CEPOS
Center for Politiske Studier

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WIND ENERGY

THE CASE OF DENMARK

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Executive summary

PART 1: The real state-of-play and its hidden costs

Denmark generates the equivalent of about 19% of its electricity demand with wind turbines, but wind power contributes far less than 19% of the Nation's electricity demand.

The claim that Denmark derives about 20% of its electricity from wind overstates matters. Being highly intermittent, wind power has recently (2006) met as little as 5% of Denmark's annual electricity consumption with an average over the last five years of 9.7%.

In the absence of large-scale electricity storage, any modern electricity system must continuously balance electricity supply and demand, because even small variations in system voltage and frequency can cause damage to modern electronic equipment and other electrical equipment.

Wind power is stochastic,especially in the very short term (e.g., over any given hour, 30 minute, or 15 minute period). This has created a completely new challenge that transmission system operators (TSOs) all over the World are only now learning how to handle. Some draw from Denmark's experience. But Denmark's special circumstances make its experience of limited transferability elsewhere.

Denmark manages to keep the electricity systems balanced due to having the benefit of its particular neighbors and their electricity mix. Norway and Sweden provide Denmark, Germany and Netherlands access to significant amounts of fast, short term balancing reserve, via interconnectors. They effectively act as Denmark's "electricity storage batteries". Norwegian and Swedish hydropower can be rapidly turned up and down, and Norway's lakes effectively "store" some portion of Danish wind power.

Over the last eight years West Denmark has exported (couldn't use), on average, 57% of the wind power it generated and East Denmark an average of 45%.The correlation between high wind output and net outflows makes the case that there is a large component of wind energy in the outflow indisputable.

The exported wind power, paid for by Danish householders, brings material benefits in the form of cheap electricity and delayed investment in new generation equipment for consumers in Sweden and Norway but nothing for Danish consumers. Taxes and charges on electricity for Danish household consumers make their electricity by far the most expensive in the European Union (EU)[1]. The total probable value of exported subsidies between 2001 and 2008 was DKK 6.8 billion (€916 million) during this period. A similar amount was probably exported prior to 2012[2] and larger quantities will be exported following the commissioning of 800 MW of new offshore wind capacity in 2013.

The wind power that is exported from Denmark saves neither fossil fuel consumption nor CO2 emissions in Denmark, where it is all paid for. By necessity, wind power exported to Norway and

[1] According to the OECD, Denmark has the World's highest tax burden. This applies across a slew of tax sources, including personal income and value added tax.
[2] The wind power subsidy arrangements before 2001 were made directly by Government and are not available to the public

Sweden supplants largely carbon neutral electricity in the Nordic countries. No coal is used nor are there power-related CO2 emissions in Sweden and Norway.

Wind energy has replaced some thermal generation in Denmark. It has saved an average emission of about 2.4 million t per year CO2 at a total subsidy cost of 12.3 billion DKK or an average cost of 647 DKK (€ 87 or $124) per ton CO2. Wind power has proven to be an expensive way to save CO2 emissions[3].

The cost of Denmark's wind capacity to Danish consumers is exacerbated by its inability to use so much surplus electricity. The surplus will increase in 2013 when 800 MW of new offshore capacity is commissioned, increasing Denmark's wind production by 2.7 TWh per year. Nearly all the additional wind power will be exported and this will further depress prices; nearly all the subsidies paid by Danish consumers will also be exported without achieving any significant fossil fuel use nor any CO2 reduction. Achieving own-consumption of all its wind power is technically impossible in the short term and will remain entirely hypothetical until electricity consumption rises and new technical and demand-side solutions have been developed and implemented. In most cases, these have yet even to be invented, let alone proven and costed.

Notwithstanding its many disadvantages wind power's one striking advantage is that, like nuclear, its marginal costs of operation are very small once the capital has been paid. However, unlike nuclear, many ten to fifteen year-old turbines are past their useful life. By contrast, most conventional rotating power plant can enjoy a working life of 40 to 60 years, as evidenced by most power plants in Europe today. This puts into question the strategic, economic and environmental benefits of a power plant that may have to be scrapped, replaced and re-subsidized every ten to fifteen years.

The Danish Parliament reached a political consensus during 2008 that in 2025 50% of Denmark's electricity demand must come from renewable resources, mostly wind power. The Ecogrid Study Group has concluded[4] that if the extra wind power is to achieve this aim, drastic re-engineering of the whole energy system will need to take place, including the retirement of much expensive, high quality, existing capacity. Wisely, it has not tried to estimate the costs of doing this. In any case, Sweden and Norway will be unable balance the extra wind capacity planned that is also planned for Germany and Netherlands.

PART 2: Wind Energy's effect on employment

Denmark has been a first-mover in the wind power industry for over ten years, and its leading wind turbine manufacturers have been able to maintain a very strong global position. This has been a consequence of a concerted policy to increase the share of wind power in Danish electricity generation. The policy has only been made possible through substantial subsidies supporting the wind turbine owners. This indirect subsidy has in turn generated the demand for wind turbines from the manufactures. Exactly how the subsidies have been shared between land, wind turbine owners, labor, capital and shareholders is opaque, but it is fair to assess that no Danish wind industry to speak of would exist if it had to compete on market terms. This paper documents the experiences gained in Denmark with regard to the employment effect of subsidizing the wind industry.

[3] The "value" of European emission allowances since the European emission-trading scheme (ETS) started has varied between € 1 and €30 per ton of CO2.

[4] http://www.energinet.dk/en/menu/R+and+D/EcoGrid/EcoGrid.dk.htm

Substantial subsidies have been directed to the Danish wind mill industry over years. From 2001-2005 the yearly subsidy has been 1.7-2.6 billion DKK.

The Danish Wind industry counts 28,400 employees. This does not, however, constitute the net employment effect of the wind mill subsidy. In the long run, creating additional employment in one sector through subsidies will detract labor from other sectors, resulting in no increase in net employment but only in a shift from the non-subsidized sectors to the subsidized sector. Allowing for the theoretical possibility of wind employment alleviating possible regional pockets of high unemployment, a very optimistic ballpark estimate of net real job creation is 10% of total employment in the sector. In this case the subsidy per job created is 600,000-900,000 DKK per year ($90,000-140,000). *This subsidy constitutes around 175-250% of the average pay per worker in the Danish manufacturing industry.*

In terms of value added per employee, the energy technology sector over the period 1999-2006 underperformed by as much as 13% compared with the industrial average.

This implies that the effect of the government subsidy has been to shift employment from more productive employment in other sectors to less productive employment in the wind industry. As a consequence, Danish GDP is approximately 1.8 billion DKK ($270 million) *lower than it would have been if the wind sector work force was employed elsewhere.*

Content

PART 1:

An Assessment of Danish wind power: The real state-of-play and its hidden costs[5]

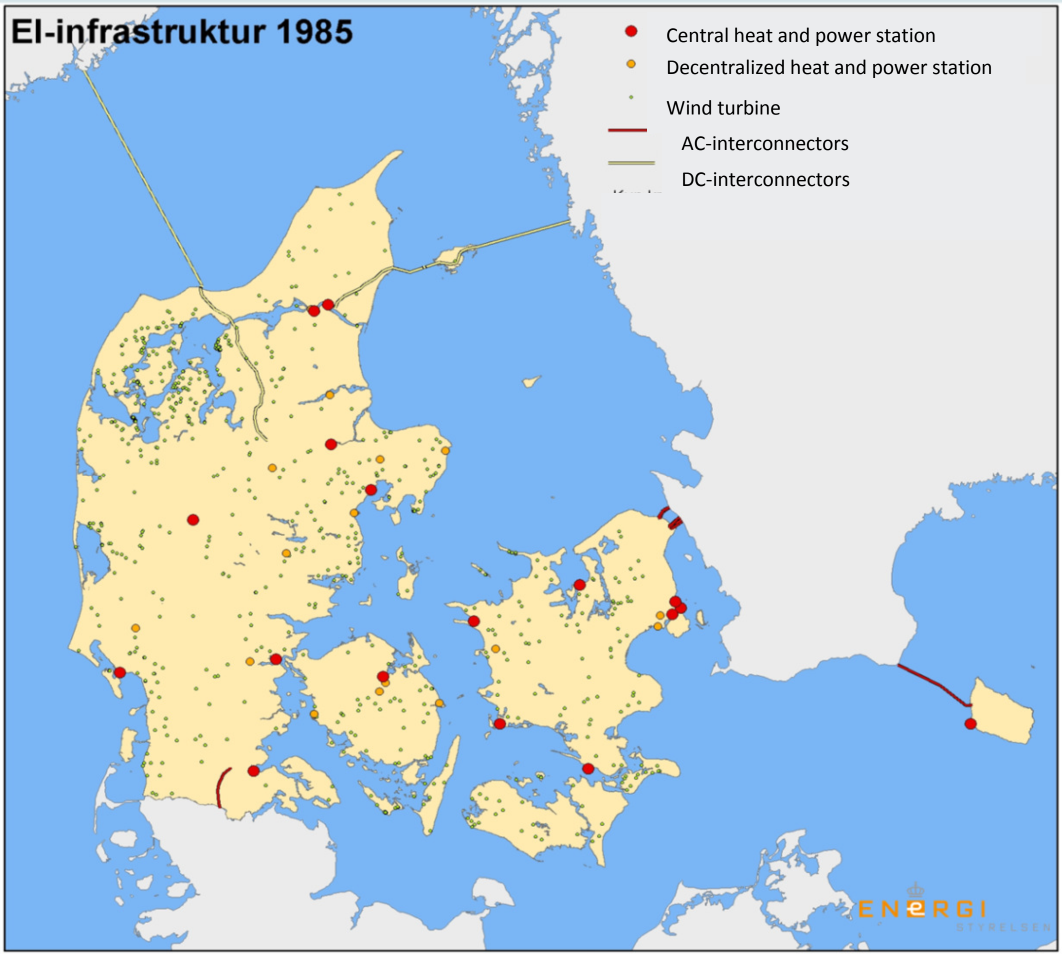
Author: Hugh Sharman[6]

Introduction

Denmark is a prosperous, well-run and notably clean country of about 5.5 million people. For the time being, it is self sufficient for all its energy requirements and is a net energy exporter. Its oil and gas production from the North Sea will continue to exceed demand until 2018[7], after which, unless it reduces demand, it will become a net hydrocarbon importer.

In addition to its hydrocarbon reserves, it has a well-developed electricity industry that continues the radical transformation which started with the shock of the first oil and second crises at the beginning and end of the 1970s, when most electricity generation was based on oil.

Evolution of the Danish infrastructure

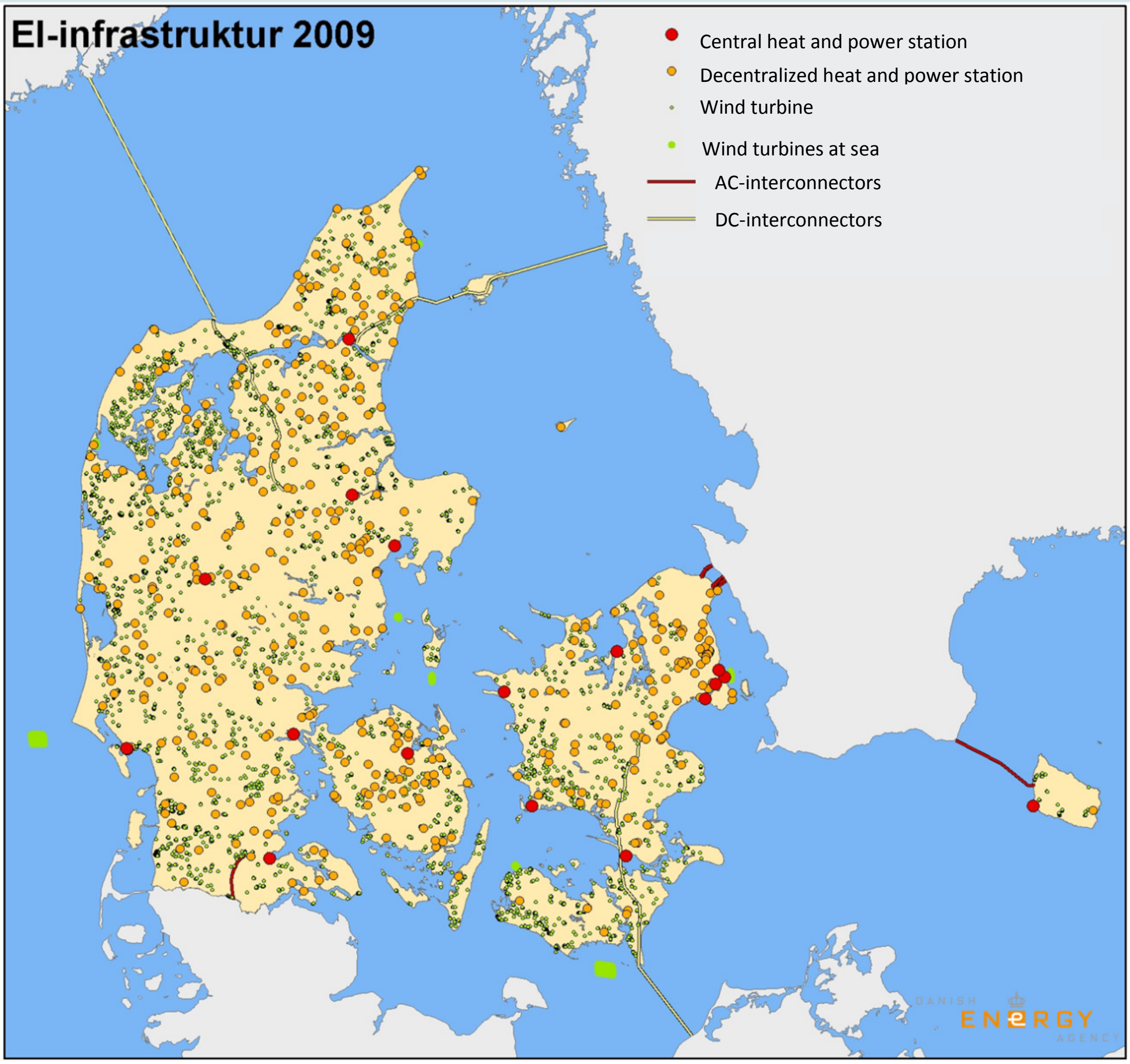


5 Reviewed prior to publication by leading peer experts

6 Hugh Sharman graduated in Civil Engineering from Imperial College, London in 1962. He worked with the design and construction of off-shore structures including oil platforms, and later with the marketing and sale construction of power stations in the Caribbean. In 1986 he founded Incoteco, which has specialized in innovative conventional and renewable energy technology and infrastructure projects. Hugh Sharman and Incoteco have been involved in large projects with multinational clients all over the globe.

7 .Danish Energy Agency, press release summer 2009

Oddly, the eastern and western parts of Denmark are still not inter-connected, although the commissioning of a 500 MW DC inter-connector will be completed during 2010. Western Denmark synchronizes with Germany and the vast, UCTE grid of Europe[8]. Eastern Denmark synchronizes with the Scandinavian system, called NORDEL[9], comprising Finland, Norway and Sweden. A crucial feature of both systems is the large scale of the inter-connectors, relative to the Danish systems. The capacities of the inter-connectors equal or exceed the wind turbine capacities in both systems.



Source: *Danish Energy Agency - 2009*

The foregoing two "energy maps" illustrate how radically the electricity system has evolved during the last twenty-four years and why Denmark has effectively become the World's leader of distributed power. The red dots show the location of its sixteen central combined heat and power stations, most of which have been re-powered and up-graded since 1980. Fifteen of these are still there and among these are the World's most thermodynamically efficient, steam turbine power stations[10]. These use up to and over 90% of the fuel (mostly coal) that they consume during the winter period as they generate electricity and distribute heat into the local district heating networks.

8 http://www.entsoe.eu/association/history/ucte/
9 http://www.entsoe.eu/association/history/nordel/
10 . The coal-fired power station, Nordjyllandsværket near Aalborg, has a condensing efficiency of 47%, based on the net calorific value of coal. Avdedøre, near Copenhagen is not only highly efficient but is also multi-fueled, burning coal, gas, wood pellets and straw. Both deliver district heat year round, ensuring that less than 10% of the energy value of the fuel is wasted in wintertime. This contrasts with the most condensing power stations around the World where more than 60% of the fuel energy is wasted to into the environment.

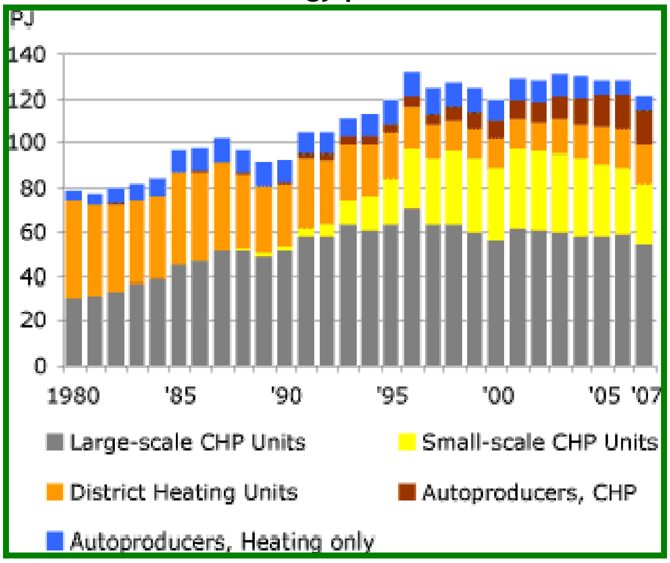
The brown dots are roughly 600, village-scale, heating-only or small combined heat and power plants having an aggregate power capacity of roughly 1,600 MW, all built during the last fifteen years. These have widened the access of district heat to even quite small villages, saving heating oil, while delivering electricity into the grid, mostly from gas engines. Straw or wood chips fuel many of the heat only stations.

The green dots represent the location of roughly 5,500 wind turbines with a total capacity of 3,160 MW of wind turbines (end 2008). Of these, roughly 2,400 MW of wind capacity are in western Denmark and 760 MW are in eastern Denmark.

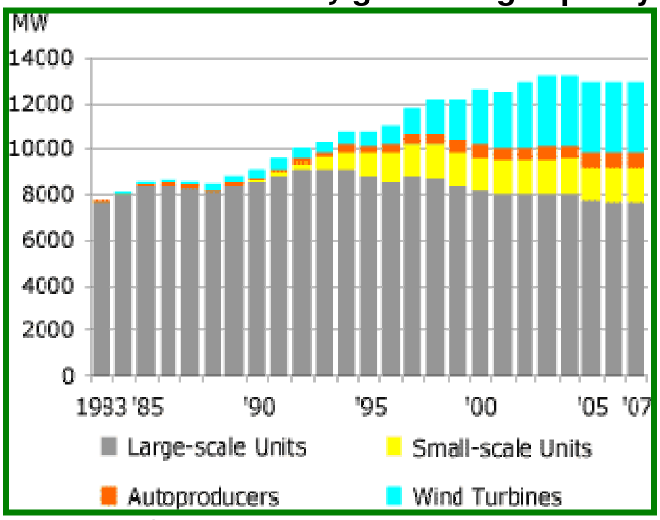
Both the wind power and decentralized power stations depend for their existence on continuing production subsidies.

Evolution of Denmark's Electricity System

Evolution of energy production as heat



Evolution of electricity generating capacity



Source: *Danish Energy Agency*

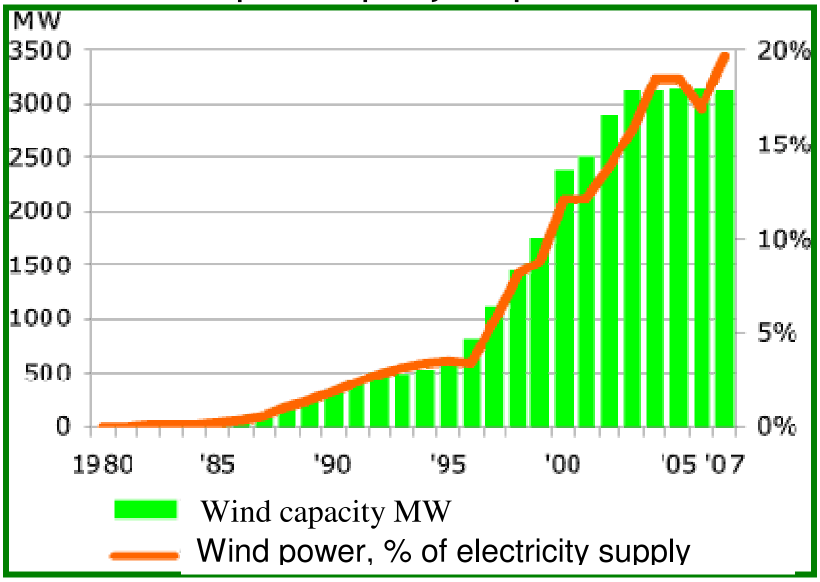
How Denmark's power generating capacity has been transformed by the installation of so much distributed generation is shown in the foregoing charts. This is why Denmark is widely regarded as a model for other countries to emulate in these times when energy security and purported anthropogenic global warming are so high on the political agenda.

The charts show how both electricity systems remain overwhelmingly dependent upon centralized power plants for system stabilization, despite the proliferation of decentralized power plants and wind turbines. The small decrease in centralized power plant capacity was caused by the retirement of obsolete power plants.

Danish Wind power

Denmark was the World's first large-scale user of wind power and was a World leader in manufacturing wind turbines until wind power became a popular source of "CO_2-free" electricity in the rest of the World. Wind turbine manufacture has since become widely dissipated outside Denmark. Between 1988 and 2003, wind-exposed West Denmark built 2,400 MW of wind capacity. The country as a whole built 3,160 MW.

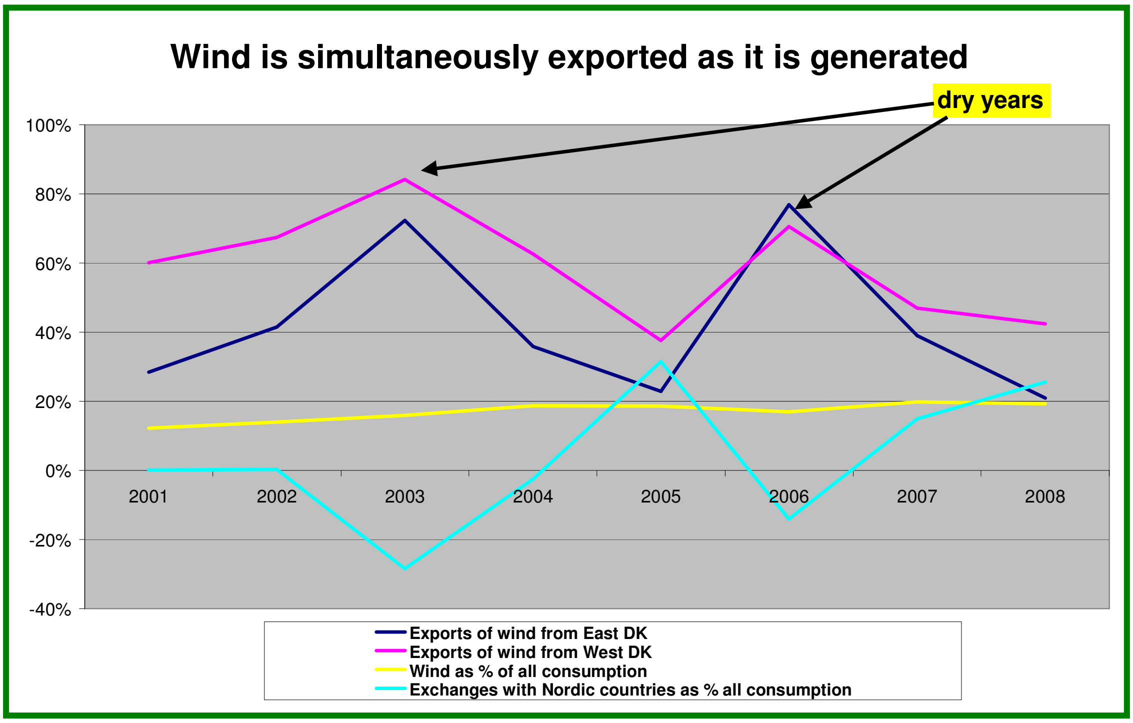
Denmark's wind power capacity and production until 2007



Source: *Danish Energy Agency*

The chart shows how wind capacity and electricity from wind power expanded between 1980 and 2007. Wind capacity expansion was particularly vigorous between 1996 and 2004, since when it has more or less ceased. Wind power output varies a great deal from year to year according to how much the wind has blown. 2007 was a particularly "windy" year when 7.1 TWh was generated from wind whereas 2006 was notably "unwindy" (wind production was 6.1 TWh).

It is true that Denmark *generates* the equivalent of about 19% of its demand by wind turbines; the figure in West Denmark for 2007 was almost 26%. That is not to say that wind power *contributes* 19% of the Nation's electricity demand.



Source: *Energinet.dk.*
The methodology for calculating exported wind power is by Paul-Frederik Bach [11]

The reasons for the low uptake of the wind power used within Denmark are as follows.

In the absence of large-scale electricity storage, any modern electricity system must continuously balance electricity supply and demand. An excess of supply over demand will result in there being in more energy in the grid than is being used at any moment. This will cause excess voltage and the alternating current frequency to rise above the safe level. Too little supply for the demand will result in too little energy in the grid for the momentary demand. This will cause a voltage dip (the so-called "brown-out") and the grid frequency to fall below the safe level[12].

Even small variations in system voltage and frequency can cause damage to modern electronic equipment and other electrical equipment, so it is a high priority of the transmission system operator (TSO) to maintain a very tight and continuous balance between power going into the system and power being consumed.

Balancing (or regulating power) reserve is only a relatively small fraction of the total amount of reserve required in a system dominated by conventional thermal and/or hydropower generation. In a mature economy, demand is well understood and can be generally forecasted very accurately by the experienced TSO who can call upon the generators to adjust their (conventional) generation equipment up and down from minute to minute with great accuracy. TSOs can always anticipate and take into account "events" like the commercial breaks in popular TV series or the half-time break in a major international soccer match, when coffee and tea is brewed simultaneously in millions of homes and call for reduced or extra power to suit the moment.

Operational evidence shows that however well forecasted, renewable energy, like wind power (especially) and solar energy, is stochastic in the very short term (next hour, 30 minutes, 15 minutes). To take care of this stochasticity, and to keep the electricity systems balanced from

[11] . Mr. Bach was director of system planning in the West Denmark system operator ELTRA until 2005. He oversaw the integration of the West Danish wind carpet into the West Danish grid throughout the build up between 1996 and 2004, since when its growth was halted. See also www.pfbach.dk

[12] .In Europe, the grid frequency is 50 cycles per second, or 50 Herz (Hz). The USA operates at 60 Hz.

minute to minute, transmission system operators (TSOs) require access to significant amounts of fast, short term balancing or regulating reserve to offset these "surprises".

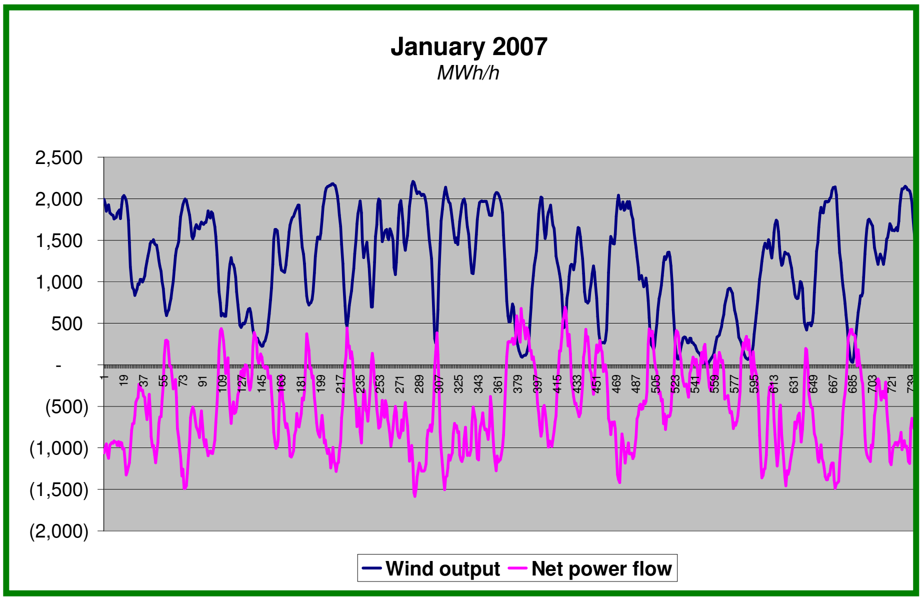
High levels of stochastic supply from intermittent sources have created a completely new challenge that TSOs all over the World are only now learning how to handle. Some draw from Denmark's experience. But there are special circumstances in Denmark that are not applicable elsewhere. These have allowed the growth of a large "wind carpet" on the grounds of technical and financial feasibility which are not readily repeatable elsewhere.

The following section will show how a recent average of 57 % (in the West Danish system) of the wind power is exported simultaneously as it is generated, so the Danish consumer's "electricity slate" contains on average about 12% as Danish generated wind power, sometimes a little more but during dry years, as little as 4%. The major part of Denmark's electricity consumption continues to originate from fossil fuel plants and during a wet year, there are significant quantities of Nordic hydropower. We will first examine the technical circumstances that allowed the construction of so much wind capacity, so quickly.

It was a lucky coincidence that although Denmark has no electricity storage within its electricity system, it has, for many years and for reasons having nothing to do with balancing wind power, been strongly inter-connected with its neighbours, Germany, Norway and Sweden. These have much larger power systems. To the north, the largely hydroelectric systems of Norway (99% hydro) and Sweden (40% hydro) are able to balance the stochastic variations in Denmark's wind power by continuously turning their hydropower systems up and down. When "excess" wind power electricity flows along the inter-connector into Norway (for example), hydropower can be rapidly turned down to match, effectively "storing" Danish wind power in Norway. As the wind energy falls or ceases, the "stored" electricity can be released very efficiently to make up any shortfall in West Denmark. The electricity trading market responds to fluctuations in the spot price (i.e. instantaneous commercial value) of power. In this way, Denmark's two closest two Nordic neighbours effectively act as Denmark's "electricity storage batteries".

It is convenient that these systems are so much larger than the two Danish electricity systems. Because they are also heavily inter-connected between themselves, stochastic flows of power that are large for the Danish system are unremarkable for the other Scandinavian systems. The 600 GW EU system to the south is a hundred times larger than Denmark's, so power can stream in both directions, limited only by the carrying capacity of the inter-connectors.

Western Denmark, wind output and net electricity flows

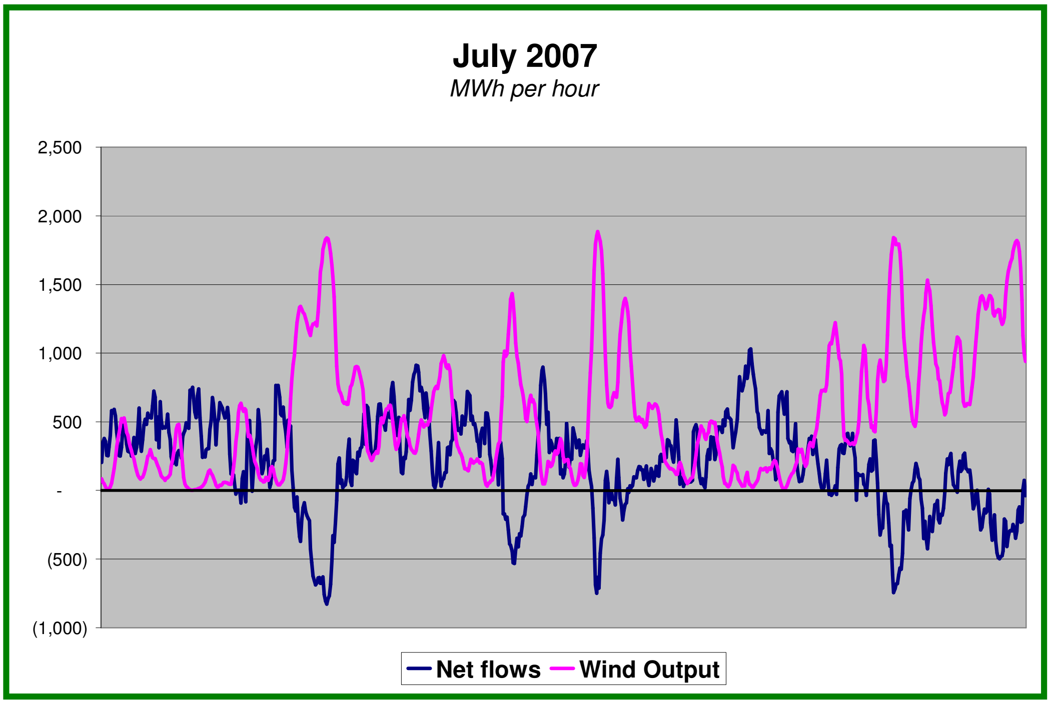


Source: *Energinet.dk (Denmark's system operator)*

What is very clear from the author's collection and analysis of data is that whenever there are large flows of wind generated electricity within the Danish system, there are invariably large outflows of electricity, usually to the North and vice versa. The preceding chart that shows wind power output and net flows during January 2007, is typical for any "windy" winter month since around 2000.

During the summer, when on average there is much less wind, the following chart shows that under light wind conditions, most wind power being generated in West Denmark is used within the country. Even so, the chart also shows how, whenever the wind turbines are generating more than about 500 MW, net electricity tends to flow out of West Denmark.

Western Denmark wind output and net electricity flows



West Denmark hosts roughly 2,400 MW of Denmark's 3,160 MW of wind capacity. It will continue to host most of the extra wind power capacity throughout the next 15 years, during which it has been decided by the Danish politicians that Denmark must supply half its electricity consumption from renewable power, overwhelmingly from offshore wind turbines.

So unless stated otherwise, this paper will concentrate on how West Denmark has already integrated so much wind power into its system and how this is operated and financed.

West Denmark is the most "wind-intensive" electricity system on Earth. There is roughly 0.9 kW of wind power capacity for each inhabitant. Germany, although hosting over 24 GW (24,000 MW) of wind has 0.29 kW per inhabitant and Spain has roughly 0.43 kW per inhabitant. Although the USA now has the World's largest fleet of wind turbines at 25 GW (end-2008), its "specific" wind power capacity is just 0.08 kW per inhabitant[13].

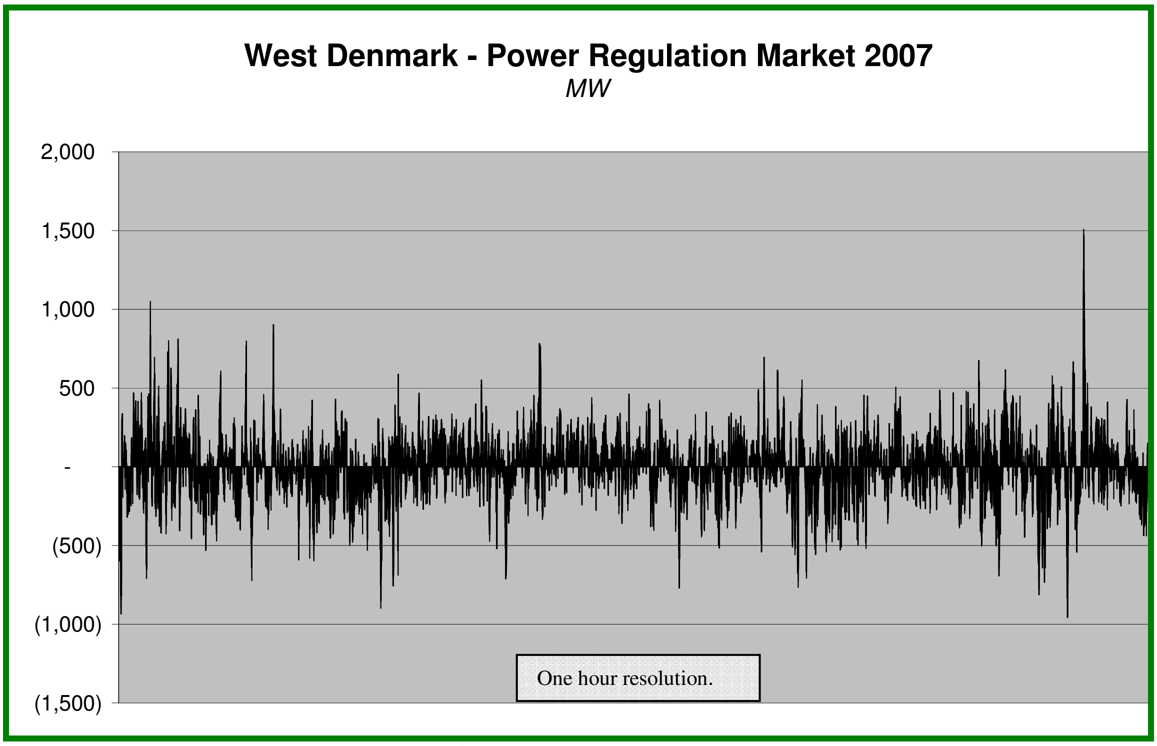
In order even to achieve 20% renewable electricity (not all energy is electricity), a similar wind intensiveness will be required, anywhere else in the World, give or take 15 – 25% depending on the capacity factor[14] of the wind turbine fleet and how much electricity is consumed by the general population.

[13] .Global Wind Energy Council, Statistics 2009, calculations per capita by author

[14] This is sometimes called capacity factor. If a 1 MW wind generator produces 8,760 MWh in a year, its load factor would be 100%. If it produces 4,380 MWh, its load factor would be 50%, etc..

In Denmark, the capacity factor of the wind turbine fleet ranges between 20% in a “low wind” year (like 2006) and 25% in a very windy year (like 2007). In Germany, it was roughly 20%[15] in 2007, although this is normally about 16%. In the USA, responding to more pragmatic considerations, most wind turbines are built in windy areas where the capacity factor is usually over 30%. The capacity factor of the USA’s wind turbine fleet is 29%[16]. This means that the US wind fleet works 50% more of the year per unit of investment than the wind fleet in Germany during a good year.

The short term balancing reserve (or regulating power reserve) needed by Denmark’s system operator to balance the stochastic effects of wind power is shown in the following chart. Relative to a conventional system the operator needs access to unusually large amounts of upward and downward reserve power at very short notice as the chart indicates.



Source: *Energinet.dk*

The West Danish power system has a peak winter load of about 3,800 MW and a summer valley load of about 1,700 MW, so the requirement for hundreds of MW of very short-term upward and downward reserve that is revealed in the foregoing chart is unusually large by the standards of global electricity systems.

Most of this reserve power is supplied along the 2,400 MW inter-connectors and in particular along the 950 MW DC inter-connector with Norway and the 600 MW DC connector with Sweden[17]. All the Scandinavian hydropower plants were already built and paid for many years ago, as were the inter-connectors, so West Denmark is able to access the reserves in these countries at a tiny incremental capital cost.

It is instructive to observe how the system works in more detail. January 2007 was a very windy month. The following chart shows clearly how, when the wind is blowing hard, much of the power

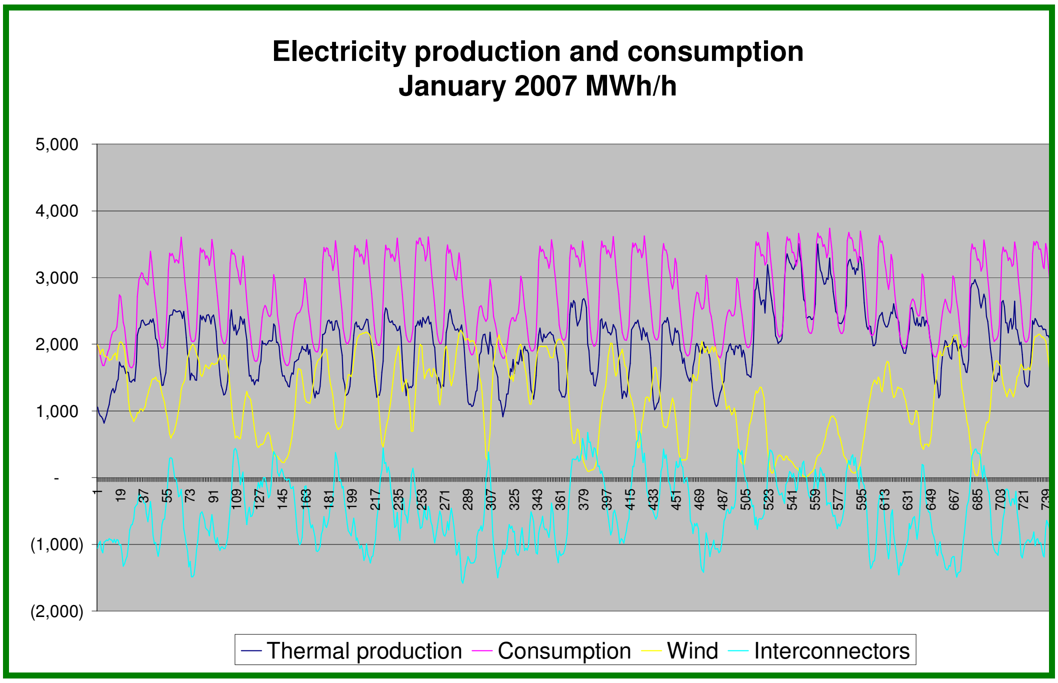
[15] http://www.wind-energie.de/en/wind-energy-in-germany/, It is interesting that 2007 was a “high wind” year in both Denmark and Germany
[16] http://www.windaction.org/documents/4032
[17] The Swedish inter-connector with West Denmark has recently upgraded to 750 MW

generated by the wind offsets fossil consumption within Denmark and the remainder is exported. Near term regulation is supplied from outside the system.

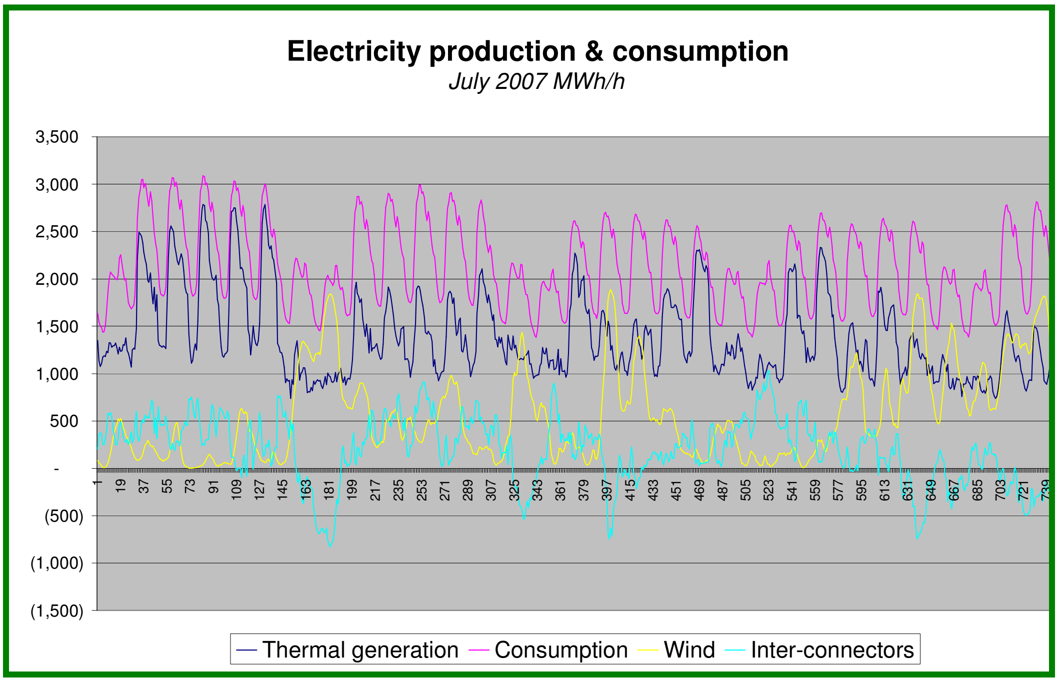
When the wind power is very low, the fraction of thermal production in the system increases and this is supplemented by imports, mostly from the north. It is important to bear in mind that all thermal electricity production in Denmark is combined heat and power. So the generators, while bidding into the spot market to sell their electricity, are simultaneously obliged to supply their heat customers.

From time to time, when there is a lot of wind, this obligation causes the Danish generators to over-supply the market with electricity, causing electricity prices to fall in the whole area, an aspect of wind power that will be dealt with later in this paper.

West Denmark

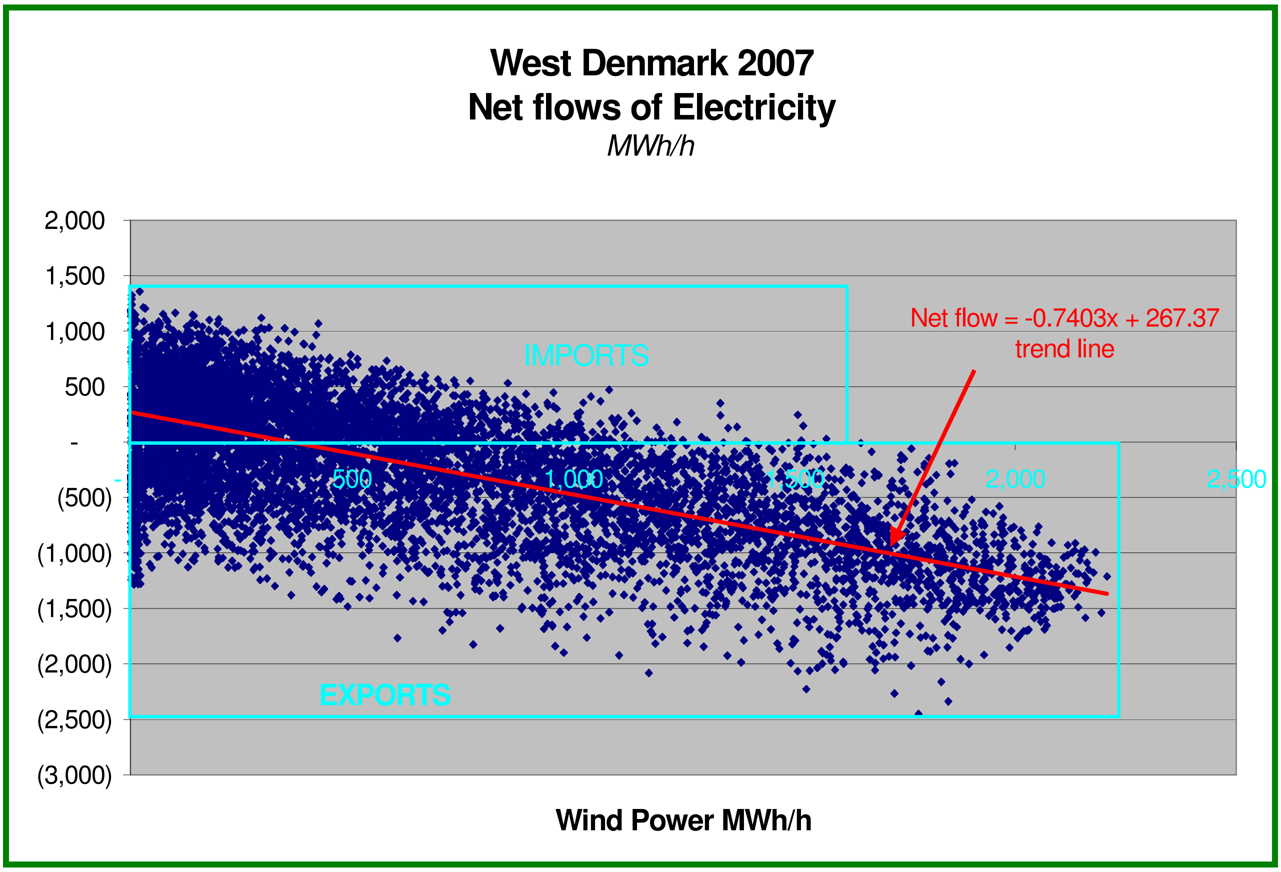


During January 2007, West Denmark was generating considerably more electricity than it could consume, even with the thermal plant turned down by almost 1000 MW to allow fuel savings. It exported throughout the month, even when the wind power fell.

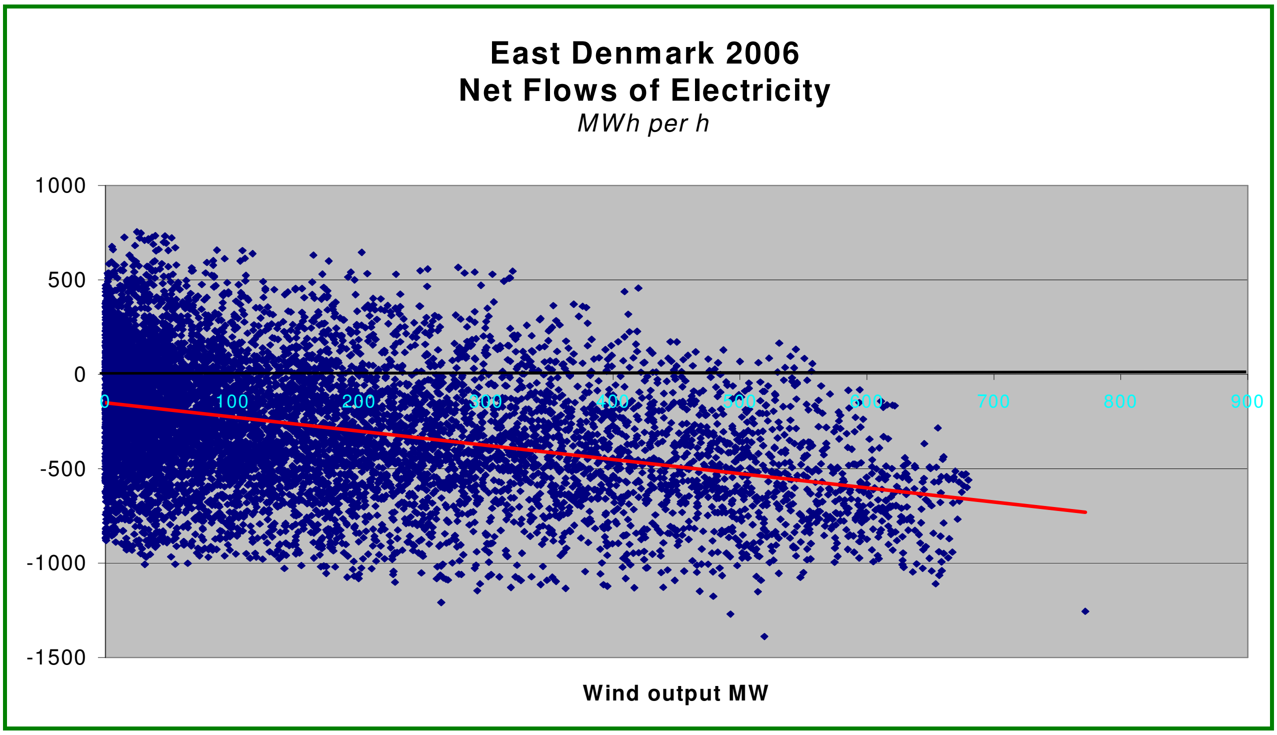


Source: *Energinet.dk*

During the summer months, when the winter snow has melted in the Nordic mountains, the Nordic reservoirs are full, the heat demand of Danish consumers is low, so Nordic hydropower is cheap and supplies a significant fraction of West Denmark's electricity. Even so, whenever the wind is blowing strongly in West Denmark the system exports net power.



This is illustrated vividly in the preceding chart where the x-axis shows the wind power during 2007, and the y-axis shows how much and in which direction the net trade is taking place. During 2007, an unusually wet and windy year, whenever wind power exceeded about 300 MW, on average, the West Danish system exported electricity.



Even though the wind capacity of East Denmark is smaller relative to that of West Denmark, the same phenomenon applied. Average power exports increase significantly as wind power increases.

The writer is indebted to Mr Paul-Frederik Bach who has developed the method used by the author to calculate how much wind power is being used in Denmark[18]. This varies enormously from year to year, showing very high wind power exports during dry years when Denmark also supplies large quantities of thermal power to its Nordic neighbours and relatively less during wet years. The average wind export during this decade has been 57 % from West Denmark and 42% from East Denmark. The wind power used in Denmark saves fossil energy and prevents CO_2 emissions in Denmark.

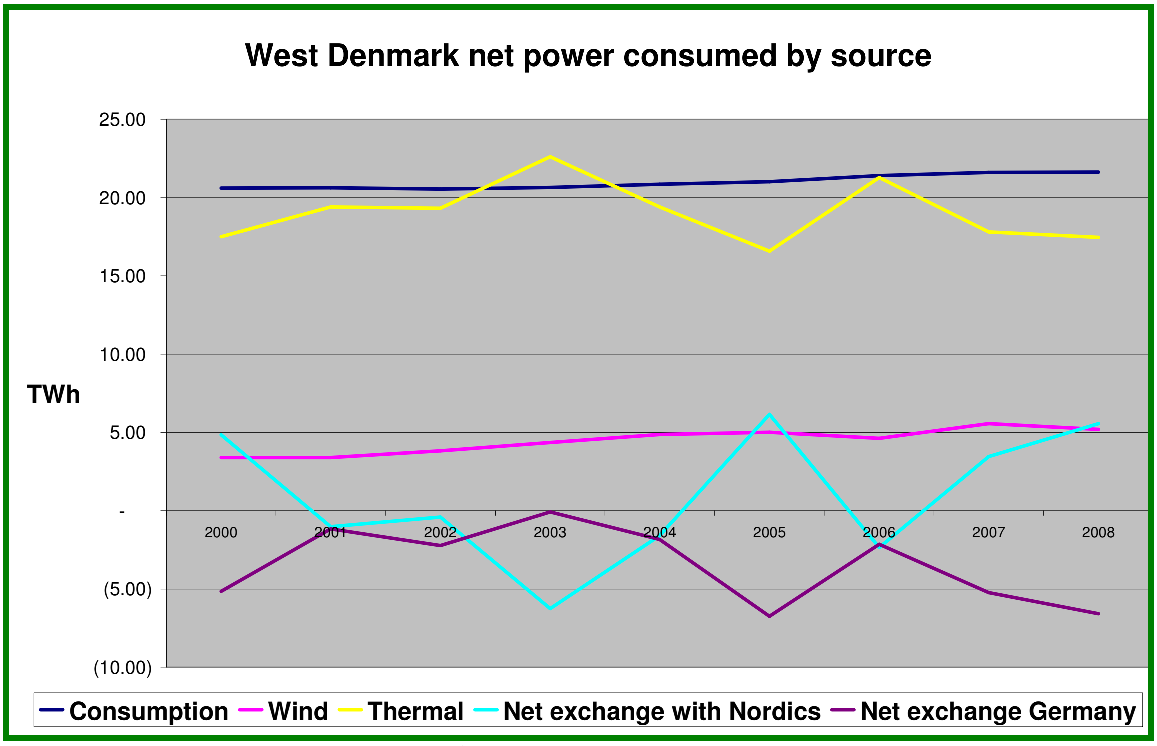
The discussion over wind power exports is tendentious for some wind power enthusiasts in Denmark. Of course, it is impossible to "tag" electrons as "coal", "wind", "hydro", or "nuclear" as they flow across the inter-connectors. But, nevertheless, the coincidence of so much wind output with net outflows makes the case for claiming that there is a large component of wind energy in the outflow, indisputable.

For other enthusiasts who accept that wind power is obviously a high component of net electricity flows out of Denmark, the Nordic reservoirs are the low cost means of "storing" Danish wind energy for use in Denmark when "wind energy" returns to Denmark in the form of hydropower imports. This argument, while true in the most general sense and often expressed in idealistic language (all wind power is "good"), ignores the simple and far from benign economic arrangements for the sponsors of all wind power in Denmark, the Danish householder. Exports of power from Denmark are often at low prices, while imported balancing is most often very costly.

[18] Mr Bach has developed an algorithm that quantifies and records the *wind energy export* as the smaller value of generated wind energy and net export for each hour.

Nordic hydropower also contributes to Danish power supplies and provide the necessary system balancing of these against constantly varying demand and intermittent wind loads. During the winter, when electricity demand in the whole Nordic area is also increased, the excess wind power in Denmark often causes a low price in the spot market. This causes power to flow north. In the summer months, an excess of generating capacity in the north, combined with lower demand, causes hydropower, when in surplus, to be more economic than thermal generation in West Denmark, more especially as thermal demand (district heating) is also much reduced in the summer.

The following chart illustrates how much annual thermal power production there was in West Denmark, therefore the significant extent to which Danish dependence on fossil fuel, is influenced by "wet" or "dry" years in Scandinavia.



Source: *Energinet.dk*

The years 2000, 2005, 2007 and 2008 were wet years, during which the Nordic hydropower reservoirs were well supplied and Norway's power was relatively cheap, not only reducing West Denmark's thermal production but also causing the supply of a substantial re-export of power to Germany.

By contrast, 2003[19] (especially) and 2006 were dry years. In both years, Norway and Sweden were not as self-sufficient as normal and were forced to import quite large amounts of thermal power from Denmark and Finland. During 2003, thermal generation in West Denmark exceeded Danish demand while 5 TWh, a quarter of West Denmark's normal consumption, was exported northwards.

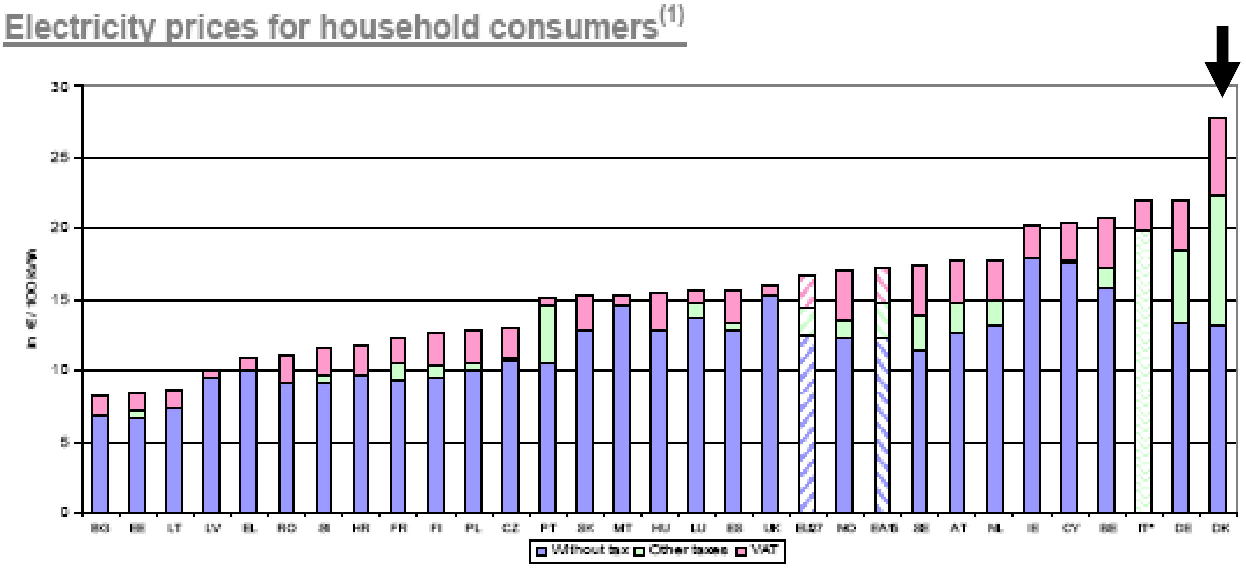
It is a notable finding of this study that wind power exports during the dry years of 2003 and 2006 were very high being 72% and 84% from East and West Denmark respectively during 2003 and 77% and 71% respectively from East and West Denmark during 2006.

[19] . By 2003, the wind capacity in West Denmark was approaching 2400 MW, the capacity that exists today.

How Denmark finances wind power

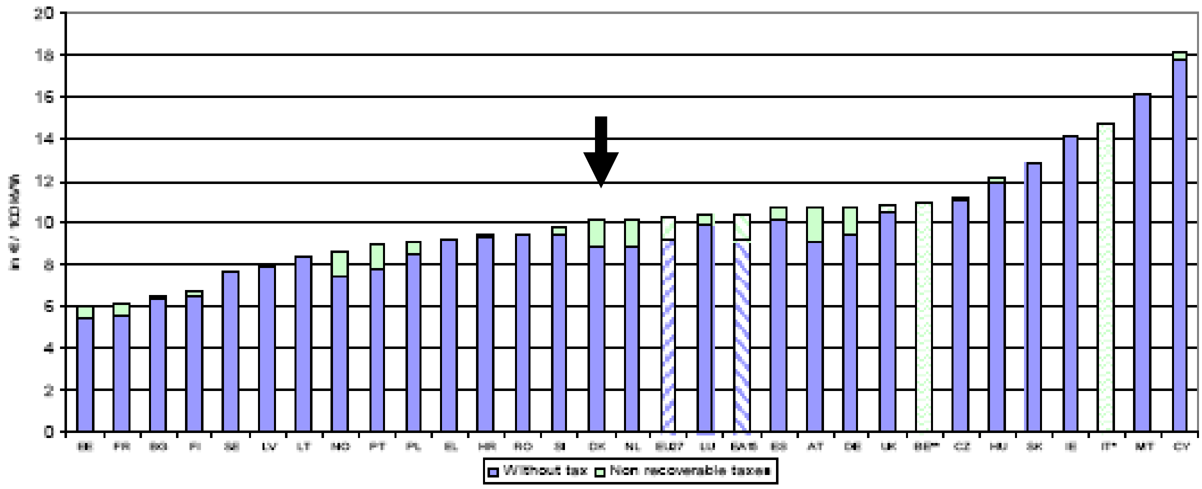
According to the OECD, Denmark has the World's highest tax burden. This applies across a slew of tax sources, including personal income and value added tax. Taxes and charges on electricity for Danish household consumers make its household consumed electricity by far the most expensive in the European Union (EU).

Electricity prices for household consumers[1]



Source: Eurostat (nrg_pc_204)

Electricity prices for industrial consumers[2]



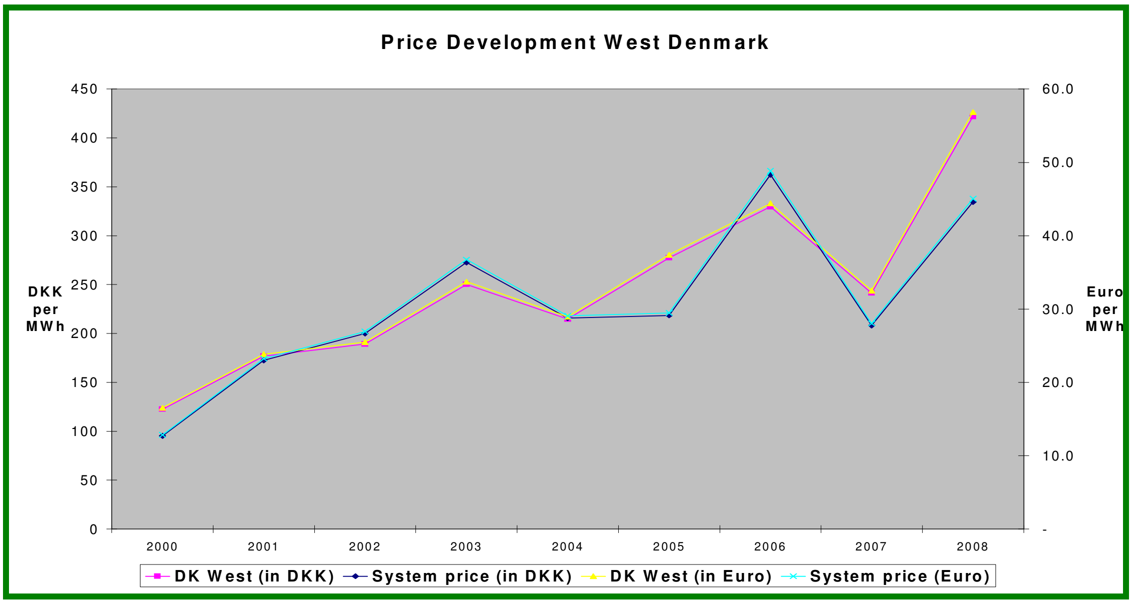
In contrast and in order to keep Danish industry competitive, power to industry is hardly taxed at all. So the disparity between what householders and industry pay for their power is very wide. As the foregoing charts show, Danish householders pay 2.5 times more than Danish industry. Not all the difference goes to general expenditure.

A significant fraction of the charges and taxes paid for electricity by Denmark's domestic consumers is recycled to support new energy research and the feed-in tariffs that make it attractive for Danish individuals and companies to invest in wind power. The feed-in support-for-wind-turbines tariff has been the key feature of the Danish wind power expansion from the beginning.

The nature and amount of the support is subject to constant review and change as the wind power carpet has expanded and market prices have evolved. The Danish Government sets the support tariffs at levels that balance between achieving the political objectives of which ever Government is in power at the time and the fear of paying excessively to those who are enjoying the largesse of the taxpayer and consumer.

The following update announcement is quoted on the Danish Energy Agency's web site 21 July 20, 2009[20]

> *"The level of support for electricity produced from wind turbines was increased in the summer of 2008. New wind turbines as well onshore as offshore recieve a price premium of 25 øre/kWh for 22.000 full load hours. Additional 2,3 øre/kWh in the entire lifetime of the turbine to compensate for the cost of balancing etc.*
>
> *Household wind turbines below 25 kW receive a fixed feed in tariff of 60 øre/kWh.*
>
> *For special wind parks at sea the support are settled by a tender procedure. In previous tenders the Horns Rev II wind park of 200 MW ended at fixed feed in tariff of 51,8 øre/kWh in 50.000 full load hours, while Rødsand II wind park of 200 MW ended at a fixed tariff of 62,9 øre/kWh for 50.000 full load hours"*



Source: *Energinet.dk*

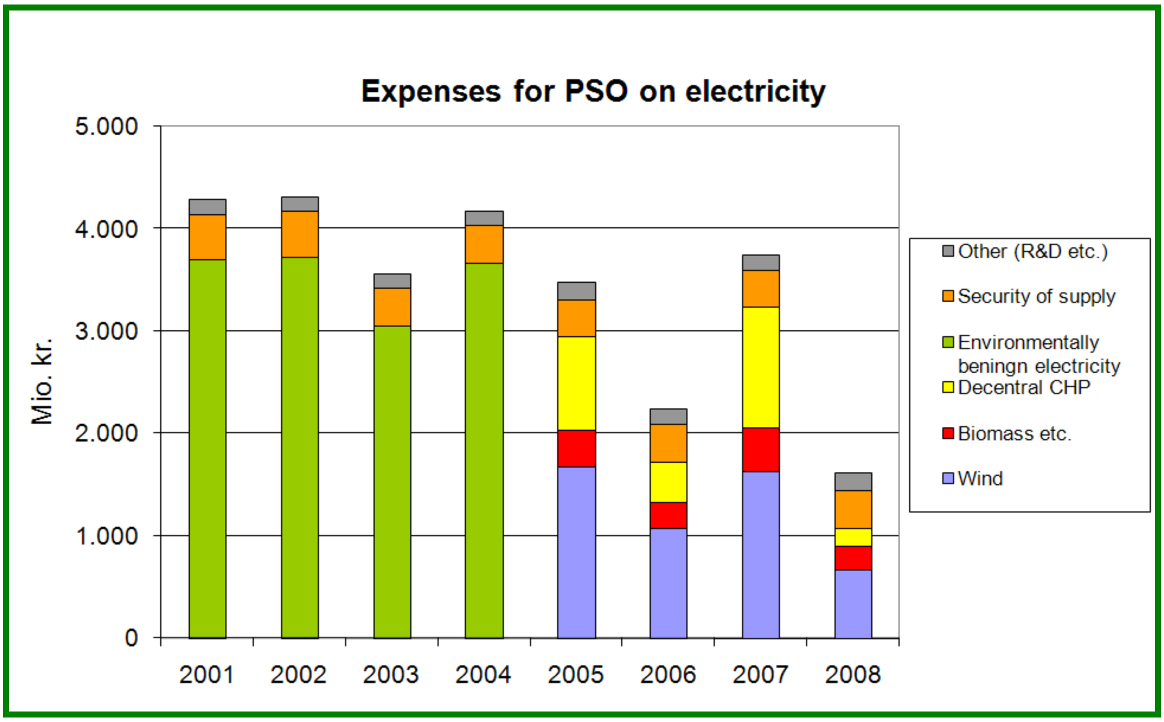
The chart shows a relentless and startling increase in the spot price of electricity on the market since 2000. Peaks in dry years of 2003 and 2006 correspond to a lack of water in the Scandinavian reservoirs and an increase in the regional use of more expensive thermal power production for those years. The "valleys" in 2004 and 2007 correspond to "wet" years when a

[20] http://www.ens.dk/en-US/supply/Renewable-energy/WindPower/Facts-about-Wind-Power/Subsidies-for-wind-power/Sider/Forside.aspx

surplus of hydropower forced down the market price of the whole area[21]. The unexpected increase in prices during 2008, a wetter-than-average year can possibly be attributed to very high fossil fuel prices globally and particularly in Germany which is heavily dependent on coal and to a lesser extent on gas.

The economic situation has resulted in a collapse of fossil fuel prices during 2009, so it is reasonable to expect an eventual reversion to the more normal patterns of higher prices in dry years and low prices in wet years[22].

Since 2001, the distribution of the subsidy to wind generators and other owners of subsidy-qualifying renewable energy, as described earlier, is made by the TSOs through a mechanism called the Public Service Obligation, or PSO. This is funded through the charges and taxes that domestic consumers pay for their power.



Source: *Danish Energy Agency*

The foregoing chart shows that the total price support that wind generators receive in Denmark has varied considerably during the last few years, as the market price of power has been increasing. All the support mechanisms devised since the beginning of the wind programme have been time-limited. They are designed to enable the wind farm investor to recover all his investment within ten years (most land turbines) or fourteen years (the latest offshore wind farms).

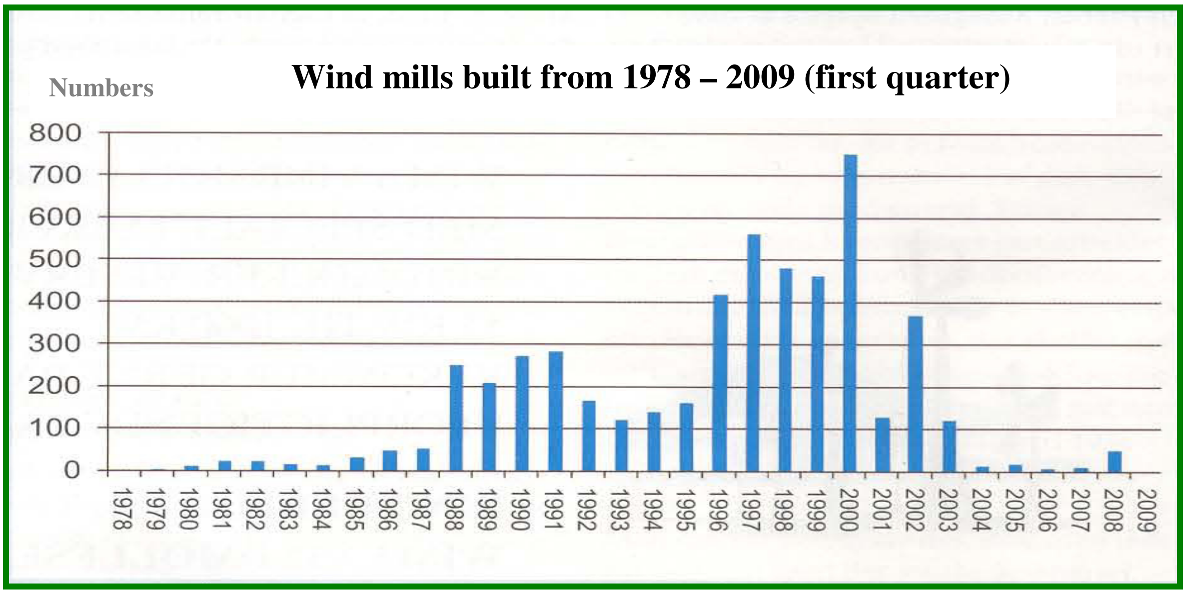
After all, the marginal cost of a paid-off wind turbine is very low, so ownership of the written down wind asset should be very profitable. At least, that is the theory.

What is not in doubt is that the early life of the wind farm, built in the main between 1996 and 2004 appears to have been very costly in consumer subsidy. The wind portion of this support amounted

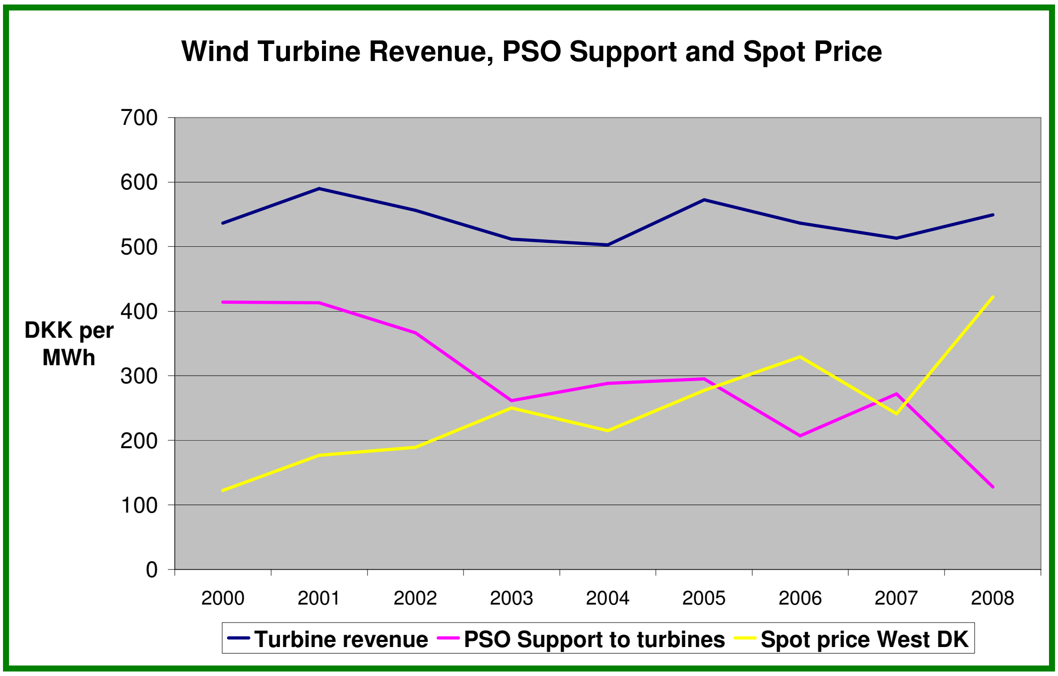
21 . In any year, Nordic hydropower companies maximize sales volume by drawing down their reservoirs, mostly between July and October, having the aim of minimizing the levels in reservoirs before the winter precipitation returns. In a liberalized market, there is no logic in maintaining inter-seasonal reserves in the reservoirs

22 A recently commissioned inter-connector between Norway and the Nederland will increase the flexibility of Norway to the detriment of West Denmark which has "monopolized" electricity transmission between Norway and the UCTE until now. In the view of this writer, the Norwegian generators will use their increased transmission capacity to drive up the value, therefore price, of providing balancing (or regulating power) reserve as wind power capacity increases along the coastal areas of northern Europe and the TSOs all over the region seek increased regulating power reserve. Another inter-connector is planned between Norway and northern Germany.

to roughly DKK 1.9 billion (Euro 257 million) per year[23]. As the decade has advanced, the rate of new building in Denmark declined sharply and to maintain their sales, the manufacturers were forced to concentrate on export markets where the subsidies are higher.



Source: *Naturlig Energi, June 2009*



Source: *Energinet.dk and Danish Energy Agency*

The preceding chart shows how the gross revenue enjoyed by the wind turbine owners is stabilized by the PSO subsidy at between DKK 500 and DKK 600 per MWh (Euro 67 and 81 per MWh), irrespective of the market conditions. It also illustrates how the cost of wind power, even under conditions of rising energy prices, is still significantly more than the spot market price in West Denmark.

[23] The split between the various technologies that were supported from 2001 thro 2004 is unclear. But subsequent years show that wind power gets about 50% of the overall subsidy. Decentralized CHPs also need public support to function economically.

Costs of balancing wind power across the inter-connectors

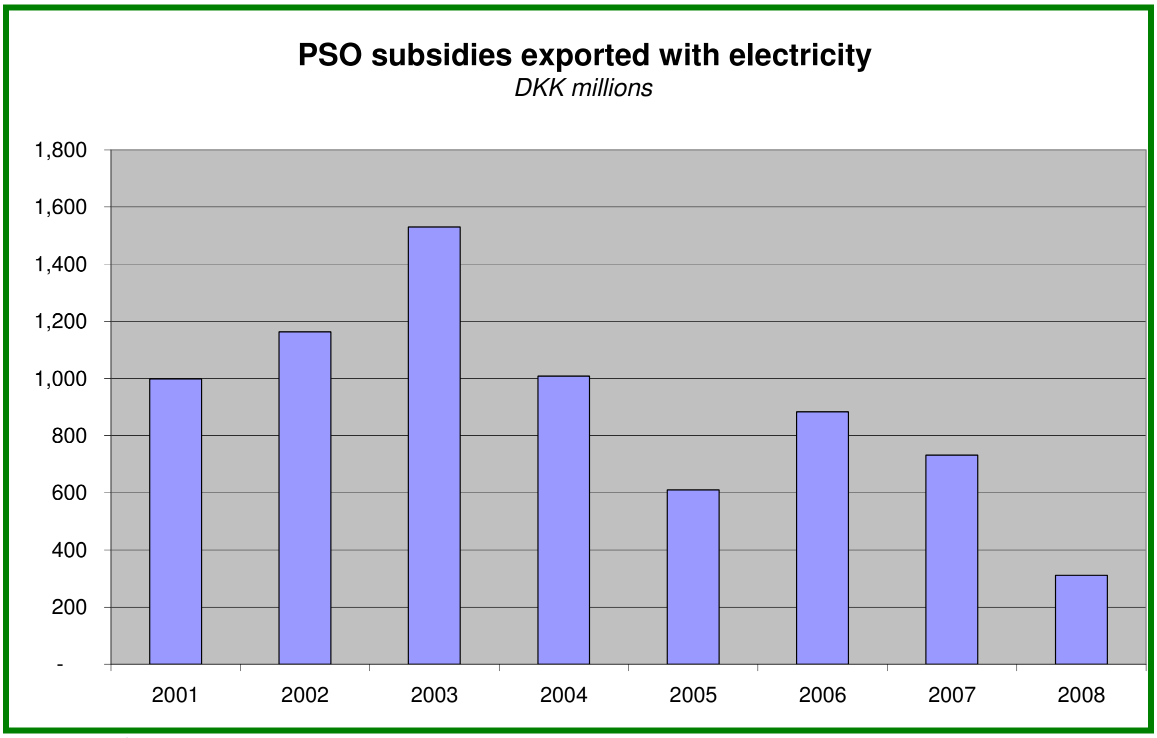
Earlier in the document, we discussed how the stability of the Danish grid is maintained by the constant use of the "electricity storages" of Norway and Sweden, as electricity flows through the inter-connectors, keeping the balance between supply and consumption constant within the Danish systems.

Each MWh of power generated from wind turbines that gets exported, carries away the subsidy that caused it to be generated. The price obtained for this by the Danish generators is, on average, the spot price. Any difference between the real cost of generating and its sale on the spot market is not a material consideration for the wind generators who are compensated retroactively when the spot price is low.

But for the Danish householder who is paying the subsidy in order to save imported fuel and CO_2 emissions, the subsidy so exported brings no direct benefit at all. The total probable value of exported subsidies between 2000 and 2008, was DKK 7.2 billion (€ 970 million) during this period.

The following chart shows how this was distributed during the current decade

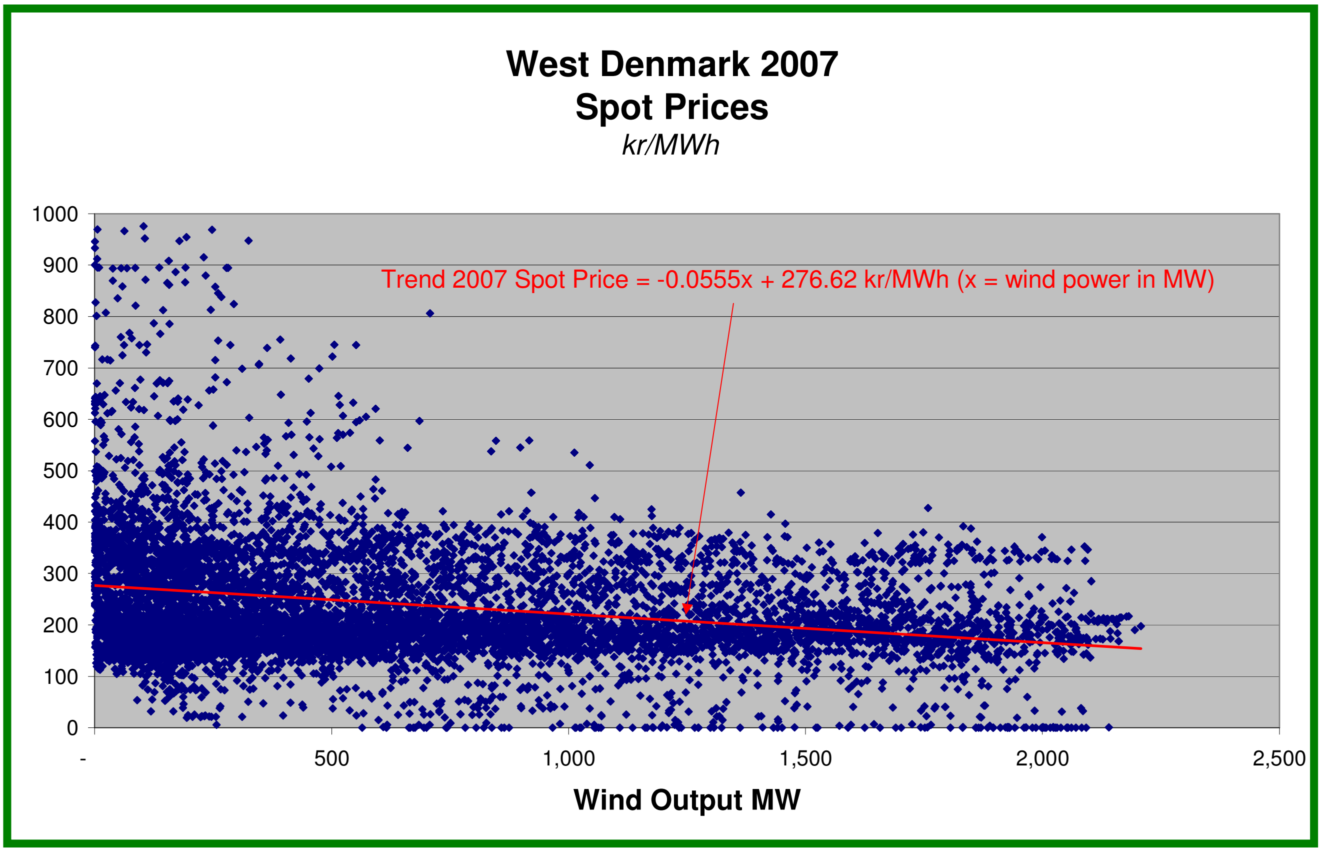
Denmark



Source: *Derived from data at Danish Energy Agency and author's calculations*

On the other hand, the wind power exported, paid for by Danish householders, brings material benefits to consumers in Sweden and Norway whose "clean energy" is effectively subsidized by the "foreign aid" received from the Danish consumers. Furthermore, the wind (and thermal) power that Denmark exports, enables its Nordic neighbors to postpone investment in needed, new generating capacity.

The trend line in the following the chart shows clearly that whereas the market price in any hour is a function of many factors, over a whole year there is a notable correlation between wind and price. The average price in the market between times when the wind output is zero and when the wind output is maximum, is consistently about DKK 100 (€ 13.5) per MWh.



Source: *Energinet.dk*

An important feature of the chart for 2007, and indeed for any similar analysis made since 2000, are the large number of hours when the electricity spot price in West Denmark is nothing at all. In the case of 2007, there were almost 100 hours when the price (= market value) of power in West Denmark was zero, as thermal generators struggled to balance their obligations to supply heat and electricity and were unable to turn down wind power, which under Danish Law, always has a preference.

The same can be shown for any year between 2000 and 2008, for East as well as for West Denmark and for other areas in Europe where there is a high penetration of wind energy, such as in Germany and Spain. Some enthusiasts for wind power hail this as a positive feature of wind power, ignoring the enormous market distortion caused in the first place by the financial under-pinning of more expensive wind power through subsidy and the trading advantage conferred by law that wind power shall be allowed to operate continuously without normal market constraints.

The low spot price for exports that is caused by a high output of wind energy especially benefits the Swedish and Norwegian power companies and their consumers without bringing any tangible benefits to Danish consumers. It is axiomatic that when the Danish thermal power companies are obliged to generate when the selling price is below the cost of operation, sooner or later this loss is made up by the much higher prices that they receive when there is less wind power, as the chart also reveals.

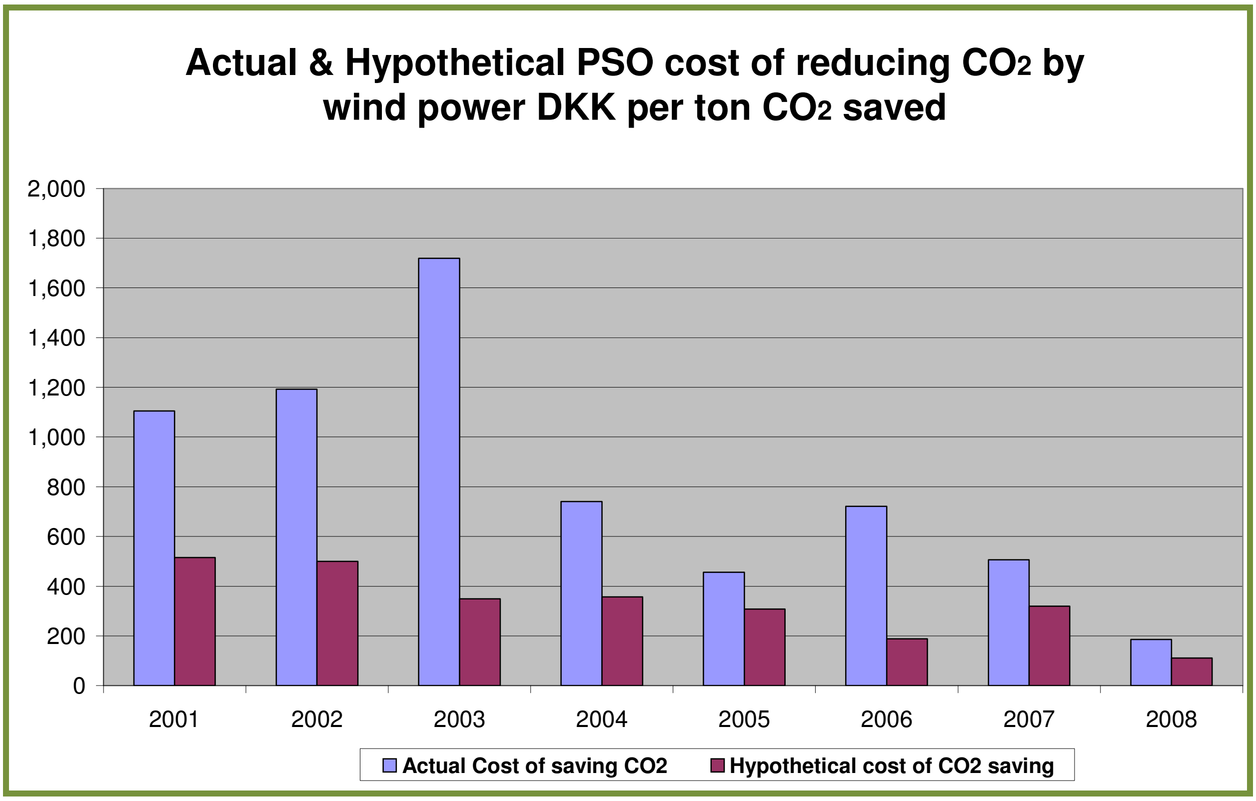
In October 2009, Nordpool[24], the electricity trading system used in the whole Nordic area, is introducing a negative price for power. The floor price that traders will have to observe, presently zero, will be extended downwards to minus €200 per MWh. This will apply in particular to Denmark and more particularly, because of its high wind capacity, the West Denmark price area. In effect,

[24] www.nordpool.com

"the market" will be penalizing other generators for excess wind power in the market. It is hoped that a negative price will incentivize the major players to find commercial and technical solutions to avoid events like this.

The wind power that is not used in Denmark, saves no coal nor gas in Denmark[25]. Indeed, as the charts illustrate, to keep the Danish system stable ***and its cities heated***, it is necessary to run the coal-fired stations, even as wind is being exported. The arrival of wind power, overwhelmingly dominant during the winter months, has done nothing to replace the need for thermal plants that can deliver secure and cheap district heating.

The following chart illustrates how the extremely high public cost of actually reducing CO_2 by wind power would be hugely and positively affected if all the wind power generated in Denmark were not hypothetically but actually used in Denmark to reduce coal consumption and CO_2 emissions.



If this were the case, the amount of coal saved by using the wind power in Denmark between 2001 and 2008 would rise from 7.9 million tons to 16.7 million tons; the consequent CO_2 emission savings would have risen from 19 million tons to 40 million tons.

The export of so much wind power that the Danish householders pay for is not widely discussed in Denmark. Nor is it discussed that this causes Denmark to burn more coal than would be the case if the wind power were somehow used within Denmark. Nor is it widely known that Danish consumers and companies are obligated, through the Kyoto process, to buy carbon offsets for the CO_2 that is not saved by the export of wind power. As this paper demonstrates, notwithstanding the transparency of public information in Denmark, this "factlet" is complicated to calculate and relatively "invisible" to the ordinary Danish consumer.

[25] . Because the Nordic electricity systems are relatively fossil fuel free (99% hydro in Norway, mainly nuclear and hydro in Sweden), the wind power exported Northwards saves water from being used to generate electricity but no fossil fuel. Some apologists for the Danish balancing method claim that a fraction of the hydro power Denmark imports is "saved wind energy". That might be true. But it always comes back with a considerably higher price than it was sold for. This paper could but has not analyzed this premium.

Nevertheless, senior civil servants and many executives in the power companies and at Energinet are aware that the default grid balancing solution is far from optimal, both from the point of view of the highly taxed consumer and indeed, because Danish society consists entirely of its citizens, Denmark.

To the foregoing, can be added the extra costs that the thermal generators incur when obliged to continue generating at below the cost of operation and which extra costs, in the end, are invariably paid by Danish consumers.

The foregoing pages show how the subsidy is declining as the wind fleet matures and the market price of power, presumably reflecting higher fuel prices, makes wind power more competitive with fossil plants, kWh for kWh.

But the technically elegant balancing mechanism that makes such use of previously installed and paid for inter-connectors, hides the fact that the true cost of Denmark's wind capacity to Danish consumers will continue to be high and might even grow as fuel prices and CO_2 prices increase, until most of the wind power that Denmark generates can be used "in country". Use of more wind power within Denmark will require greatly increased electricity demand and new technical solutions that have yet to be invented, proven and costed.

Finally, as already mentioned, the striking advantage of wind power, even with its many disadvantages, is that the marginal costs of its operation are very small once the capital has been paid. However, it is a fact that many ten-year-old turbines are already past their useful life. By contrast, most conventional rotating power plant can enjoy a working life of 40 to 60 years, as evidenced by many power plants in Europe today. One has to question the strategic, economic and environmental benefits of a power plant that may have be scrapped and replaced every ten to fifteen years.

This applies especially to offshore turbines.

Further expansion of wind power in Denmark

We have shown that over the last eight years that West Denmark exports, on average, 57% of the wind power it generates and East Denmark exports an average of 45%. In dry years more than 70% of the power generated by the wind is exported. So the rolling average of wind power consumption is at best about 12% and during some years, ironically when the thermal plant is most busy supporting power supplies in the Nordic region, wind power consumption in Denmark can be as little as 4%.

On the contrary, and to repeat, most Danish politicians and many Danes deem its wind industry to be successful, and sincerely believe that Danish wind power is supplying almost 20% of Denmark's electricity in 2009. Believing this, the Danish Parliament reached a political consensus during 2008 that in 2025, 50% of Denmark's electricity demand must come from renewable resources, mostly wind power.

Although Danes accepted the first generation of wind generators without much fuss and bother, they have since proven resistive to being asked to live alongside the giant wind turbines that have been developed during this decade and are a common feature in the landscape of many countries across Europe, in particular Germany, Spain and Scotland.

To sidestep the NIMBY[26] issue, nearly the whole of the expansion of wind power in Denmark will come from offshore wind farms, mostly "over the horizon". This is no idle promise. As mentioned previously, two contracts have been agreed (2 no x 200 MW) and bidders are lining up to bid the remaining 400 MW project off Anholt. So by 2013, a further 800 MW of offshore capacity will be installed within the system, delivering a further 2.8TWh per year from 2014 onwards, already

[26] Not in my back yard. Danes are fond of their landscape and this is recognized by Denmark's politicians.

committing Danish consumers to major future expenditure. Unless more stringent measures are shortly put in place, most of this additional wind power will be exported

Offshore wind is more expensive and more risky to build, own and operate than onshore turbines. Learning from the recent history of Government support, the bidders and the Government have accepted the idea of a fixed feed-in tariff over a lifetime of 50,000 so-called "full load" hours[27] for these turbines.

The agreements are now in place for Horns Rev 2 - 200 MW (feed-in tariff DKK 518 per MWh) and Rødsands 2 – 200 MW (feed-in tariff DKK 629 per MWh). The tender for the 400 MW offshore wind farm between Anholt Island and Jutland will be closed in April 2010[28].

The awards given so far imply a capital cost for offshore wind in the range of €2.2 million per MW to which will have to be added the under sea connection to land and the integration of these connections into the electricity system. All this will have to be paid for, as in the past, by private Danish consumers.

By 2025 (some are arguing 2020), the total wind power capacity of Denmark will be 6,900 MW, assuming that the average capacity factor of the offshore fleet will be 40%.

The peak load in Denmark today is 6,500 MW, with a valley load of about 3,500 MW. So unless there is a revolution in the way energy is supplied and used within Denmark, it seems certain that the electricity supply industry will be forced to re-engineer the whole electricity system, and/or export even more wind power or, in extremis, the wind power will have to be curtailed at the very moment it is generating most power (and revenue).

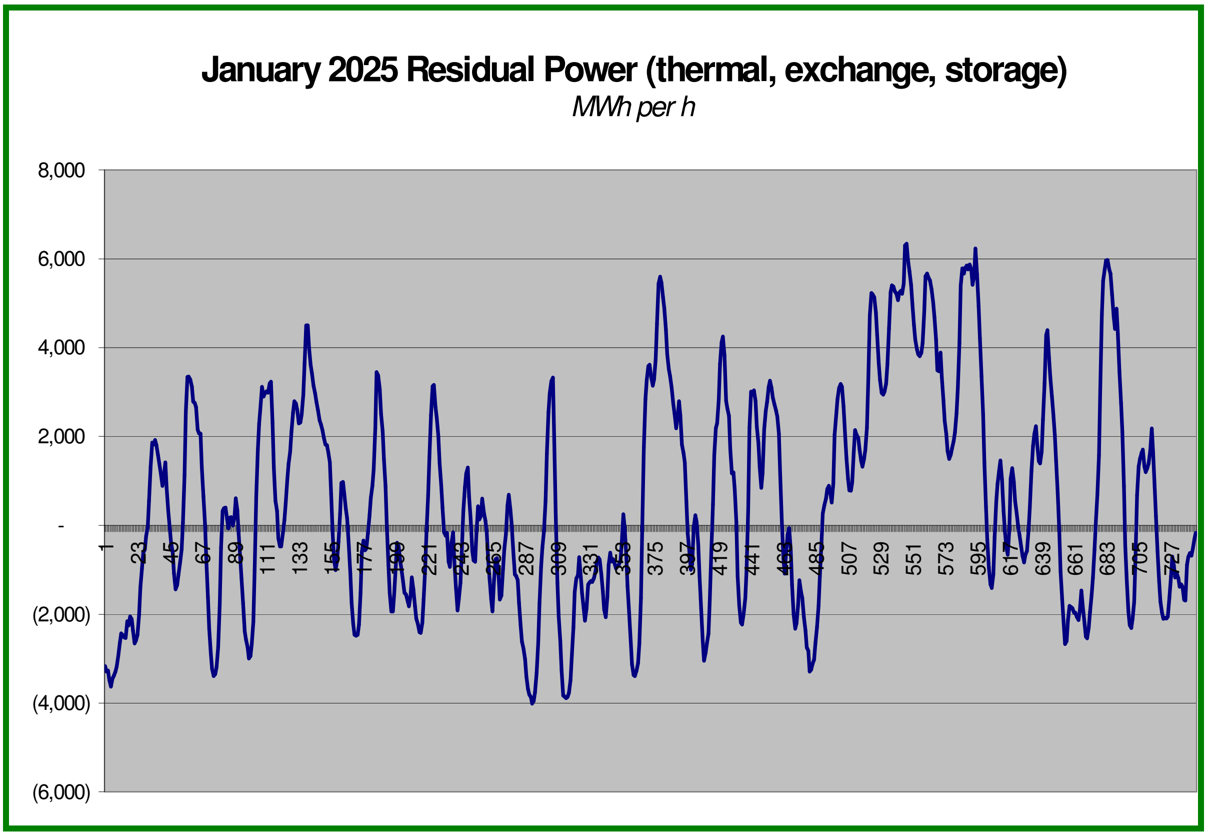
This expansion has been anticipated and studied by Denmark's, *Energinet.dk*, which commissioned outsiders to do the "radical thinking" required for this eventuality. In May 2009, the first summary report of the *Ecogrid* group was published[29].

The Ecogrid Study Group has concluded that extrapolating the future from the past is not feasible, so that if the extra wind power is to achieve the aims of the consensus, drastic re-engineering of the whole system will need to take place. Wisely, it has not tried to estimate the costs of doing this.

[27] On land, a 1 MW Danish wind turbine, with a capacity factor of 25% will deliver 8,760 * 0.25 = 2,190 MWh per year. The early, land-based Danish turbines were given subsidies for 22,000 full load hours which means in practice 10 years. The average capacity factor of the offshore wind farms has been shown to be roughly 40%. That means a one MW offshore turbine should generate 3,504 MWh per year

[28] Danish Energy Agency

[29] http://www.energinet.dk/en/menu/R+and+D/EcoGrid/EcoGrid.dk.htm



In the foregoing chart, it is assumed that wind power (extrapolated from January 2007) will not be curtailed but that daily demand and system balance will be achieved by an extremely flexible "residual power reserve". The reserve will consist of:

- New types of thermal power stations because it is most unlikely that Denmark's fifteen modern central heat and power stations will be able to operate economically under the conditions foreseen in the chart. The new re-build cost of this roughly 8GW will be at least €16 billion.
- Electric-based district heating. There is much discussion of using heat pumps that can deliver from two and up to six times as much heat as they consume in electricity. These will require enormous reserves of low grade heat to operate and such heat pumps have never been delivered on the scale foreseen.
- The switch over to electric vehicles on a very large scale,
- Stationary electric storage possibly in conjunction with heat pumps, and
- No doubt, a continued, although relatively reduced, use of the inter-connectors and European trade.

By then, new wind capacity in Sweden and Norway is likely to cause operating constraints within their own systems and therefore there may be constraints on the use of the inter-connectors with Denmark.

All this will not be cheap. We are in a position to make some very rough estimates about some of the capital costs.

- Additional offshore wind turbines, 3,700 – 4000 MW € 8 - 10 billion. Unlike traditional power generating equipment which has a useful economic lifetime of 40 – 50 years, these turbines are not seriously expected to operate very much beyond their pay-off lifetime of 14 years. So it is likely that there will be a recurring cost for the offshore turbines.

- Connections between the offshore turbines and the HV Danish grid. In deference to objections about new overhead lines, many of these will be buried so it is prudent to anticipate a very high cost, say € 4 – 5 billion

What is not included in this investment estimate is any idea of how the residual balancing reserve will be provided and configured, save for the very general statements and rough cost estimates already made.

Hitherto, the radical transformation of the Danish energy system has almost entirely been driven by economic considerations based on technical feasibility. The recent imposition of arbitrary targets by politicians that require unquestioning implementation by the infrastructure suppliers, without any apparent estimates of costs, is a relatively new and worrying departure for the way Denmark is organized.

The very fact that the wind power system, that has been imposed so expensively upon the consumers, can not and does not achieve the simple objectives for which it was built, should be warning the energy establishment, at all levels, of the considerable gap between aspiration and reality.

Denmark needs a proper debate and a thorough re-appraisal of the technologies that need to be invented, developed and costed before forcing the country into a venture that shows a high risk of turning into an economic black hole.

PART 2:

Wind Energy's Effects on Employment in Denmark[30]

Author: Henrik Meyer[31]

> *"It's estimated that if we fully pursue our potential for wind energy on land and offshore, wind can generate as much as 20 percent of our electricity by 2030 and create a quarter-million jobs in the process -- 250,000 jobs in the process, jobs that pay well and provide good benefits. It's a win-win: It's good for the environment; it's great for the economy."*
>
> *"Today, America produces less than 3 percent of our electricity through renewable sources like wind and solar -- less than 3 percent. Now, in comparison, Denmark produces almost 20 percent of their electricity through wind power."*
>
> Barack Obama, US President, Earth Day Speech, April 22, 2009[32]

Introduction

The US wind industries estimates US employment within the wind energy industry of 85,000 in 2008.[33] Correspondingly 28,400 are employed in the Danish wind energy industry, as estimated by the Danish Wind Industry Association (DWIA).[34] Electricity generation from wind in the US is around 1% in 2007. [35] In Denmark the electricity generation in 2007 was equal to 19.7% of electricity consumed.[36] But in contrast to the modest US generation, the Danish wind energy is to a large extent exported.[37]

The assumption in Obama's speech is that regulation, as formulated by Michael Porter[38], can be a win-win solution to environmental pollution and at the same time improve the economy. This is often considered common-sense among a broad number of policy-makers. However, Porter's win-win hypothesis is poorly documented empirically.[39]

In this context, is it interesting that Denmark is seen as the good example of job creation.

The purpose of this paper is to document the actual experiences gained in Denmark – the world's leading wind energy country – with regard to employment and subsidies of the wind industry. Obviously the abatement of CO_2 is a main issue, but the employment effect is also frequently underlined by policy makers.[40]

Job creation and destruction is an integral part of today's economies and societies. Job creation therefore is not the success criteria *per se*. The crucial question is whether the wind industry is outperforming other manufacturing industry as such with regard to generating additional employment and stimulating the economy.

General statistics on economy, jobs, exports and growth

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30 Reviewed prior to publication by leading peer experts

31 Henrik Meyer is Master of Economics from Copenhagen University. He has been working with environmental and development economics for twenty years, including externalities, growth and climate issues. He has been employed at: Copenhagen University, Risø/Denmarks Technical University, and the Danish Environmental Assessment Institute. From 2003 he has been responsible for the day-to-day management of Copenhagen Consensus; from 2006 as Deputy Director at Copenhagen Consensus Center (presently on leave).

32 See transcript for instance at: http://www.cbsnews.com/blogs/2009/04/22/politics/politicalhotsheet/entry4962412.shtml.

33 AWEA (2009), p. 17.

34 DWIA (2009a), p. 9. For Europe the corresponding figure for 2007 is 108,600 persons (EWEA, 2009, p. 7).

35 EIA (2009).

36 DEA (2008), p. 3.

37 Sharman (2009), infra.

38 Porter (1991), p. 96.

39 See for instance: Stæhr (2007) for an overview.

40 For instance:"*Denmark gained the position as global leader in wind power. This provided ten thousand of new jobs …"* Former Minister for the Environment Svend Auken, Berlingske Tidende, July 7 2008, Magasin, p. 23.

A number of data are available on employment by the wind industry, but there are also several areas, where data is either not completely updated or not available. The approach has been to utilize existing and available data and make conservative conclusions based on them.
The main source for the employment statistics in the wind industries is the Danish Wind Industry Association (DWIA). As there are no useful government statistics available before 2008, the DWIA statistics are used throughout in this paper.[41]

Wind energy experience in Denmark focusing on the employment effects

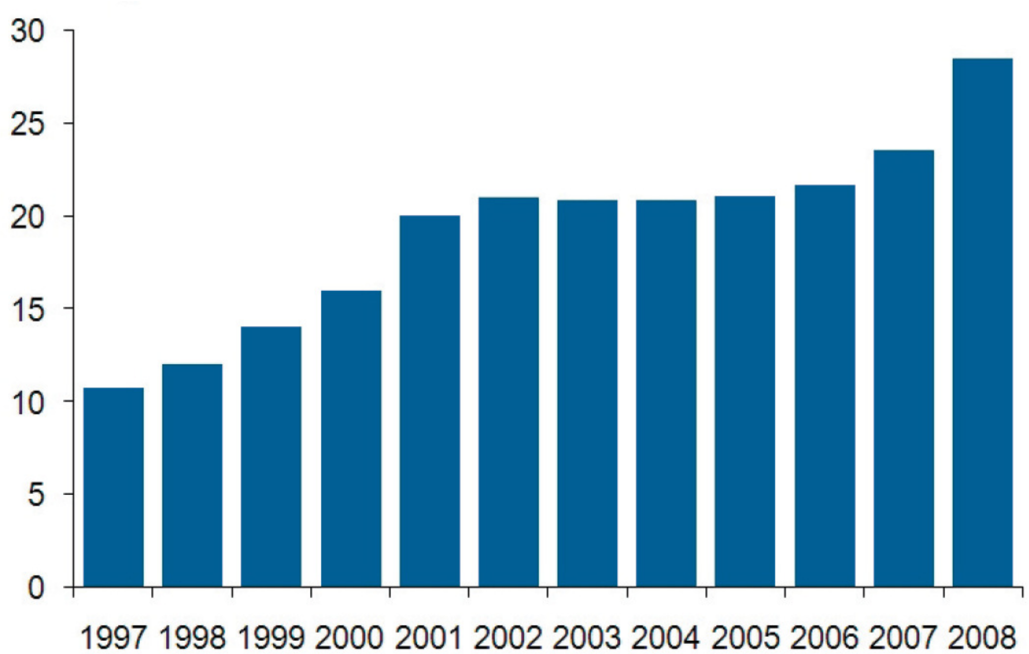
Economic effects of the wind industry in Denmark

The effects on the overall economy of government subsidizing the wind industry in the 1990's were negative according to the most authoritative report from the independent, but government-funded Danish Economic Council where the Council concludes: "*The wind power expansion in the 1990's is an example of a policy that was unprofitable from society's point of view, even taking the economic advantages that the wind business enjoyed into consideration*".[42]

Employment in the wind industry in Denmark

The overall employment in the wind industry in 2008 was 28,400, a relatively strong increase from the preceding seven years of almost constant employment around 20,000 to 21,000 workers.[43]
Figure 1 shows employment over the last ten years.

Figure 1 Employment in the wind industries in Denmark, 1997-2008 in thousand.



Source: DWIA, 2009a, p. 9. Total employment in the wind the sector.

Compared to other sectors in Denmark, wind is clearly a very high growth subsector although other sectors such as IT services, oil and gas extraction, and other services are not far from the growth rates in the wind industry.[44]
After a period with a number of wind turbine manufacturers, the industry in Denmark is as of 2008

[41] Statistics Denmark have from 2008 changed to new industrial group system called DB07 (from the 111-group system). From 2008 and on the DB07 system include a specific wind category (28001 Manufacture of engines, windmills and pumps). This category in total employs 29,862 in 2008, showing only a difference of around 1,500 workers from the DWIA's figures, probably because of smaller non-wind manufacturing such as for instance pumps.
[42] DORS, 2006, p. 14, translated from the Danish Summary.
[43] DWIA (2009a), p. 10.
[44] Statistics Denmark (2009), 111-group definition.

strongly dominated by two companies: Vestas and Siemens (a Danish-based wind division and successor to Bonus Wind bought by Siemens in 2004). The global market shares of Vestas and Siemens are respectively 19.8% and 6.9%.[45] The employment in Denmark for Vestas and Siemens in 2008 is 7,500 for Vestas[46] and over 2,500 for Siemens Wind Power.[47] Furthermore, the industry comprises a number of subcontractors developing for instance fiberglass wing. The distribution between wind turbine manufactures and subcontractors is one to one (see table 1).[48]
According to DWIA (see table 1) 55% of the employment in the sector is related to production. Compared to other industrial sectors, the R&D proportion is relatively high at 10%.
When assessing the effect on employment, the relevant measure is *net* job creation in the sector (see this section for more on this).

Table 1 Employment shares according to job function and manufacturing type in the wind sector, 2008.

Employment type	Share
Production	55
R&D	10
Process and quality management	10
Sales and marketing	10
Other	15

Employment, manufacturing type	Share
Primary manufacturers	44
Subcontractors	46
Other	10

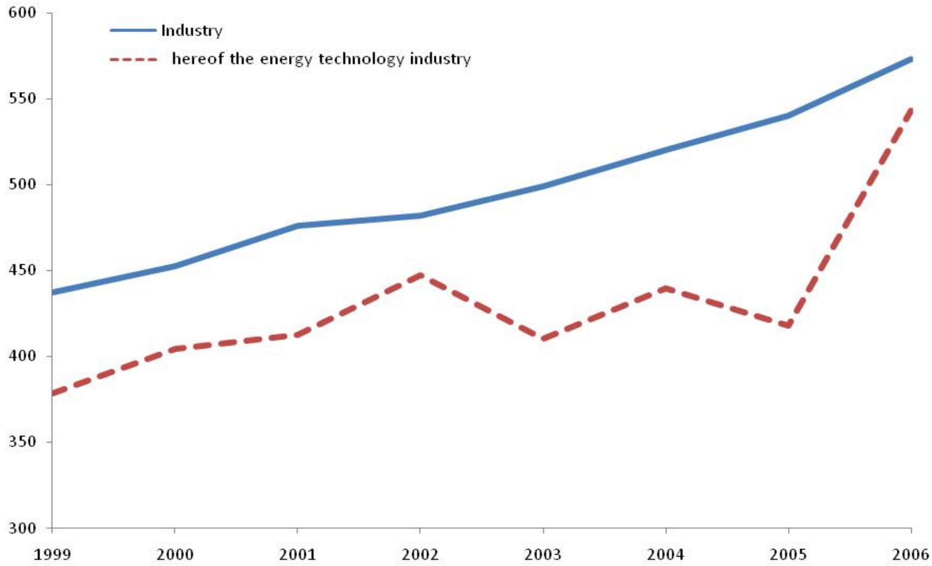
Source: DWIA, 2009a, p. 10.

Value added in the wind energy sector

In relation to an assessment of the benefits of a sector such as the wind industry to the economy, a very relevant figure is the sector's value-added contribution since this corresponds to the income received by the factor (in this case wind turbines). Industries with higher than average value added are industries that would benefit the economy and consequently sectors one would like to expand.
Jointly the Danish Energy Agency and Confederation of Danish Industry have prepared an overview of the value added from the Danish energy technology industry. As defined in this analysis the energy technology industry in 2006 employed 29,200.[49] Correspondingly, the wind industry employed 21,500 in 2006.[50] Therefore, the wind industry makes up almost 75% of the energy technology industry as here defined.
In figure 2 the most updated figures on energy technology industry, based data from Danish Energy Agency and Confederation of Danish Industry, are shown.[51]

[45] BTM Consult (2009), p. 24 based on installed MW in 2008.
[46] Employment: globally 20,829 and hereof in 15,507 in Europe and around 7,500 in Denmark at the end of the year 2008 (Vestas, 2009a, p. 19 and Borsen.dk, May 11 2009: http://borsen.dk/investor/nyhed/157193/).
[47] Siemens: http://www.siemens.dk/jobswindpower/working_at_siemens_wind_power__our_location.html, comprising three facilities in Denmark with respectively 1,600, 700 and 200 workers.
[48] DWIA, 2009a, p. 10.
[49] DEA, 2009b.
[50] DWIA, 2009a, p. 9.
[51] It should be noted that 'energy technology' includes more than the wind industry. However, the wind industry is dominant with a share of 73%; with 21,200 employed in wind and 29,200 in 'energy technology' in 2006 (respectively DWIA, 2009a, p. 9 and DEA, 2009a).

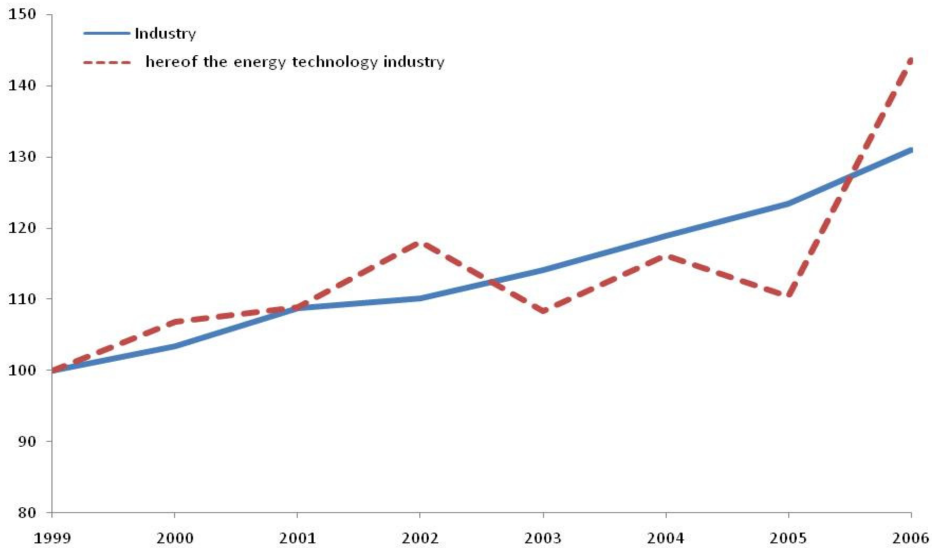
Figure 2 Value added in the industry and the energy technology sector. Value added per employee in 1,000 DKK.



Source: DEA (2009a).

The overall picture is that the energy technology industry for all eight years underperforms compared to the broader manufacturing sector. The striking fact is that the energy technology sector on average underperforms by 13% (1999-2006). This corresponds to the manufacturing industry on average delivering 66,000 DKK per worker ($10,000) more than the energy technology industry. Even in the best year (2006) the energy technology industry underperforms by 5%.
On the other hand, one might expect that the energy technology industry is catching up with the other industries starting from a lower value added but having a higher growth rate. In figure 3 (where 1999 is indexed to 100) the growth in value added is shown.

Figure 3 Value added in the industry and the energy technology sector. Value added per employee, index 1999=100.



Source: DEA (2009a).

The conclusion is that there is no significant tendency for the energy technology sector to have a higher growth rate than the Danish manufacturing industry as a whole. The statistics show two clear tendencies: the energy technology industry is more volatile, and the growth rate is comparable to the manufacturing industry.

In conclusion, based on the statistics, the evidence is that the energy industry has underperformed in comparison with the industry as a whole, and furthermore there is no indication that this is changing over time.

The Danish manufacturing industry's value-added would be about 1.8 billion DKK ($270 million) per year higher if the energy sector were to reach the average of the broader manufacturing industry's performance. This has been a clear trend for eight consecutive years with high growth and cannot be explained as temporary or by classifying the energy sector as an infant industry. The underperformance is even more striking in light of the subsidies the industry receives (see below).

Job creation

Job creation is an important issue for both policy-makers and economists since employment is a key factor for the economy. There is a common belief among economist that in the short run – through increased aggregate demand – employment is likely to be stimulated and increase. However, there is an equally strong belief that in the medium run employment is determined by the supply of labor. Thus output and employment will return to their natural level.[52] Therefore, subsidies to for instance the wind industry are only likely to reallocate employment from other sectors to the wind industry, while generating no additional jobs through the subsidies.

Two theoretical arguments for job stimulation in the wind industry

Two theoretical arguments are used to justify environmental regulation. They both stress positive effects on the environment and profitability of companies as the top advantages and employment as a secondary advantage. The two main theoretical arguments for environmental regulations are: the first-mover advantage and Porter's hypothesis. In the public debate, versions of these often appear in various forms such as 'win-win' solutions. [53] Unfortunately, the arguments are seldom well founded.

Regarding first-mover advantage there are normally three mechanisms that facilitate it: technological leadership, preemption of scarce resources, and the costs of switching for consumers and choice under uncertainty (consumers preferring the already established brand with lower expected risk). In the case of wind turbines, the only really relevant advantages of the three is consumers' cost of switching to other products. Regarding technological leadership there is limited advantage since wind turbines are relatively simple technology (a steel tube, a gear, a break, transmission, and blades) and thus present a low entry barrier. With regard to resources there are no relevant limitations in the production.

From an economist's perspective, the Porter hypothesis is more extraordinary since it contradicts standard economics, claiming that (environmental) regulation will not have any costs and can even be an advantage for at least part of the regulated industry.[54] But even the advocates of the Porter hypothesis accept that it cannot be universal, as this would lead to perpetual environmental improvement and at the same time increasing profits. In contrast to the first-mover advantage, the empirical evidence does not support the Porter hypothesis.[55] In conclusion, the Porter hypothesis is not a sound principle for environmental regulations as it is unlikely that the hypothesis has validity other than for a few cases.

Job creation in Denmark in general

[52] See for instance standard macroeconomics text books as Blanchard, 2009, ch. 27.

[53] An example is Danish Minister of Climate and Energy, Connie Hedegaard: *"We have to look at the costs of environmental protection and the sound management of natural resources as an investment - rather than as an expense. And experience has shown that concerns for the environment as well as for growth can be mutually supportive".* The Danish Perspective, speech delivered March 2, 2006, http://www.ecoinnovation.dk/English/News/Latest+news/tale+IMV.htm.

[54] It is obvious that the Porter hypothesis at first fit the Danish wind undertaking.

[55] Stæhr (2007), p. 7. Wagner (2003) and SQW (2006) give a detailed discussion of the empirical aspects of the Porter hypothesis.

In an analysis of overall job creation and destruction in Denmark, Ibsen & Westergaard-Nielsen (2005a and 2005b) find that the average job creation was around 125,000 annually for the private sector in the period 1980-2001.[56] This roughly corresponds to 4.5% of all employed.

The unemployment rate for skilled and unskilled workers in the wind sector (Danish Metalworkers' Union) is not significantly different from the general unemployment rate. There are, on the other hand, clear regional differences in the employment in Denmark with more remote regions typically having experiencing higher unemployment. However, from 2006 there has been a change in that pattern where the capital, Copenhagen, has experienced a higher unemployment than the traditional candidate (Northern Jutland). The wind manufacturing industry has production units in most regions of Denmark. Consequently, the wind industry is generally not located in high unemployment areas. Therefore job creation in low employment areas has been limited with a few exceptions.

Government's subsidies to the wind energy sector and job creation

Important in relation to assessing the effects of the wind industry's employment are the subsidies the sector has received. The main subsidy to the wind industry is indirect, through a premium rate to wind turbine owners in contrast to other mainly coal generated electricity. The wind industry has only received relatively modest direct subsidies. However, government support for R&D in renewable energy – to a large extent wind – is projected to reach 1 billion DKK yearly ($150 million) in 2010, not an insignificant amount.[57]

The main subsidy process is transfers from mainly private consumers to the wind turbine owners and then on to the wind industry.

Since 1976 the wind industry has been supported through various policies.[58] Since the 1990's the main public support has been subsidies to wind turbine owners delivering electricity to the grid. From 1991 to 2001 turbine owners received 3.6 c€ per kWh. For comparison the average consumer prices (excluding taxes), i.e. the cost of primarily coal generated electricity, for the same period was around 2.3 c€ per kWh.[59] Thus the price of wind generated electricity was more than 50% higher than that of coal generated electricity. An interesting aside regarding the electricity prices is that the real price faced by the consumer – adding taxes such as energy, carbon and VAT – for the same period is 11.5 c€ per kWh or more than 500% higher.

According to The Auditor General (Rigsrevisionen) the overall subsidy to the Public Service Obligations (PSO) for the period 2001-05 was 21.6 billion DKK ($3.27 billion) or 4.3 billion DKK ($650 million) on average per year.[60] The isolated subsidy for wind turbine owners is estimated to be 2.6 billion DKK ($390 million) per year from 2001-05.[61]

The argument for government provided support – typically through subsidies and taxation of competing business – for specific industries, such as wind energy, is mostly theoretical, and the empirics behind it are called into question among the larger community of economists.[62] It is unlikely that this is a feasible approach to permanently increasing growth and employment, although the policy is likely to benefit the targeted industry at the expense of neighboring industries and society as a whole.

Subsidies in relation to job creation

[56] Unfortunately, it has not been possible to obtain research for the period after 2001, but most likely due to the beneficial general economic national and international economic situation the job creation minus destruction have been higher (as unemployment in 2008 was 51,721, down from 130,578 in 2001, Statistics Denmark, 2009, AUL01: Unemployed persons by region, type of benefits, unemployment insurance fund, age and sex (final)).

[57] Prime Minister's Office (2007).

[58] This is briefly described in a short paper from DEA (2009b).

[59] According to DERA, 2002, table 2.

[60] Rigsvisionen (2007), p. 5 and 45.

[61] Rigsvisionen (2007) and for instance Danmarks Radio, Jan. 27 2007, http://www.dr.dk/Nyheder/Penge/2007/01/29/065209.htm.

[62] In their analysis of Danish wind energy the three government appointed economics professors conclude that: *"Generally speaking targeting specific individual [industrial] branches is problematic since it is necessary that the potentially [good] branches can be identified beforehand"*. (DORS, 2006, p. 14, translated from the Danish Summary).

Job generation in the wind industry as a consequence of the subsidies is obvious. The really interesting question is how many *additional* jobs the wind industry generates. A ballpark estimate is that the industry, through the indirect subsidies to wind turbine owners, receives 1.7-2.6 billion DKK per year. This is likely to be a lower estimate as it for instance does not include various R&D subsidies.

Based on the total subsidies to the industry, the average subsidy per worker employed in the sector equals 60,000-90,000 DKK ($9,000-14,000).[63] This figure provides a rough estimate of the average subsidy per worker.[64] One very important issue should, however, be considered. Calculating the average subsidy does not reflect the actual costs of the *additional* job creation. The most relevant figure in this context is cost per job created. The Danish job market in last ten years until 2008 has been characterized by full or almost full employment. The average unemployment from 2000 to June 2009 have been 4.3%, ranging from 1.7% (May-Sept. 2008) to 6.2% (Dec. 2003). In the case of full employment, as experienced in the 2000s, creating a job in the wind sector will in effect only have moved that job away from another sector and have resulted in no additional job creation.

In the case of especially regional unemployment, where the wind industry would actually create new jobs and move people from unemployment to employment, there is a clear benefit to society.

During the 2000s there have only been a few pockets of high unemployment in Denmark, mainly in North Jutland with a 28% higher unemployment rate than the country average. However, all other regions of Jutland with substantial wind turbine factories have had below average unemployment. Obviously, one cannot completely rule out that specific factories can have brought real additional employment to a district.[65]

Nevertheless, the empirical data do not support any significant real job creation from 2000 to 2009 due to a low unemployment rate of 4.3% on the average for the period. A very optimistic ballpark estimate – in favor of the job creation hypothesis – of real jobs created is around 10% of the total workforce or 2,800 new jobs. In this case, allowing for the rough estimate, the actual subsidy for the additional, created jobs is 600,000-900,000 DKK per job ($90,000-140,000). In reality this is a low figure for the real subsidy per created job in the wind sector. Even such regional employment effects must be expected to be fairly short lived and thus add no extra employment in the long run.

Compensation of employees in the wind industry

A large proportion of those employed in the wind industry are skilled or unskilled, but specialized workers. It is relevant to compare the salaries in the wind industry with industries employing the same type of labor. If wind industry is a high growth sector, one would expect salaries to be above the industry average.

Obtaining sufficiently detailed data has not been possible since the financial report only provide aggregated numbers for the whole company in order to fulfill the formal requirements. However, cursory calculation using available data indicates that compensation in the wind industry is not significantly higher than the average skilled worker. This indicates that the subsidies are only to a low degree transferred to the employed in the sector. It should be stressed that a final conclusion is pending better data.

[63] In reality, however, the wind subsidies are not only intended for job creation. Also environment, climate and possible security are externalities that the subsidies should cover. Furthermore, the dead weight loss is not included in this calculation.

[64] One should note that this figure does not necessarily translate into over-normal wages. There is no available empirical evidence on how the subsidies are shared between the main agents, namely: the wind turbine owners (initially receiving the subsidies), labor (employed) and capital (the shareholders). This division depends on markets and the relative strength of the input factors, and institutional institutions.

[65] Such as the case of Vestas Blades factory in town of Nakskov where a rapid employment took place up to 600 workers. On the other hand, this factory was one of the first to announce layoff 50% of the workforce in 2009.

The dead weight loss and wind subsidies[66]

The effect of taxation, whether direct and indirect, has a dead weight loss. The dead weight loss will vary depending on the tax. However, for policy recommendations several governments have fixed an average figure although some bodies refrain from doing it. In Denmark the dead weight loss is estimated at 20%, effectively increasing the costs of tax financed public projects by at least 20%. However, more specifically, the tax distortion factors for energy taxes are estimated to be 30%.[67] On the other hand, the central Danish tax authorities estimate the deadweight loss for energy taxes to 8-15%.[68] In the case of wind subsidies, one cannot directly translate the tax deadweight loss into a subsidy deadweight loss. However, assuming that the subsidy deadweight loss is in same the order of magnitude, *i.e.*, between 8-30%, the total deadweight loss from wind subsidies is probably somewhere between 140-780 million DKK yearly ($21-120 million). This deadweight loss is a pure loss to society.

The wind industry - a volatile sector highly depending on politics

As the wind industry is a small sector in the Danish economy, it has an almost intrinsic tendency to be more volatile than the whole industry. But strengthening the volatility of the wind industry is that wind power cannot yet compete on market terms with other electricity generation (especially coal). Therefore, the industry is totally dependent on subsidies to the wind turbine owners and political goodwill.[69]

Concluding remarks

The ambitious goal of Denmark is to double renewable energy consumption to 30% in 2025.[70] With constant energy consumption this results in 4% per year growth in renewable energy consumption. At the same time the government aims to reduce the overall consumption of energy by 1.4% annually from 2010. This is highly ambitious compared with the trend from 1980 to now, where energy consumption has been almost constant.[71] The government's plan translates into a net growth in the renewable energy sector of 2.6% yearly for the period. Based on past evidence, it is unlikely that this can be implemented without prolonging the subsidies.

Applying the experiences from Denmark

Denmark has been a first-mover in the wind industry for over ten years, and its leading companies have been able to maintain a very strong global position. This has been a consequence of a concerted policy to increase the share of wind in Danish electricity generation such that Denmark now generates the equivalent of almost 20% of the electricity it consumes using wind turbines. It has been a policy only made possible through substantial subsidies of around 2 billion DKK yearly ($300 million) supporting the wind turbine owners. This indirect subsidy has in turn generated the demand for wind turbines from the manufacturers. Exactly how the subsidies have been shared between land, wind turbine owners, labor, capital and shareholders is opaque, but it is fair to assess that no Danish wind industry would exist if it had to compete on market terms.
The labor force in the US is 155 million in 2008 (est.).[72] The present number of those employed in the US wind industries is 85,000 making up 0.05% of the US workforce (in Denmark the wind industry employs 20 times this number). Obama's stated ambition to increase the employment in the wind industry to 250,000 may be achievable if Denmark's policy of high level of subsidies is followed. However, a central issue is how this is going to be financed, and furthermore how 20% wind electricity is to be integrated into the existing energy system. Finally, it should also be considered that the US electricity consumption per capita is almost twice the consumption in

[66] Møller & Jensen (2004) gives a thorough presentation of the issue including a 10 page English summary.
[67] Møller & Jensen (2004), p. 15. This is mainly due to a relatively higher increase that for instance VAT, a smaller taxation base (only energy) and that only some energy forms are taxed (Møller & Jensen, 2004, p. 107).
[68] SKAT, 2004.
[69] This effect was especially clear after a new government took office in 2001 and changed the subsidies scheme. Once the changed subsidies took full effect in 2004 the consequence was an almost total stop for new wind turbines (DWIA, 2009b).
[70] Prime Minister's Office (2007).
[71] DORS (2008), p. 142.
[72] CIA Factbook, https://www.cia.gov/library/publications/the-world-factbook/geos/us.html.

Denmark, so wind intensity would roughly have to be twice the intensity of Denmark. The proposal from President Obama does not explicitly deal with these difficulties and does not appear well documented.[73]

As mentioned above, the Danish wind industry is a strong export industry, and this makes a direct comparison with Obama's plan difficult with regard to actual job creation in the wind industry. It seems highly unlikely that large country's wind industry such as the US – having a population of more than 50 times the population of Denmark – would be able to replicate the Danish share of exports of wind turbine technology. In that way a US expansion is expected to be predominantly domestic, and at the same time the industry is probably going to face foreign competition from companies such as Vestas, Siemens and new low cost producers in countries like India.
Based on the Danish experiences with wind power, subsidies to wind need to be significant or corresponding taxes on carbon-based electricity need to be increased substantially.
The Danish experience also suggests that a strong US wind expansion would not benefit the overall economy. It would entail substantial costs to the consumer and industry, and only to a lesser degree benefit a small part of the economy, namely wind turbine owners, wind shareholders and those employed in the sector.

[73] See for instance recharge.com: "*Obama did not say what criteria his administration used to make those estimates, which critics contend are overly optimistic*", http://www.rechargenews.com/regions/north_america/article176487.ece.

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