

The Wind Turbine Market in Denmark

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Wind Resources

Denmark has relatively modest to good average wind speeds in the range of 4.9 to 5.6 m/s measured at 10 m height (with a Weibull form factor of 1.74), equivalent to typically 6.5 m/s at a wind turbine hub height of 50 m. (The highest average wind speed at hub height onshore is about 7.5 m/s). Onshore wind resources are highest in the Western part of the country, and on the Eastern islands with coastlines facing South or West. [1]

The country has very large offshore wind resources, and large areas of sea territory (and economic zones) with a shallow water depth of 5 to 15 m, where siting is most feasible. These sites offer higher wind speeds, in the range of roughly 8.5 to 9 m/s at 50 m height. [2]

Wind Generation Structure

Wind development in Denmark is spread geographically throughout the country, although with higher concentration in the windiest areas noted above. [3]

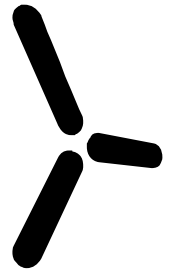
Single wind turbines or, increasingly, clusters of turbines are the most common siting method. There are comparatively few large wind parks. The reason for this is partly the planning policy preferences (generally against large parks, and favouring clusters), [4] and the Danish ownership restrictions which effectively (though not intentionally) encourage single turbine siting. [5]

80 per cent of Danish wind power capacity is owned by individuals or wind co-operatives. The rest is owned by power companies. [6]

Renewable Energy Policy for Wind

Denmark, which in the early 1970s was extremely dependent on (imported) oil, pursued a very active policy of energy savings, increasing self sufficiency, and diversification of energy sources until the mid 1980s. Since then, energy policy has increasingly promoted the use of renewable energy to ensure environmentally sustainable economic development. [7]

Long term planning is considered to be important, with a planning horizon presently set at the year 2030 in the Government policy document "Energy 21". [8] The reason for this very long term planning is to ensure consistency in policy, and to send strong signals to market actors about the policy scenario in which they will operate. In the electricity sector, plant and equipment have long lifetimes (e.g. transformers, transmission systems and generating plant). One important aspect of present planning is to ensure that the future electricity system will be able to accommodate a very large share of intermittent renewables.



Since the mid 1980s, the country has had an official goal of meeting 10 per cent of Danish electricity consumption by wind in the year 2005, implying an installed base of 1,500 MW of installed wind capacity. [9]

It now seems likely that the target will be reached by the year 2000, and new ambitious Government plans in the "Energy 21" policy document indicate that around 50 per cent of electricity consumption should be covered by wind by 2030, most of the remainder through new offshore wind turbine installations.

The Energy Policy Role of Power Companies

The Danish Government has very wide ranging powers to regulate utilities. Regulation takes many forms, including energy efficiency and demand-side management (DSM) measures. Integrated Resource Planning (IRP) is an integral part of the procedure through which power companies obtain permission to install new generating capacity. Other measures include price and accountancy controls .

The Government has ordered the utilities to install 400 MW of wind power on land to date. The first two orders of 100 MW each were issued in 1985 and 1990. The latest onshore order for 200 MW to be completed before the year 2000 was issued in 1996. In 1998 a new order was issued for 750 MW of offshore wind power.

Wind turbine orders from power companies are filled by competitive public tendering. Formerly the tenders were based on power companies doing an extensive part of site prospecting, installation, and servicing work. Lately, turnkey contracts with manufacturers have become the rule, since they are expected to be significantly less expensive for the power companies.

The use of turnkey tendering makes the process more similar to the NFFO or SRO system used in the UK than what is generally realised.

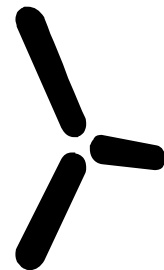
Power Companies' Ownership of Wind Power

Danish utilities are mostly nonprofit co-operatives owned by the electricity consumers in each area, although some municipalities in the larger cities are the owners of distribution companies. Ownership of distribution companies cannot be traded, but is implicitly held by the property owners who consume electricity. Governing boards are elected locally. The distribution companies jointly own transmission and generating companies.

The many local power companies operate an internal sharing arrangement for their wind energy deployment, which means that they effectively pool their wind energy investments to ensure that wind energy is deployed primarily in good, windy areas.

Attitudes to Wind Energy in Power Companies

Danish development of wind power could probably have been carried through with private (non-power company) investment only, like in Germany. The primary advantage of power company participation from a political point of view has been to ensure that expertise and renewable energy commitment within power companies has been much larger than what would otherwise have been the case. Until recently,



however, there was a dividing line between an overall positive attitude at the technical level, dealing with practical wind power implementation, and a more reserved attitude at the political level of utility boards, basically resenting cost and tariff increases due to (costlier) renewables.

The improving economics of wind energy has changed this: Power companies today realise that wind is the cheapest option for meeting the (legal) environmental requirements for power companies, the objectives of which are likely to remain on the political agenda for the foreseeable future. In this situation, the power companies have urged that the Government leave wind development to power companies only, since with the present energy tax refund system, it is far cheaper for power companies to produce their own wind power than to buy it from independent generators. The average cost for power companies' own wind generation is around 0.28 - 0.34 DKK/kWh (0.04 USD/kWh). But since they get a CO₂ tax refund of 0.10 DKK/kWh, their generating cost is really 0.18 - 0.24 DKK/kWh. versus 0.30 to 0.37 DKK/kWh (0.05 USD/kWh) for energy purchased from independents. [11]

It should be realised however, that these power company costs are quoted on the basis of a 5 to 6 per cent real rate of interest, and a 20 year project lifetime, and that the costs do not include grid reinforcement. It should also be noted, that Danish infrastructure is characterised by a strong electrical grid, and widespread local expertise in installation and planning. The extensive 20 year experience with wind energy is indeed reflected in lower installation costs than elsewhere in Europe. [12]

The strengthened commitment of Danish power companies to wind energy can be seen in their eagerness to develop the first 750 MW of offshore wind power, where applications for planning permission were launched even before the actual Government order was issued.

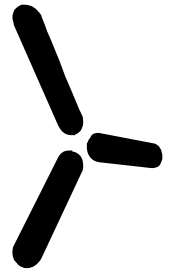
Public Service Obligations

The European Union directive on the liberalisation of electricity markets allow member countries to impose a "public service obligation" (PSO) on electricity suppliers, which are allowed to shift the cost burden onto consumers. The obligations may, for example, be related to ensuring universal service to all consumers in a region at the same tariff, meeting obligations in relation to environmental policy, or funding research.

In regard to renewables, the Danish legislation ensures that all electricity consumers effectively have to share the excess cost, if any, of using renewables in the electricity system, in order to avoid distortion of competition between suppliers. In practice this means that electricity generated using renewables, or all forms of combined heat and power production (CHP) has a priority access to the grid.

Municipal Planning

The policy of installing 1,500 MW onshore in Denmark has been considered a challenge for municipal and regional planning, given the country's high population density. For the past few years Danish municipalities have been required by a



planning directive from the national Government to make plans for wind turbine siting. [13]

Although no specific quotas were set by the national Government, most regions (counties) have required municipalities with good wind resources to provide suitable sites for turbines. After the recent round of planning with extensive hearing procedures for local residents, sites for more than 2,600 MW have been made available. [14]

The Danish system has inspired a similar system which is being implemented in Northern Germany. [15]

Advanced Wind Resource Mapping

To assist municipalities carrying out planning for wind turbines, a national wind map based on rough manually prepared estimates was made available in 1991. [16]

A new and much more advanced method is being employed in 1997-98: Using the European Wind Atlas Method (WAsP) developed by Risoe National Laboratory, software from the leading commercial wind software vendor Energy & Environmental Data, and detailed digital maps, a very detailed, automated analysis of the entire country (divided into cells of 100 by 100 metres, with automatic assessments of terrain roughness out to 20 km distance) is being prepared.

The system already includes an exact mapping of all 4,800 wind turbines in the country, and the results will be calibrated by production data from more than 1,500 wind turbines reporting to the monthly statistics system run by the software vendor for the Danish Wind Turbine Owners' Association.

Market Development Schemes

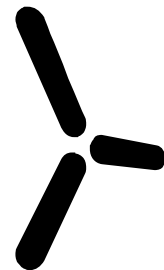
In the beginning of the 1980s the Danish Government instituted a number of successive market development schemes, originally funding 30 per cent of investments in new wind turbines, but gradually lowering this support until it was abandoned in 1989 (it was 10 per cent by then). [17]

Pricing of Wind Energy from Independent Power Producers

Power companies are by law required to pay for electricity from privately owned wind turbines at the rate of 85 per cent of the local, average retail price for a household with a (high) annual consumption of 20,000 kWh (effectively allowing a gross 17.6% markup on sales of electricity from this source). [5] (The reason for the 20,000 kWh rule is that electricity prices in most areas include rental fees for meters, but the tariff structure varies with the local distribution company).

The electricity price paid by power companies for wind energy from privately owned wind turbines varies between 0.25 and 0.35 DKK/kWh (0.036 to 0.05 USD/kWh), reflecting the varying prices of electricity from different local distribution companies.

The price is not substantially different from what would have been obtained under the time tariff system applied to other independent power producers. Under that



system the generator is paid different rates, depending on whether deliveries are made during peak, medium load or low load hours. Since wind energy production in Northern Europe tends to be highly correlated with demand (more wind at day than at night, much more wind in winter than in summer), wind is actually some 40 per cent more valuable in the grid, than if production were purely random. [19] Originally the pricing arrangement was negotiated between the Danish Wind Turbine Owners' Association and the Association of Danish Power Companies. In 1992 the power companies terminated the agreement, and subsequent negotiations with the turbine owners failed to reach a compromise. After this, the Government and Parliament intervened and made a general law on renewable energy, including a purchasing obligation with the tariff mentioned above.

Partial Refund of CO₂ and Energy Tax

Households in Denmark pay very high electricity prices, even though Denmark has some of Europe's lowest generating costs for thermal plant. The reason is an extremely high indirect taxation of electricity, as shown in the graph above. [20] The political reasoning behind the high taxation is to reduce pollution emissions and encourage energy savings. (The fiscal motive plays a role as well, of course: "Green" taxes are less resented by voters than other taxes).

The electricity tax is collected on all electricity sold to households, service businesses etc. Only manufacturing industry is to a certain extent exempt from this taxation.

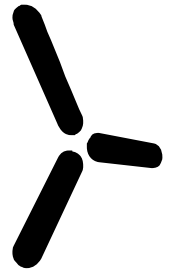
Electricity from renewable sources gets a refund of the 0.10 DKK/kWh (0.014 USD/kWh) CO₂-tax [5]. This refund is paid regardless of whether the generating equipment is owned by power companies, firms or households. This particular tax is called the CO₂ tax. (The labelling of different electricity taxes is historically somewhat random, depending on whether the originally declared political aim was environmental or fiscal).

Special Rules for Private (Individual or Co-operative) Owners

Wind turbines owned by non-power companies, i.e. other firms, individuals or co-operatives, in addition get a refund of 0.17 DKK/kWh (0.024 USD/kWh) of electricity tax. [5] The size of the refund has been set to ensure a reasonable profit for wind turbine owners, given existing tax regulations. On the other hand, there is currently some political concern that the profitability of wind energy is "too high" on the very best sites. [21] Some future adjustment, primarily concerning these sites cannot be excluded.

Total remuneration for private (non-power company) wind turbine owners varies between some 0.5 and 0.62 DKK/kWh (0.071 to 0.089 USD/kWh).

The basic reason for treating power companies and other turbine owners differently, is that power companies in Denmark are tax free, provided that they do not make a profit. (Generous accounting rules allow power companies advance depreciation, which effectively ensures, that they are tax free, "non profit" institutions.



They are allowed to collect investment financing in their tariffs, before investments are actually made, thus obviating the need for shareholders or other external sources of finance).

Grid Connection, Grid Reinforcement

According to the Executive Order on Grid Connection of Wind Turbines of 1996[5], local power distribution companies are obliged to provide grid connection facilities at any site which in municipal planning has been set aside for the development of at least 1.5 MW of wind power (rated generator power).

In other cases, power companies are obliged to allow grid access to the local 11-20 kV grid, but the turbine owner is responsible for paying for the extension of the grid to reach the site in question. The power company has to pay for the entire grid extension, however, if the cabling can be used for other purposes in the normal extension of its grid facilities.

The necessary reinforcement of the grid is paid for by the power company, unless the power company can prove that the reinforcement in the area is particularly uneconomic. The Danish Energy Agency (part of the Ministry of Energy and the Environment) is the authority to whom prospective turbine owners may appeal power company decisions on these matters.

Wind turbine owners have to pay for the transformer to connect to the 11 kV grid. In addition a fee for rental of electricity meters apply. (Reactive power consumption is not charged, but turbines generally have to observe a certain phase angle[27])

Tax Treatment of Wind Turbine Investments

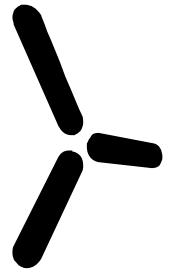
Wind turbines are treated like machinery in industry, i.e. a declining balance 30% annual depreciation is allowed.

Wind turbine owners may alternatively (once and forever) opt for a simplified tax system, being taxed on 60% of gross revenues from electricity sales exceeding 3,000 DKK/year (450 USD/year) without any depreciation allowance or any deduction of other costs. This means that people who only own a few shares in a wind turbine co-operative are not taxed on their wind turbine income.

Value Added Tax (VAT) Scheme

Contrary to what is stated a number of international consultancy reports, there is no special regulation for value added tax for wind turbines or electricity production from wind turbines in Denmark. Denmark has a single rate 25% VAT system with an exceptional zero rating only for newspapers and shipbuilding above 5 DWT.

(Most of the erroneous reports seem to be quoting an erroneous report from Bond Pearce in the UK, financed by the European Union).



Limitation on Private Ownership

The private (non-power company) ownership of wind turbines in Denmark is limited by regulations in the executive order on national grid connection rules, requiring that members of wind co-operatives be resident in the municipality where the wind turbine is located, or in a neighbouring municipality. [5] Municipalities make exceptions for individual wind turbine projects, but exceptions are fairly rare.

The regulation also limits the number of shares residents may own in a wind turbine co-operative to an annual production of 30,000 kWh per (adult) person, corresponding to a total investment of some 120,000 DKK (17,000 USD).

These restrictions were allegedly made "to prevent the misuse of Government support schemes for wind energy" (quote from the Minister for Energy and the Environment in Parliament), but the basic political aims are probably to preserve local ownership of the exploitation of a natural resource, much like it is practised in Danish agricultural legislation which requires that farm owners be resident on their farm.

Individuals may own one wind turbine located on the same property on which they are resident (no size limit). The ownership of a complete wind turbine and co-operative shares are mutually exclusive.

The quantitative restrictions on independent power production were likely imposed as a result of visibly strong political pressure from power companies.

Market Size

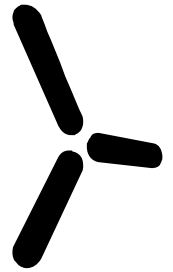
The total installed base of wind power was some 1,100 MW at the end of 1997, making Denmark the third largest wind power country in the world after Germany and the USA. Almost 300 MW were installed in 1997, making it another record year for installation of wind power (with 200 MW and 98 MW in the two previous years).

Turbine and Component Suppliers

All of Denmark's 5,000 wind turbines (mid 1998) have been manufactured domestically. Denmark hosts five of the world's ten largest wind turbine suppliers: NEG-Micon, Vestas Wind Systems, Bonus Energy, Nordex, and Wind World (DATA TABLE PLEASE). The first three companies account for more than 50 per cent of world production of wind turbines measured in MW. Most of these companies have a background in agricultural machinery manufacturing, with the exception of Wind World which was founded on gearbox and marine technology manufacturing.

Competition in the Danish market is definitely the toughest in the world, making the market rather uninteresting to foreign turbine suppliers. Another problem facing some foreign suppliers may be the very stringent safety regulations which e.g. require two independent failsafe braking systems on turbines, one of which must be aerodynamic, or providing equivalent safety.

The Danish component industry includes LM Glasfiber, which is the world's largest rotor blade manufacturer, with an employment of more than 1,000. Danish



manufacturers of electronic wind turbine controllers likewise have a very large market share world wide. Other component manufacturers include suppliers of braking systems, hydraulics, etc.

Employment

Denmark is home to 60 per cent of the world's wind turbine manufacturing capacity. Presently about 2/3 of production is exported. The Danish wind turbine manufacturers presently employ some 2,200 persons, in Denmark, while domestic component and service suppliers employ another 10,000 people (1997).

In addition, another 4,000 - 5,000 jobs are created abroad through deliveries of components, and installation of Danish turbines. These figures do not include assembly work etc. done in foreign subsidiaries or licensees of Danish firms.

Export Policy

Contrary to popular belief (or wishful thinking) among the Danish manufacturers' foreign competitors (who tend to use it as a tool to lobby their politicians), there is not, and there has never been any official export policy or financial schemes to favour the exports of Danish wind turbines. Denmark does not have any scheme similar to e.g. the German Eldorado programme.

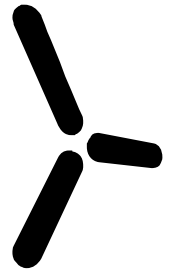
A small number of Danish turbines were exported to India and China under the normal development aid programmes, and proved to be important for future market development, but there is, in fact, no official Government policy in this respect.

Lately, a number of turbines to China have been partly financed through soft loan schemes in accordance with OECD rules, but interestingly, Denmark was approximately 15 years later than e.g. the U.S. The U.K., Sweden, and Germany in implementing a generalised soft loan scheme for exports to middle income developing countries.

The Home Market's Role in Industry Development

The Danish home market is what created the modern Danish wind industry originally, and gave it the testing ground to sort out both wind technology and manufacturing technology, including the important issue of quality control.

When the Great California Wind Rush started in the early 1980s, the Danish companies were practically the only ones in the world with a substantial track record. The result was that investors tended to prefer Danish machines, which in the end made up around half of the capacity installed in California. The importance of the learning process within the major Danish manufacturing companies from manufacturing thousands of machines for the California market cannot be overestimated.



The Danish Concept

The track record of the early Danish machines in California has in general been better than those of the competitors, leading to yet another track record advantage. The result is, that the so called "Danish Concept" in its newer and more refined versions today dominates the international wind turbine market more than ever, despite occasional revolutionary technology predictions in the press.

The last company manufacturing vertical axis machines (Flowind) went bankrupt in 1998, and manufacturers who used to stick firmly to a two bladed concept (WEG, Nedwind and Lagerwey) have all launched new three bladed designs.

As matters stand at the time of writing, it appears that the "Danish Concept" consisting of a three bladed upwind design with fixed speed operation and direct grid connection rules about 75 to 80 per cent of the market. [23] This design dominance resembles the status of the 4 stroke petrol engine which has actually been around since 1856.

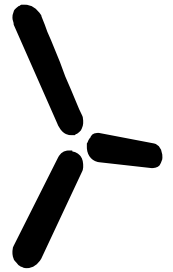
Whether other designs (full variable speed operation, indirect grid connection) will penetrate the market is largely a matter of component costs, in particular the costs of power electronics. There is, of course, a bit of circularity in this argument: Costs will decline with large scale manufacturing, so nothing is given about future technology in this area. It seems likely however, that the present basic design will dominate the market well into the next century.

Can the Danish Industrial Success be Replicated?

The Danish success in wind energy is not easy to replicate elsewhere, and certainly not with the same means. Technology development is different today, markets and competition are different, and in some sense the Danes were fortunate enough to be in the right place at the right time with the right concept.

Starting from scratch is much more difficult today, when the largest market segments have tougher competition, with a more mature and reliable technology. The same market segment requires large machines with larger capital requirement and higher development risks. Furthermore, there currently are no fundamentally revolutionary turbine technology concepts in sight, i.e. demonstrably economically superior technologies, although there are many options for further development and cost cutting within the major variants of present technology. [24]

Manufacturers in several countries have chosen to link up with Danish manufacturers in a variety of joint ventures. This coupling has included significant technology transfer to local companies, and developed local manufacturing. Most of the licensees have a machinery and equipment manufacturing background. The primary advantages of a technology link to an existing manufacturer is to acquire proven technology, and the possibility of being able to offer a more complete and continuously optimised model range.



Origin and Mainstay of the Market: Private Citizens

Denmark is somewhat unique among wind turbine markets, since the market really grew out of a popular interest in alternative generating technologies, partly in opposition to the use of nuclear power, partly as a result of the energy supply crisis in the late 1970s, when oil prices skyrocketed due to OPEC action and political and military unrest in the Middle East.

Private individuals, either as members of wind energy co-operatives, or as whole owners of a wind turbine (farmers) account for about 80 per cent of installed wind power capacity in Denmark. (Almost 900 out of 1100 MW of installed wind power capacity at the end of 1997). 100,000 families in Denmark own shares in a local wind turbine, and almost 2,000 wind turbines are owned by individuals.

Wind co-operatives are organised as unlimited partnerships, but since the turbine and its installation is usually completely paid up, partnerships have no loans and no (joint) risk in this respect.

The Benefits of Thorough Statistical Coverage

Wind turbine owners are highly organised in the Danish Wind Turbine Owners' Association which publishes a monthly magazine giving production figures and notes on technical failures for more than 1,500 turbines. This excellent statistical data base, plus user groups, and technical consultancy services for members has been a very important instrument to ensure a transparent market with tough competition between manufacturers.

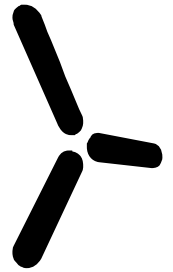
Turbines are usually sold with 5 years guaranteed production (insured with insurance companies). This makes all manufacturers keen on not overstating expected production, as this would bounce back in the form of a higher risk premium for that particular brand from insurance companies.

The Role of Publicly Financed R&D

In stark contrast to Germany, Sweden, the USA, Canada, and the UK, publicly financed R&D projects played a relatively minor role in initiating the early development of the Danish wind turbine industry. [25] The early stimulus came in the form of investment grants, supporting market development for small scale privately owned turbines, (5 to 11 kW) which typically covered their owner's annual electricity consumption, by a factor of 2 to 4.

Later, the Danish Government and the European Union have financed a significant number of basic research projects, and given some support to development projects. It is estimated that a staff of about 60-80 people in Denmark (including both researchers and administrative staff) work on (partly) publicly financed R&D. Danish wind turbine manufacturers have a staff of about 100 people working on technology development. Total public support for this work is below 2 million USD/year.

Type Approval Requirements



In the late 1970s Risoe National laboratory (whose original task was nuclear research) was charged with type approval of wind turbines which could be installed with public investment grants. The type approval process was extremely useful for weeding out low quality and potentially dangerous products, and put a pressure on manufacturers to upgrade their design and manufacturing skills. [22, 25]

Risoe's very strict safety requirements, its demands for physical testing of rotor blades, and conservative norms for load calculations, indirectly saved the core Danish manufacturers from the fate of many foreign competitors whose turbines collapsed in these early days. The result was very sturdy and stable, but rather heavy machines. (The potential for weight saving has in fact been so large, that Danish wind turbines have shed half their weight per kW power installed during the past 5-10 years, despite a 50 per cent growth in their physical size).

The Role of Risoe National Laboratory and Others

Risoe has since the early eighties evolved to become probably the foremost international research institute on basic research in wind turbine technology and wind resource assessment.

A much smaller, complementary Institute of Fluid Dynamics developed at the Danish Technical University. Its parallel development of turbine design software has served as a commercial tool in many companies, and as an important tool to ensure mutual verification of its own and Risoe's methods of aeroelastic analysis.

The Role of Power Companies in R&D

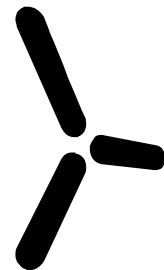
Danish power companies played a pioneering role in the early technology development of wind energy. When the Danish Government instituted a publicly financed wind energy research programme in the mid 1970s, the power companies once again became involved in wind power research, concentrating on relatively large machines for their time (630 kW), and building two experimental wind turbines near the town of Nibe around 1979 (one pitch, one stall controlled). These machines were finally closed down in 1997. In the early 1980s another group of five 750 kW machines were built, and during the 1990s another two experimental machines of 1 and 2 MW were built.

The primary aim of these ventures appeared to be the training and development of in-house wind energy expertise in the power companies, rather than aiming at commercially relevant equipment.

Is the Danish Market System an Economic Success?

The Danish market system for wind energy has been a popular success, in regard to the public's possibility of direct involvement in energy policy.

The power company share of the market (determined by Government orders to power companies) has worked reasonably well, except for the fact that power companies have been three years behind schedule in fulfilling their obligations (with no consequences for them) .



The refund of 0.10 DKK/kWh (0.014 USD/kWh) for power companies has apparently been based mostly on political considerations of the name "CO2 levy" which was a convenient amount to refund. Since then SO2 taxes have been implemented without any talk of a similar refund to wind. Today the 0.10 DKK/kWh roughly compensates for the difference in average generating costs between wind and fossil fuel plant.

Rationing Gives Questionable Market Efficiency

The Danish wind energy support system has lately come under political attack for being too generous to private wind turbine owners, and conversely unnecessarily expensive in terms of energy tax refunds. The attack has been justified by reference to the capital gains (land rents) for windy sites.

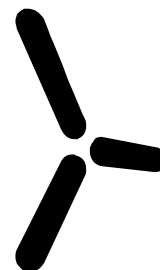
The timing of the attack is directly related to the discovery of the regulatory loophole described above, which created a record boom in turbine investment in Denmark. (The boom was reinforced by the fact that the authorities by accident warned about a change in regulations beforehand, thus creating a virtual "buying panic before closing time").

This has been a clear demonstration of the fact that the "segregation policy" which had effectively excluded anyone but farmers from owning their own wind turbine, had the effect of keeping less risk averse (and more bankable) investors out of the market, and of keeping yield requirements (on the windiest sites) higher than necessary.

Likewise, the apparently acceptable price differential between negotiable shares in wind co-operatives and non-negotiable shares gives an indication of the liquidity premium paid for the "localness" of wind turbine ownership.

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