates how the output of the wind varied from one hour to the next during the first four months of 2003.

It shows that there were 4 events when the wind output changed by over 400 MWe in a single hour and 56 events when the output changed by more than 200 MW and less than 400 MW.

The UK’s proportionate equivalent to the Danish hourly load change of 400 MWe, would be about 6,300 MWe.

In other words, if wind output changes as rapidly in the UK as it does in Denmark, it will be necessary to ramp thermal plants, equivalent to 2 Drax power stations, up or down, per hour, many times per year.

In Denmark, with some difficulties, these wind surges are accommodated by exporting and importing power to and from the much larger, neighbouring grids.

In the UK, all the accommodation will have to be within the system.

I argue that, without a huge storage system, “mopping up” surplus wind at peak wind output, patterns of wind load which are difficult to balance in a strongly interconnected system like West Denmark’s can simply not be accommodated in the UK.

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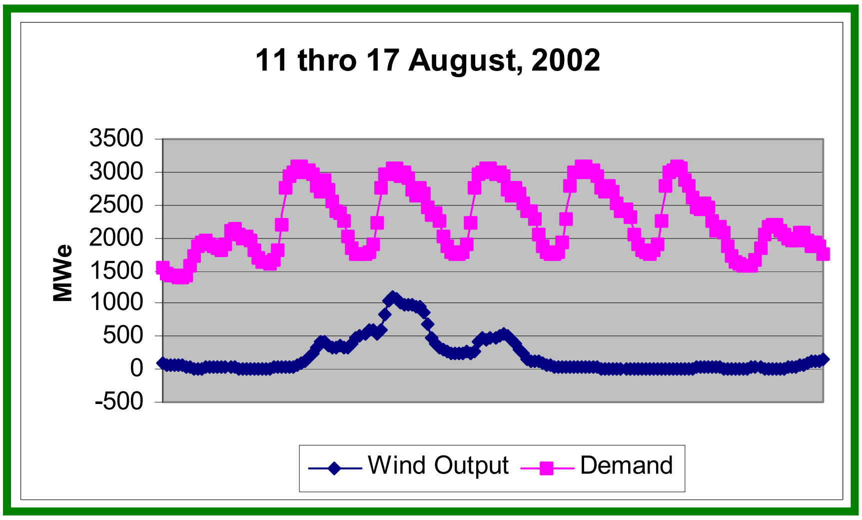
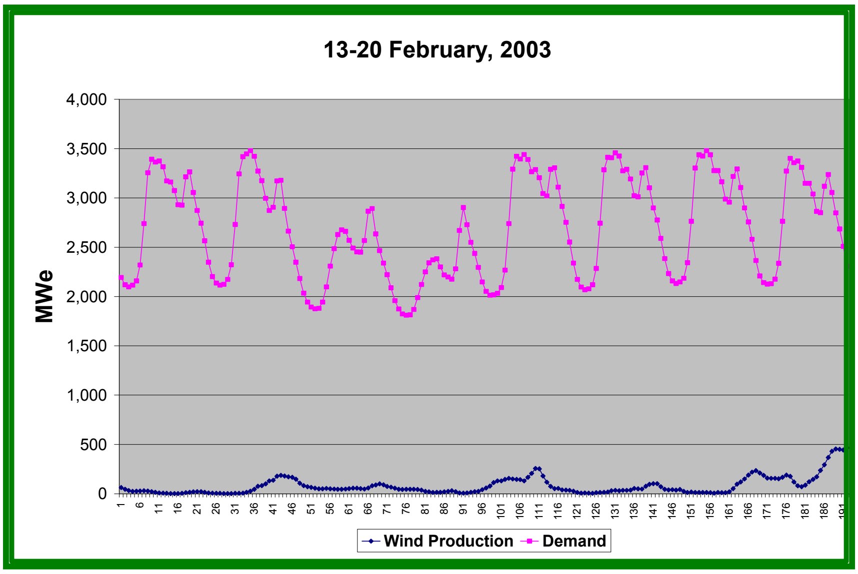
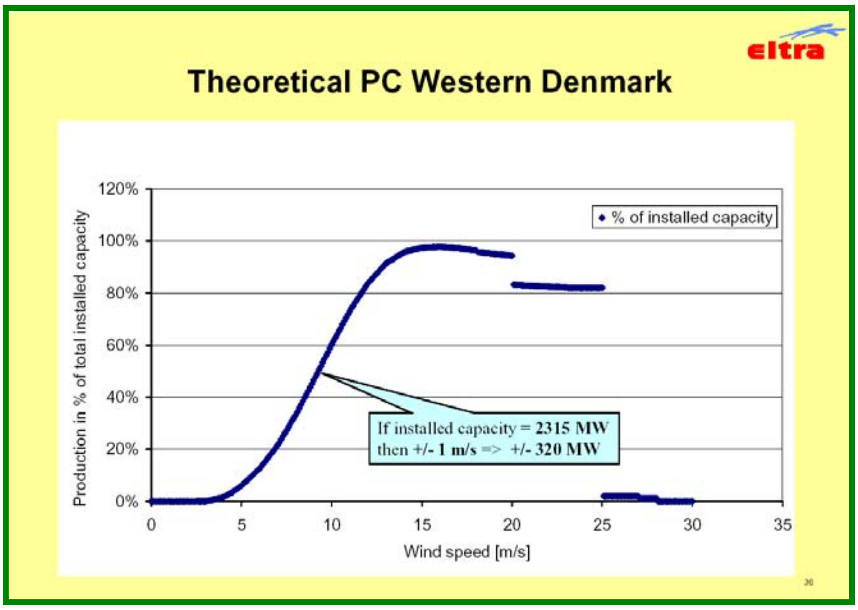
4. Can Wind Supply Any Firm capacity?







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 any hope in the likelihood that the UK, because of its larger size and more westerly geography, can expect firm demand, even arising from 36 or more GWe of wind capacity. If the wind does not blow, no power can be generated. And high-pressure systems can be very large and persistent.

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

This is demonstrated by ELTRA's chart which illustrates how the country-wide wind carpet, consisting of the modern wind machines on which the UK's renewables hopes are founded, actually behaves.

The output of West Denmark's wind carpet increases more or less linearly between a wind speed of 5 m/s and 13 m/s.

Above this speed, the carpet's output levels off and at 20 m/s (45 mph, Force 8) 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, Force 9 - 10).

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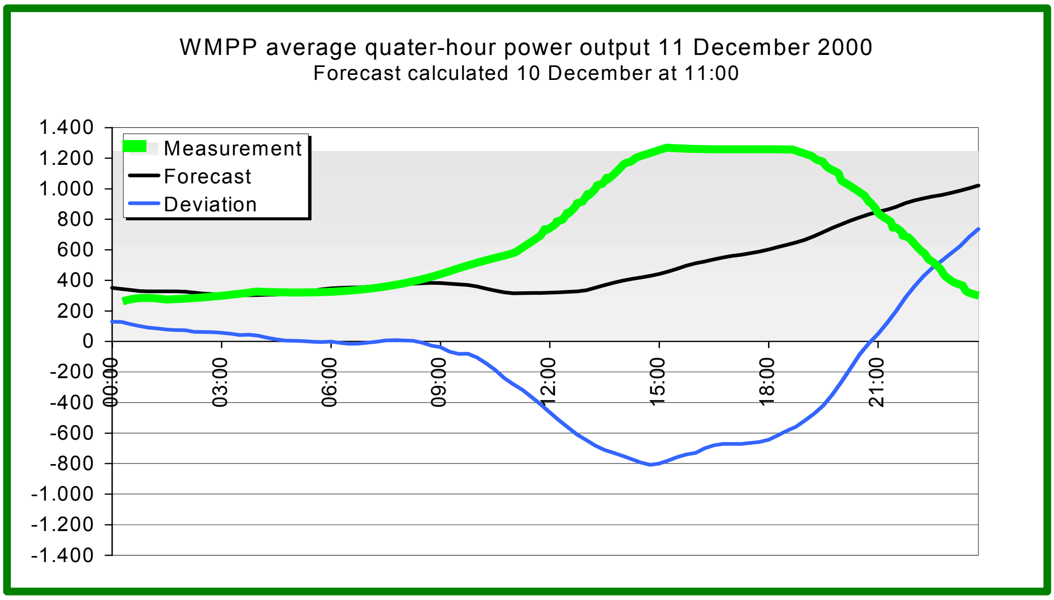
Much play is made by the UK wind lobby of the fact that isovents in the UK, particularly in the western and northern parts, reveal Britain as “the richest wind resource in Europe”.

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, in turn raising new and interesting questions about how thermal plants are supposed to respond when this happens.

5. The Price of Surprise

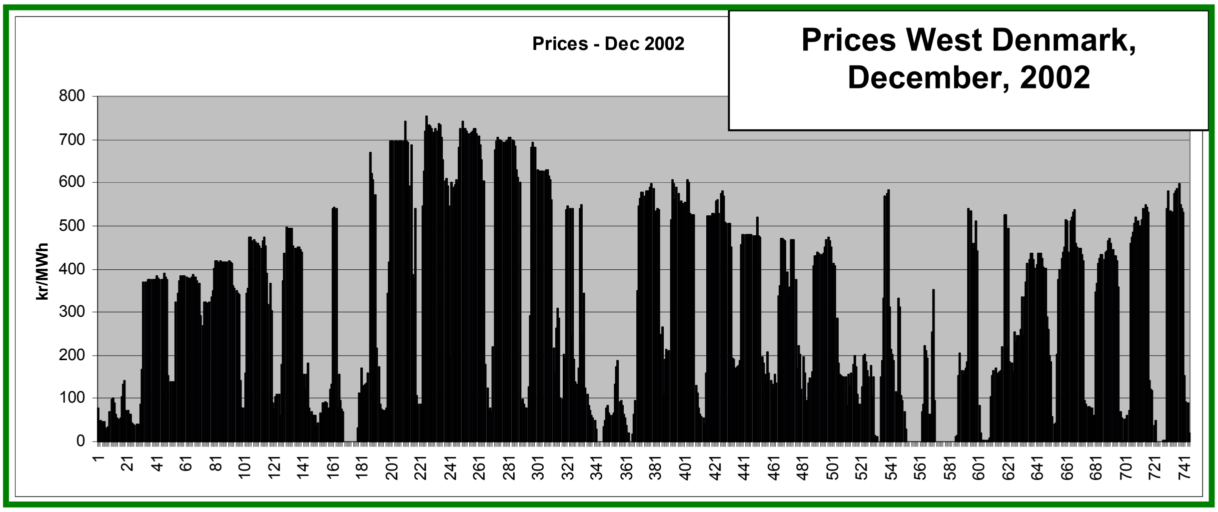


The difficulty of forecasting the weather is not confined to the UK. In order to accommodate demand, it will be necessary to cycle thermal plant according to wind output.

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

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 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 the UK where the thermal generation industry has already suffered enormous losses and will be challenged, perhaps mortally, if forced to live with the effects of more uncertainty.

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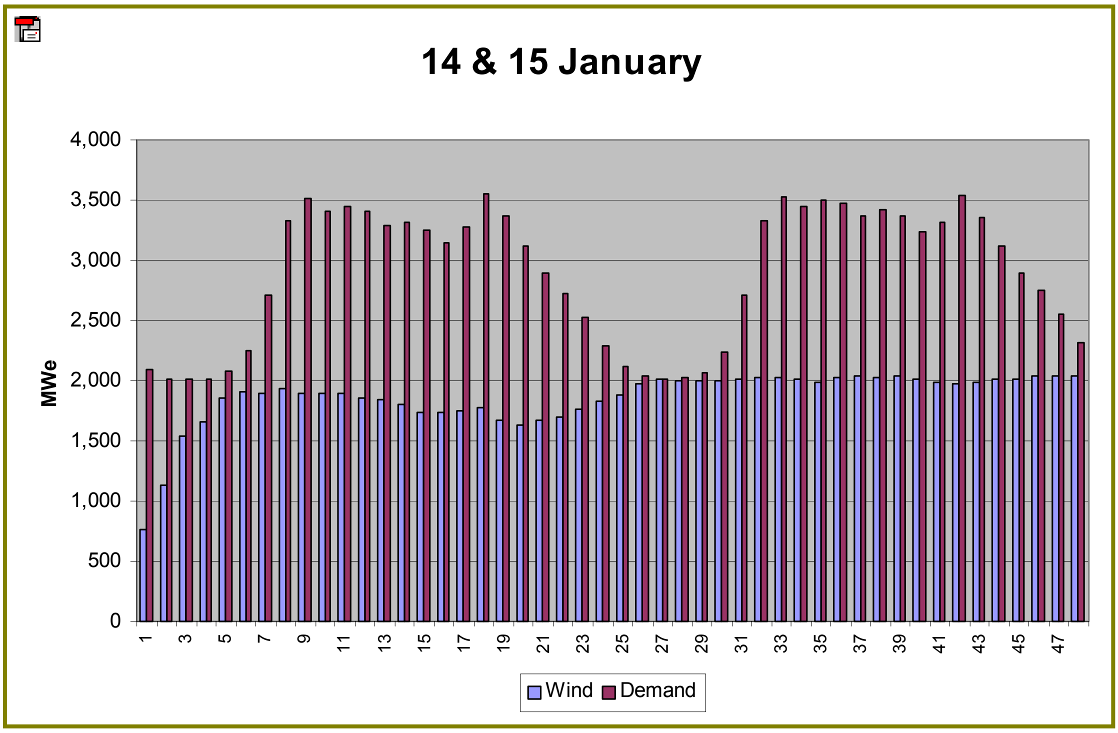
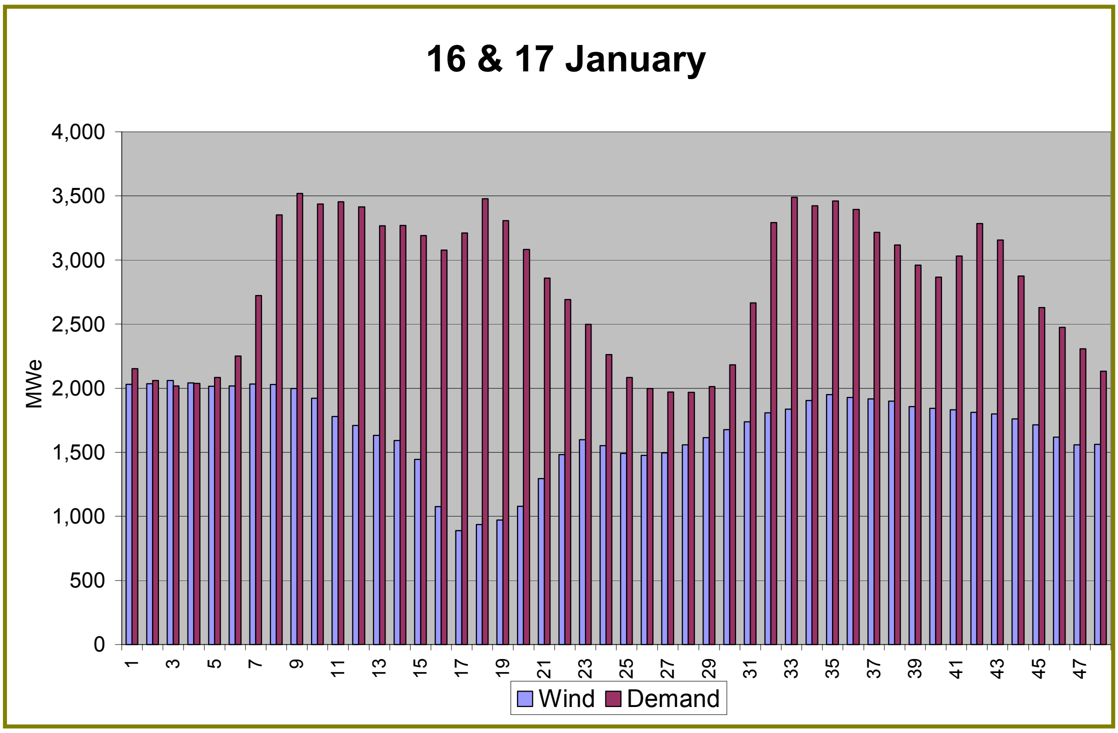
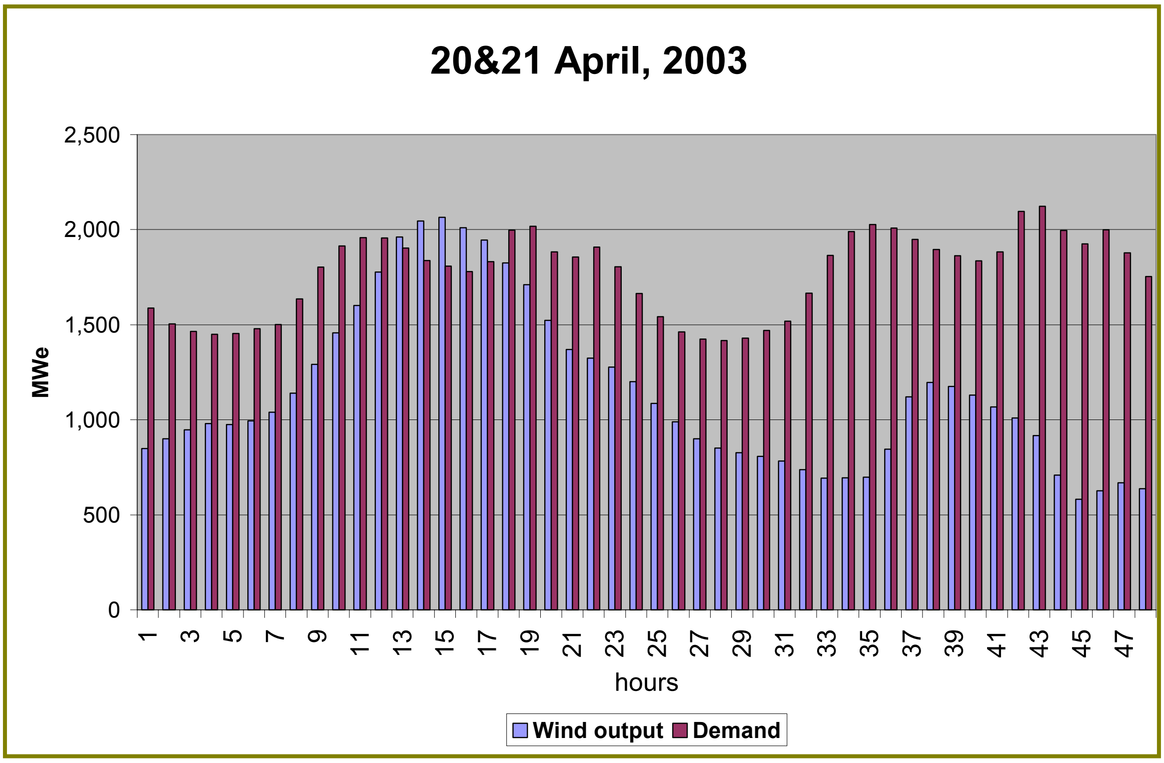
Appendix I

Snapshots of Interaction between Wind input and Customer Demand in West Denmark during 2003

The following "snapshots" show how the West Denmark wind carpet, with a capacity equal to 61% peak winter demand, feeds into the West Denmark grid. Energy surplus to demand is mostly exported to Norway and Sweden. In the author's opinion, these charts provide an accurate picture of how the UK's grid might often look, if roughly 20% of power is supplied by wind.






20&21 April, 2003
MWe
2,500
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1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47
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Wind output
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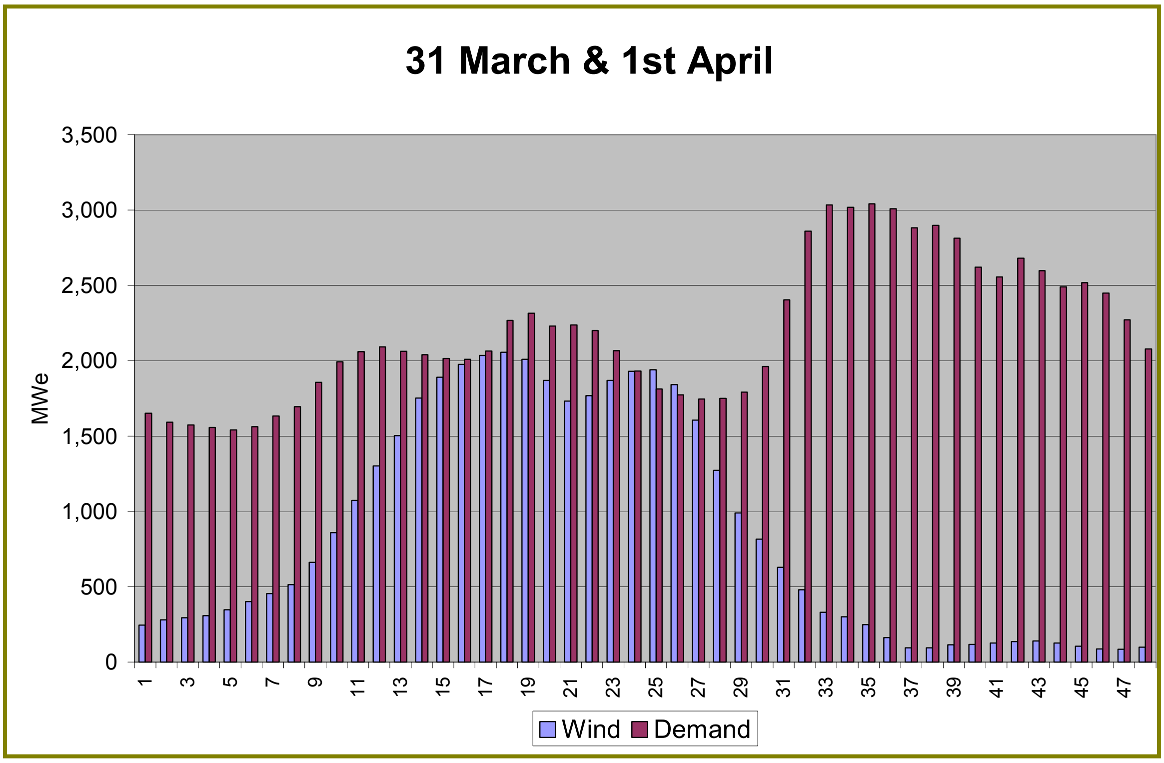
31 March & 1st April
MWe
3,500
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Wind
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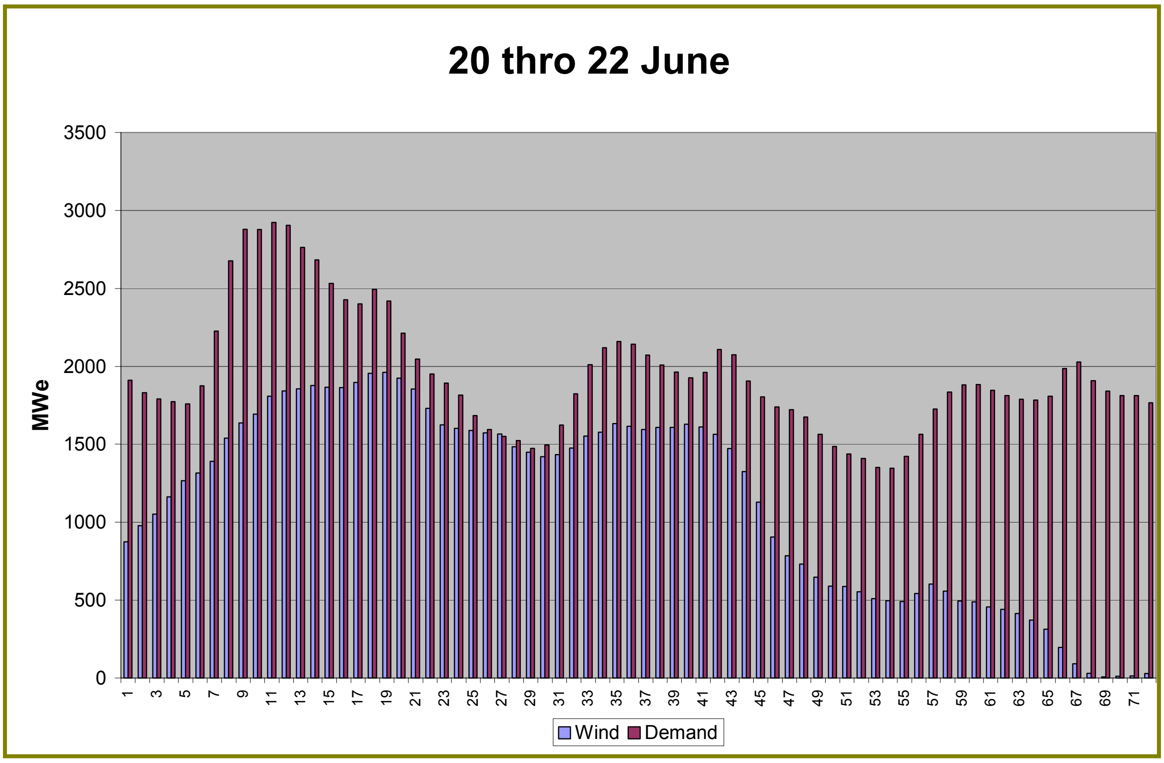
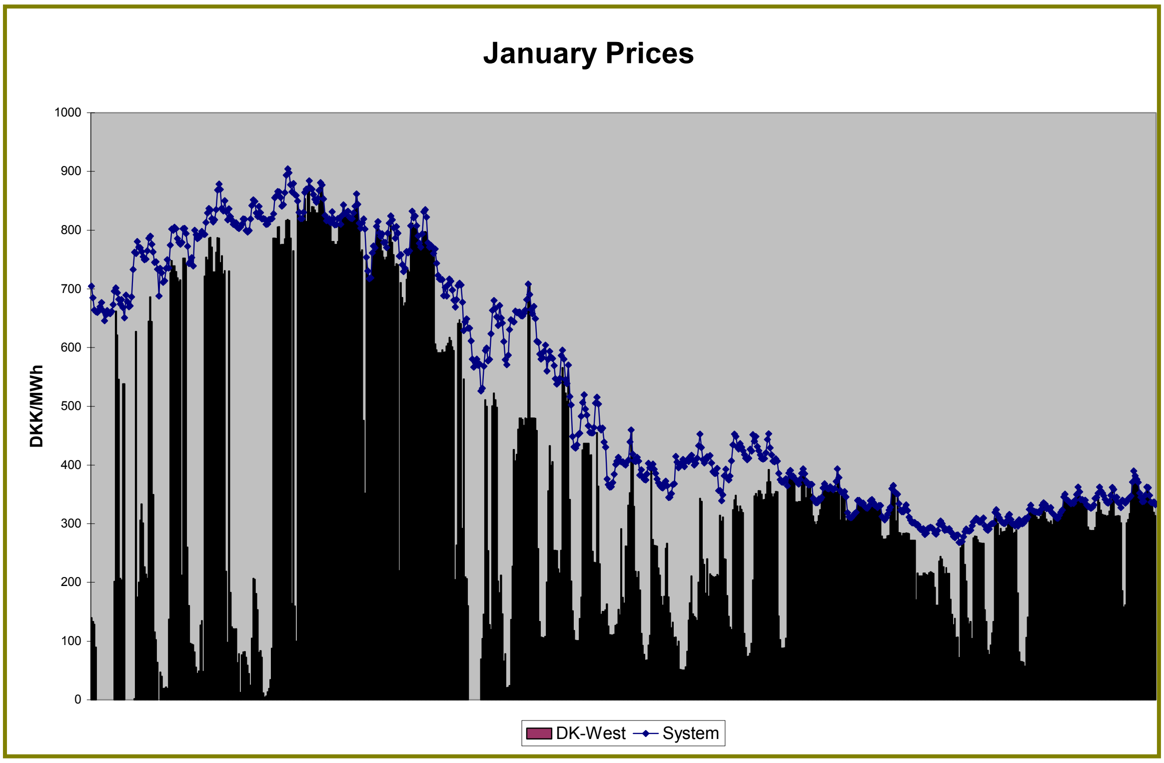
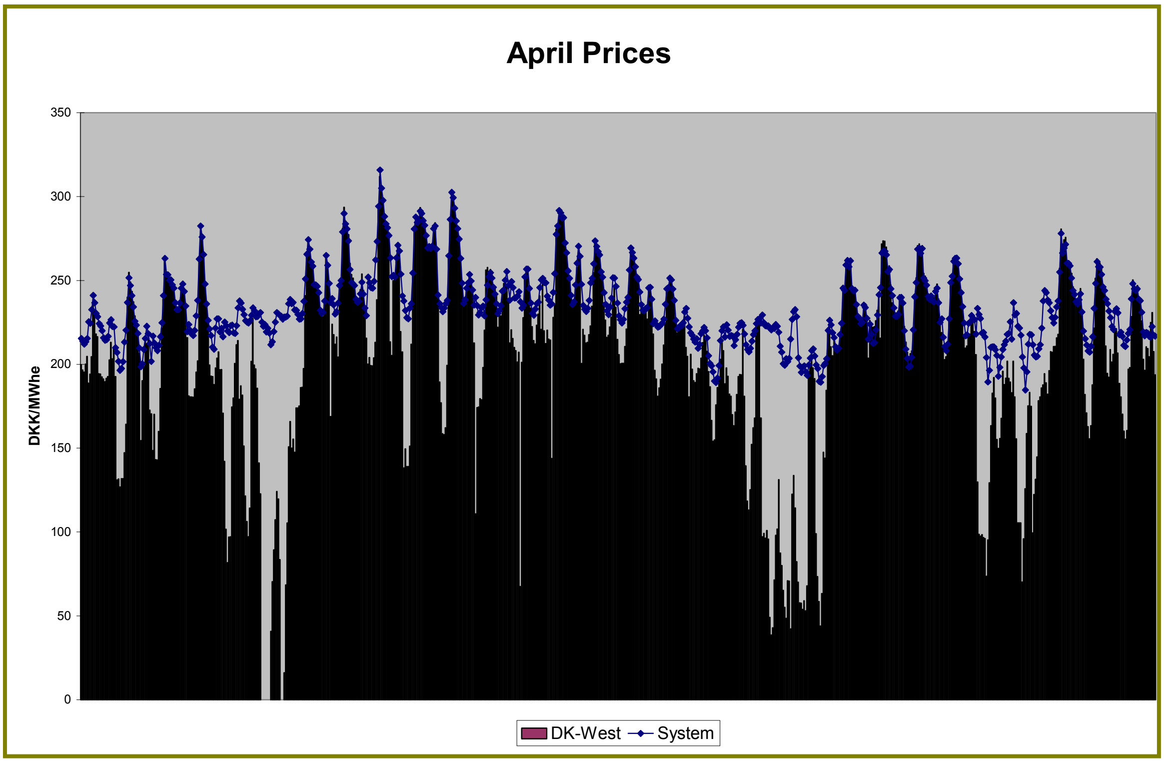


The following snapshots describe the "pool price" records during the months illustrated. When more wind blows than the system can consume, the value of energy drops and can become negative. These illustrate the urgent need for storing intermittently produced energy and releasing it when demand requires.





Wind energy exceeded demand 5 times during the first 6 months of 2003. This happened for the first time only in 2002 – and never ever, before 2002.