Wind Farms Provide Negligible Useful Electricity

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March 2006

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Abstract

Wind farms (i.e. local assemblies of wind turbines) for power generation can only provide negligible useful electricity to grid supply systems. Because they provide intermittent only power, they merely displace thermal power stations onto standby mode while the thermal power stations wait for the wind to change. Wind farms make no significant reduction to pollution because thermal power stations continue using their fuel and producing their emissions while operating in standby mode. The large scale use of wind farms requires upgrading of an electricity grid, more complex grid management, and operation of additional thermal power stations to protect against power cuts in time of supply failure. These effects increase the cost of electricity supplied by the grid in addition to the capital, maintenance and operating costs of the wind farms themselves. Also, wind farms cause significant environmental damage. These severe environmental costs may be worth suffering if wind farms actually provided cheap, clean, useful electricity. They do not.

Executive Summary

Wind farms are expensive, polluting, environmentally damaging bird swatters that produce negligible useful electricity, but do threaten electricity losses.

Thermal power stations

Conventional power stations fission a material or burn a fuel to obtain heat that is used to boil water and superheat the resulting steam which is fed to the steam turbines (some power stations also use gas turbines in combination with steam turbines). The turbines drive turbogenerators that make electricity.

A power station takes days to start producing electricity from a cold start. Time is needed to boil the water, to superheat the steam, to warm all the components of the power station, and to spin the turbogenerators up to operating speed.

Each power station is designed to provide an output of electricity. It can only provide very little more or very little less than this output (i.e. a power station has a "low turndown ratio").

Electricity demand matching

Electricity is wanted all the time but the demand for electricity varies from hour to hour, day to day, and month to month. The electricity grid has to match the supply of electricity to the demand for it at all times. This is difficult because power stations cannot be switched on and off as demand varies, and only small variation to the output of each power station is possible.

The problem of matching electricity supply to varying demand is overcome by operating power stations in three modes called 'base load', 'generation' and 'spinning standby'. Some power stations operate all the time providing electricity to the grid, and they are said to provide 'base load'.

Other power stations also operate all the time but do not provide electricity all the time. They burn (or fission) their fuel to boil water and superheat the resulting steam which is fed to the steam turbines that are thus kept hot and spinning all the time. Of course, they emit all the emissions from use of their fuel all the time. But some of this time they dump heat from their cooling towers instead of generating electricity, and they are then said to be operating 'spinning standby'.

One or more power stations can be instantly switched from spinning standby to provide electricity to match an increase to demand for electricity. It is said to be operating 'generation' when it is providing electricity.

Power stations are switched between spinning standby and generation as demand for electricity changes. Thus the grid operator manages the system to match supply with demand for electricity by switching power stations between 'generation' and 'spinning standby'. And the small available variation in output from each power station is used to avoid large step changes in the supply when this switching is conducted.

Wind farm input to electricity

Wind farms only provide electricity when the wind is strong enough and not too strong. So, they suddenly provide electricity when the wind changes. The grid operator must match this changed supply of electricity to the existing demand for electricity. Of course, the grid operator achieves the match by switching a power station to spinning standby mode. That power station continues to operate in this mode so it can provide electricity when the wind farm stops supplying electricity because the wind has changed again. Wind farms only force power stations to operate more spinning standby. They provide no useful electricity and make no reduction to emissions from power generation. Indeed, the wind farm is the true source of emissions from a power station operating spinning standby in support of the wind farm.

Wind farms have capital, maintenance and operating costs that add to the cost of electricity. These costs are their only contribution to the electricity supply system. But they disrupt operation of the system.

Power surges

A sudden, large addition to electricity in part of the grid is called a 'power surge'. It can overload a component of the grid with resulting widespread damage to the grid. For example, in recent years power surges have damaged components with resulting loss of power to the London Underground system, the city of Turin, and most of North America.

Wind turbines provide power when the wind is strong enough and not too strong. It is very difficult to predict the precise moment when a wind farm will start to provide electricity to the grid. And the wind can change over a large area. Hence, the presence of many wind farms in a locality causes power surges.

Denmark has many wind farms and so is subjected to power surges from them. The Danish grid manages this problem by dumping the electricity across its borders as a free gift to Denmark's neighbours. But some countries cannot do that. For this reason in December 2003 the Irish grid operator announced that he would accept no more electricity from wind farms onto the Irish grid. Additional wind power would be so unmanageable that grid failures would be inevitable.

The UK has a similar problem. The Interconnector with France could not handle the dumping of a power surge. Hence, large use of wind power in the UK would cause damage to components of the UK grid and frequent power cuts throughout the UK. Indeed, the UK grid is being upgraded to withstand the problems caused by the intermittent operation of the existing wind farms.

Managing supply risk

As earlier explained, power stations operate spinning standby to match electricity demand to supply. In addition to this, other power stations operate spinning standby to manage risk of supply failures. There is a risk of failure of a base load power station or the transmission system from it. Such failures would cause power cuts in the absence of the additional spinning standby.

Wind farms only provide power when the wind is strong enough and not too strong. Hence, wind farms increase the risk of supply failures. Indeed, they give the certainty of supply failures when the wind is too strong or not strong enough.

The increased risk of supply failures from wind farms is insignificant when there is small contribution of electricity to the grid from wind farms. All the output from the wind farms forces thermal power stations to operate spinning standby that can cope with the risk.

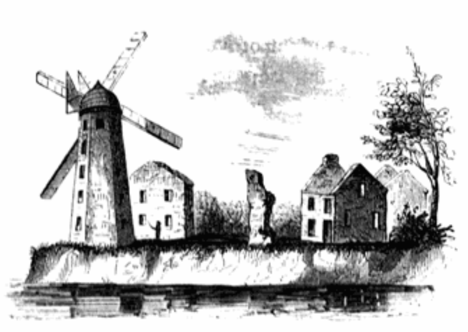
But the problem of managing the risk increases disproportionately as the risk increases. Electricity is not wanted in the same amounts everywhere, and electricity is lost when it is transmitted over long distances. The additional risk management difficulties require additional spinning standby when the risk of supply failures is very large. Otherwise it would be impossible to match supply with demand throughout the grid when a large supply failure occurred.

Additional power stations must be built and operated on spinning standby (using their additional fuel and providing their additional emissions) to manage the increased risk of power cuts from supply failures when wind power contributes 20% or more of the potential electricity supply.

The construction of wind farms instead of power stations has caused these problems in California where scheduled voltage reductions are continuously provided around the State as an alternative method to manage the risk of power cuts from supply failures.

Sec. 1 - Wind power in history

Wind power has been used for ages. Wind energy powered most of the world's shipping for thousands of years. Primitive wind turbines powered pumps (notably in the Netherlands and England) and mills throughout Europe for centuries.



There are a number of types of wind turbines. They are divided into Vertical-Axis and Horizontal-Axis types.

Vertical-axis windmills were first developed by the Persians to mill corn around 1500 BC, and they were still in use in the 1970's in the Zahedan region. Sails were mounted on a boom attached to a shaft that turned vertically. The technology had spread to Northern Africa and Spain by 500 BC.[1] Low-speed, vertical-axis windmills are still popular in Finland because they operate without adjustment when the direction of the wind changes. These inefficient Finnish wind turbines are usually made from a 200 litre oil drum split in half and are used to pump water and to aerate land. Low speed vertical-axis windmills for water pumping and air compressing are commercially available.

The horizontal-axis wind turbine was invented in Egypt and Greece around 300 BC. "It had 8 to 10 wooden beams rigged with sails, and a rotor which turned perpendicular to the wind direction".[2] This type of wind turbine later became popular in Portugal and Greece. Around 1200 AD, the crusaders built and developed the post-mill for milling grain. The turbine was mounted on a vertical post and could be rotated on top the post to keep the turbine facing the wind. This post-mill technology was first adopted for electricity generation in Denmark in the late 1800's.[3] The technology soon spread to the U.S. where it was used to pump water and to irrigate crops across the Great Plains. During World War I, some American farmers rigged wind turbines to each generate 1 kW of DC current. Such wind turbines were mounted on buildings and towers. On western farms and railroad stations, wind turbines for pumping water were between 6 and 16m high and had 2 to 3m diameter. With 15km/h wind speed, a 2m-diameter turbine operating a 60cm diameter pump cylinder could lift 200 litres of water per hour to a height of 12m. A 4m diameter turbine could lift 250 litres per hour to a height of 38m.[4]

Sec. 2 – Useful Niches

The above brief history demonstrates that wind turbines can have useful niches to the present day. For example, small wind turbines can be used to economically pump water or generate electricity in remote locations distant to – or disconnected from (e.g. on boats) – an electricity grid supply. But wind power lost favour when the greater energy concentration in fossil fuels became widely available by use of steam engines. Wind power has recently found favour for large scale electricity generation in some places, and this paper explains why such use is uneconomic and impractical.

Today, if wind power were economically competitive with fossil fuels, then oil tankers would be sailing ships. Japan has conducted several studies to ascertain if use of automated sails could assist modern shipping. These studies have demonstrated that available wind power is so small a contribution to the powering of a ship that the systems to obtain it cannot recover their capital costs[5] (which agrees with the considerations provided in this paper).

However, since the 1970s, the use of large, modern wind turbines has become popular for electricity generation in some places. This is especially true in Denmark, the UK and also in parts of the USA where it has resulted in California's 'Energy Crisis'. Reasons for this use are entirely political. As this paper explains, the low energy concentration in wind requires use of very many turbines with associated very high capital and maintenance costs. Also, the output of the turbines depends on the weather and, therefore, cannot be predicted with accuracy for more than a few days in advance.

Wind farms are local assemblies of wind turbines for power generation. Their turbines generate electricity when the wind is strong enough but not too strong.[6] This makes their output intermittent, and electricity is not a commodity so it cannot be stored in significant amounts and must be used at its existing distribution system when generated. This intermittent supply of electricity disrupts the electricity grid (as also explained in this paper).

Sec. 3 - Theoretically available wind power[7]

Wind is the movement of air. Perpendicular to the wind direction, the wind's kinetic energy per unit time (e_k) is provided by the mass (m) and the square of the velocity (v) of the air with density (ϱ) moving through a unit area (A).

$$e_k = ½ m v^2 = ½ (A v \varrho) v^2 = ½ A \varrho v^3$$

Air has low density (ϱ) that varies with its altitude (h). Its density at ground level (ϱ_o) is ~1.225 kg / m^3. For heights below ~6 km, ϱ can be estimated to a reasonable approximation using the expression.

$$\varrho = \varrho_o \exp(-0.297 h / 3048)$$

where h is in meters

ϱ also varies with the air's temperature (T) and pressure (P). For heights below ~6 km, the relationship of ϱ, T and P can be estimated to a reasonable approximation using the expression.

$$\varrho = 3.4843 P / (T + 273)$$

where P is in kPa and T in ºC

For the standard atmosphere, T is defined to decrease linearly with height

$$T = 15 – 1.983 (h/304.8) ºC$$

So, the air affecting a wind turbine blade has little mass per unit of time unless the wind speed is high. This means there is little wind energy available for collection at low wind speeds. And most wind turbines can only operate when the wind speed is low.

The high capital and maintenance costs of each turbine provide only the small return it can obtain by extracting the little energy which is carried by normal winds. For example, an average wind speed of 14 mph is needed to convert wind energy into electricity competitively with coal-fired or nuclear electricity in the U.S., but the U.S. average wind speed is 10 mph.

Sec. 4 - Technical limitations of wind turbines for power generation

Horizontal-axis wind turbines (developed from post mill technology) are inherently more efficient than vertical wind turbines.[8] Hence, horizontal-axis wind turbines are favoured for electricity generation. They are fitted with one, two, three or (very rarely) more turbine blades. A schematic of a typical wind turbine for power generation is shown in **Figure 1**.

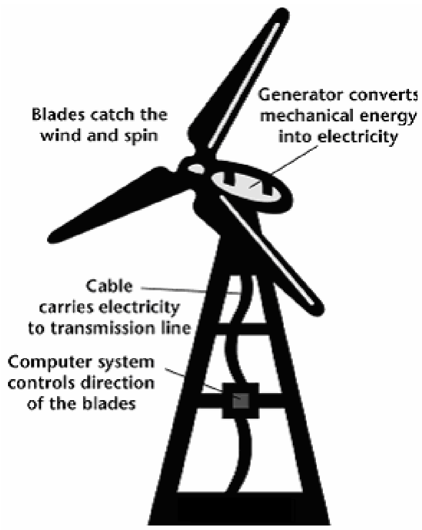


Figure 1. Schematic of a typical 3-blade wind turbine for electricity generation.

Modern wind turbines are large to maximise interaction with the air and, thus, gain efficiency. A typical wind turbine can produce 1.5 to 4.0 million kWh of electricity a year.[9] The largest wind turbine in operation is the Vestas V44-600. Its blade is 144 feet in diameter and is mounted on a 160-foot tower west of Traverse City, Michigan.[10] It provides slightly less than one percent of the Traverse City Light and Power Company's total output.

Wind turbines require much land. Turbines would take the wind from each other if sited too close together.[11] Each wind turbine needs about two acres of land, and several turbines are needed to generate much electricity.[12] An assembly of wind turbines is called a wind farm, and a typical wind farm covers hundreds of acres. However, agriculture can be conducted between the foundations of the turbines of an installed wind farm.

Little energy is obtainable from a wind turbine unless the air has high velocity (i.e. the wind is strong) because low velocity air has little kinetic energy per unit volume. But wind turbines only operate when the wind is sufficiently strong and not too strong. Hurricanes, cyclones and tropical storms carry large amounts of energy because they have high wind speeds, but they are rare. A wind turbine designed to collect energy from tropical storms would rarely operate, and a wind turbine designed to collect energy efficiently from ordinary winds would be damaged if it tried to operate in a tropical storm.

The highest wind speed at which a wind turbine generates electricity is called its furling speed. The theoretical maximum output of a typical turbine as a function of wind speed is shown graphically in **Figure 2**.[13]

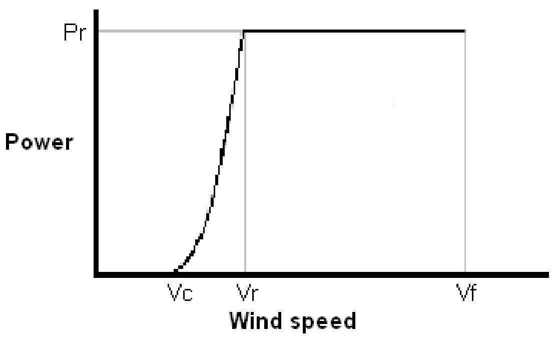


Figure 2. Schematic of an ideal wind turbine's output as a function of wind speed.
Pr is the rated power of the turbine
Vc is the lowest wind speed at which the turbine generates electricity
Vr is the lowest wind speed at which the turbine generates its rated output
Vf is the furling speed

So, a wind turbine only provides power when the wind speed is high enough and not too high. The precise values of the lowest and highest wind speeds for power generation depend on the design of wind turbine. But the proportion of time a wind turbine operates is called its load factor. And the load factors achieved by commercial wind farms are low. This is shown in **Table 1** that provides the achieved load factors of wind farms in three countries with significant generating capacity from wind farms.

Country	**Time Period**	**Achieved Load Factor**	**Source**	**Notes**
West Denmark	1999 2000 2001 2002 2003 1999-2003	19.7% 21.0% 19.9% 18.9% 21.0% 20.0%	Eltra (Danish grid operator)	Denmark has most installed wind power capacity of any country. West Denmark is its windiest region
Germany	2003	14.8%	Reuters	
United Kingdom	1999 2000 2001 2002 2003 1999-2003	28.2% 28.2% 26.4% 29.9% 24.1% 27.3%	UK Department of Trade and Industry (DTI)	The UK is Europe's windiest country

Table 1. Achieved load factors of wind powered electricity generation.

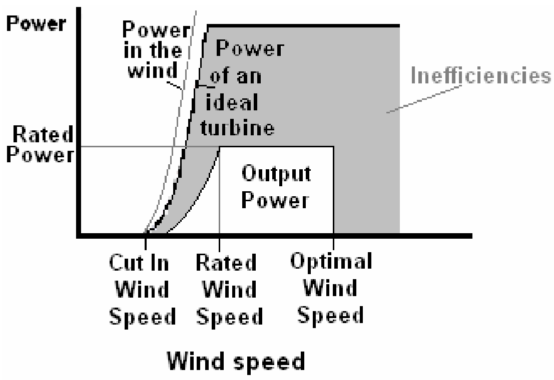


Figure 3. Schematic of actual wind turbine output as a function of wind speed.

Table 1 demonstrates that wind farms provide very intermittent electricity supply. Assuming the performance of wind farms could be extended so they provide power for more of the time, then it could be optimistically assumed that their load factors may be increased to 30%. But that should be compared to the typical load factor from a thermal power station of 85 to 90% that does not depend on the wind speed so it stops only for maintenance.

The problem is compounded by the actual output of a wind turbine being less than its theoretical maximum (shown schematically in **Figure 2**). As shown in **Figure 3**, wind turbines have between 30% and 40% efficiency[14] (i.e. they output as electricity about a third of the wind power they collect) which is comparable efficiency to that of thermal power stations.

The low load factors and low efficiency of wind turbines combine with the little energy available from normal winds to make it very difficult to recover the capital costs of a wind turbine used to generate electricity from sale (at commercial rates and without subsidy) of the small amount of electricity it can produce.

Sec. 5 - Relative costs of wind power and conventional electricity generation

The costs of fuel, infrastructure and capital borrowing vary between countries. Therefore, the relative costs of electricity generating systems differ between countries. However, wind farms produce such expensive electricity that any country which is a large user of wind power is illustrative of the high relative cost of wind power.

A report from the UK's Royal Academy of Engineering on 'The Costs of Generating Electricity'[15] claims that electricity from offshore wind farms will cost at least twice as much as that from conventional sources in the UK. The Academy estimates the generating costs of electricity in UK pence per kilowatt hour (p/kWh where 100p = £1). Their report concludes that for the foreseeable future the UK's cheapest electricity will come from gas turbines and nuclear stations, costing just 2.3 p/kWh, compared with 3.7 p/kWh for onshore wind and 5.5 p/kWh for offshore wind. The nuclear cost included decommissioning costs of nuclear power stations.

A significant contributor to the high cost that the Academy estimates for wind power is the need to provide back up generating capacity for when the wind is not at a speed to operate wind turbines. Their report says it is 'rather generous' with its wind generation figures: it assumes only 65% back-up power is needed whereas previous estimates were for 75 to 80% (65% is very generous because it assumes a load factor of 35%, but see Table 1). Even so, their report estimates the need for backup capacity adds 1.7 p/kWh to the costs of wind power.

Sec. 6 - Environmental effects of wind farms

Environmentalists who oppose roads for normal transportation campaign for construction of wind farms.

Wind farms have significant environmental costs. Some people dislike their appearance, but this is a matter of aesthetic opinion. More importantly, wind farms cover the landscape in concrete foundations for their turbines and roads to access the turbines. They are very effective at this in the UK because

1. the UK Planning System has been deliberately altered to encourage construction of wind farms,
2. large subsidies are provided to owners of wind farms, and
3. so-called environmentalists who oppose roads for normal transportation campaign for construction of wind farms.

Some other European countries and American States are providing similar biases towards construction of wind farms. For example, tax breaks are given to offset maintenance costs of power plants that use 'renewable' energy sources in some U.S. States. Also, the Public Utility Regulatory Policies Act (PURPA) requires utility companies to purchase electricity from independent power producers in the U.S.

The long-term effects are potentially serious. *Land that has been converted to an industrial use (i.e. power generation) is not likely to return to agriculture.*

Wind farms kill significant numbers of birds and bats, hence may alter local ecology and reduce biodiversity.

Wind farms also swat birds. One wind farm at Altamont Pass, California, kills thousands of birds – including an estimated 880 to 1300 birds of prey – each year.[16] Hence, the widespread use of wind farms may alter local ecology and reduce biodiversity.

Additionally, wind farms provide serious noise pollution down-wind. An efficient wind turbine blade removes much energy from the air. For this reason, a rotating blade generates pulses of reduced pressure in the air flowing behind the turbine which provide loud, throbbing, often subsonic noise. This has potential to disturb breeding habits of wildlife and is certainly unpleasant for people exposed to it.[17]

Winds are stronger and more constant at sea than on land, and the noise pollution from wind turbines would not be a problem at sea. But large ocean waves would be likely to displace the turbines from their moorings unless the turbines' mountings were very expensive,[18] and these mountings would destroy the sea bottom where they were sited. Also, the wind turbines would provide hazard to shipping if not carefully sited, charted and lit.

It is sometimes claimed that some of these environmental effects of wind farms may be overcome by dwellings each having their own wind turbine(s) for their personal use as electricity generators. It should be noted that large adoption of this policy by an urban area would significantly increase the noise pollution in the area.[19] Also, such an urban wind farm would have all the other problems of every wind farm.

Sec. 7 - The purpose of Wind farms

Wind farms have negative environmental effects and generate expensive electricity, but some governments are promoting them. The justification for this promotion is often said to be that

- wind farms provide useful electricity to an electricity supply grid, and
- the use of wind farms reduces emissions from conventional power stations supplying to the grid.

Both these claims are false: this paper explains that the grid supply and demand profiles ensure that

- wind farms add a large, unnecessary cost to the provision of electricity by a grid supply,
- wind farms cannot provide significant amounts of useful electricity to an electricity grid at any time, and
- the large use of wind farms increases emissions from conventional power systems supplying to the grid.

Sec. 8 - Thermal power stations

Conventional (i.e. thermal) power stations fission a material or burn a fuel to obtain heat that is used to boil water and superheat the resulting steam which is fed to the steam turbines (some power stations – e.g. combined cycle gas turbine: CCGT – also use gas turbines in combination with steam turbines). The turbines drive turbogenerators that make electricity.

A thermal power station takes days to start producing electricity from a cold start.[20] Time is needed to boil the water, to superheat the steam, to warm all the components of the power station, and to spin the turbogenerators up to operating speed.

Each thermal power station is designed to provide an output of electricity. It can only provide very little more or very little less than this output (i.e. a power station has a "low turndown ratio").[21]

Sec. 9 - Electricity demand matching[22]

Electricity is wanted from a grid supply all the time but the demand for electricity varies from hour to hour, day to day, and month to month. The electricity grid has to match the supply of electricity to the demand for it at all times. This is difficult because thermal power stations cannot be switched on and off as demand varies, and only small variation to the output of each power station is possible.

The problem of matching electricity supply to varying demand is overcome by operating thermal power stations in three modes called

- 'base load',
- 'generation' and
- 'spinning standby' as backup capacity.

Some power stations operate all the time providing electricity to the grid, and they are said to provide the 'base load'.

Other power stations also operate all the time but do not provide electricity all the time. They burn (or fission) their fuel to boil water and superheat the resulting steam which is fed to the steam turbines that are thus kept hot and spinning all the time. Of course, they emit all the emissions from use of their fuel all the time. But some of this time they dump heat from their cooling towers instead of generating electricity, and they are then said to be operating 'spinning standby'.

One or more power stations can be switched from spinning standby to provide electricity to match an increase to demand for electricity. It is said to be operating 'generation' when it is providing electricity.

Power stations are switched between spinning standby and generation as demand for electricity changes. Thus the grid operator manages the system to match supply with demand for electricity by switching power stations between 'generation' and 'spinning standby'. And the small available variation in output from each power station is used to avoid large step changes in the supply when this switching is conducted. But operating a power station at less than its optimum output severely reduces its efficiency so it has little reduction to its fuel consumption and emissions although it supplies less electricity.[23]

Additionally, the need for power stations to operate is reduced by use of 'pumped storage'. Electricity is used to pump water uphill to a reservoir when there is little demand from the grid. Then, when there is peak demand for electricity the water is allowed to flow back down and generate power. This consumes electricity because of mechanical losses, but it is economic because it removes the need for a few power stations to operate almost continuously on standby mode so they can supply electricity at the (very short) times of peak demand. The pumped storage provides the extra electricity needed to meet the peak demand.

Large use of wind farms provides no reduction to the need to operate conventional thermal power stations and makes little or no reduction to emissions from them.

Sec. 10 - Wind farm input to electricity grid supply

Wind farms only provide electricity when the wind is strong enough and not too strong. So, they suddenly provide electricity when the wind changes. The grid operator must match this changed supply of electricity to the existing demand for electricity. Of course, the grid operator achieves the match by switching a conventional (i.e. thermal) power station to spinning standby mode or by operating it at low output with much reduced efficiency. That power station continues to operate in this manner so it can provide electricity when the wind farm stops supplying electricity because the wind has changed again. Therefore, large use of wind farms provides no reduction to the need to operate conventional thermal power stations and makes little or no reduction to emissions from them.

The United Kingdom provides a good illustration of the problem because it intends to increase its use of 'renewable' energy to 20% of its generating capacity mostly by increased use of wind power. David Tolley (Head of Networks and Ancillary Services, Innogy, a subsidiary of the German energy consortium RWE) has said of wind farms, "When [thermal] plant is de-loaded to balance the system, it results in a significant proportion of deloaded plant which operates relatively inefficiently ... *it has been estimated that the entire benefit of reduced emissions from the renewables programme has been negated by the increased emissions from part-loaded plant* under NETA." (NETA is the New Electricity Trading Arrangements; the UK's deregulated power market.) (Emphasis added)

Table 2 shows the results of model studies conducted by the UK's National Grid Corporation that indicate the effect of wind's unreliability on the generating plant required to achieve that 20% UK renewables target:[24]

Contribution from wind % of 400 TWh	**Wind capacity GWe**	**Conventional capacity GWe**	**spare capacity GWe**
2%	0.5	59	9.5
5%	7.5	57	14.5
20%	25	55	30

Table 2. Generating capacity to achieve increased use of wind power in the UK.

Table 2 shows that increased use of wind power provides very little reduction to need for conventional power plants. This is because the wind power is intermittent. The building of 25 GWe of wind capacity – approximately equal to the present world total and equivalent to almost half of UK peak demand – will only reduce the need for conventional fossil and nuclear plant capacity by 6.7% (and arguably less). Some 30 GWe of spare capacity will also be need to be on immediate call continuously to provide a normal margin of reserve and to back up the wind plants' inability to produce power on demand – about two thirds of it being for the latter. **Figure 4** also shows this problem.[25]

Wind farms mostly force power stations to operate more spinning standby. They provide negligible useful electricity and make negligible reduction to emissions from power generation. Indeed, a wind farm is the true source of emissions from a thermal power station operating spinning standby as spare capacity in support of the wind farm.

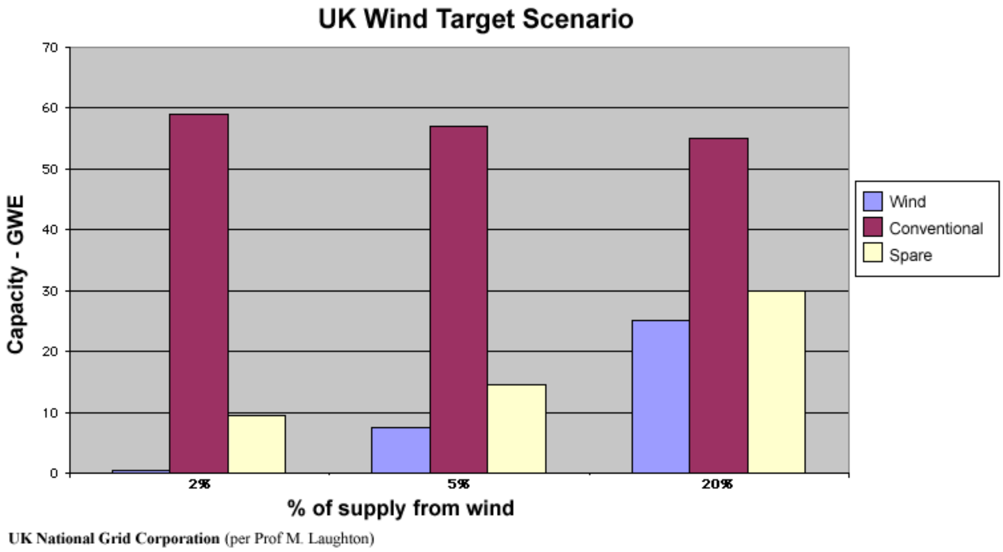


Figure 4. Histogram of generating capacity to achieve increased use of wind power in the UK.

Wind farms have capital, maintenance and operating costs that add to the cost of electricity. These costs are their only real contribution to the electricity supply system. But they disrupt operation of the system.

Sec. 11 - Power surges

A sudden, large addition to electricity in part of the grid is called a 'power surge'. It can overload a component of the grid with resulting widespread damage to the grid. For example, during recent years power surges have damaged grid components with resulting loss of power to the London Underground system, the city of Turin, and most of North America.

Wind turbines provide power when the wind is strong enough and not too strong. It is very difficult to predict the precise moment when a wind farm will start to provide electricity to the grid. And the wind can change over a large area. Hence, the presence of many wind farms (or a large wind farm) in a locality causes power surges.[26]

Denmark has many wind farms and so is subjected to power surges from them. The Danish grid manages this problem by dumping the electricity across its borders as a free gift to Denmark's neighbours. But some countries cannot do that. For this reason in December 2003 the Irish grid operator announced that he would accept no more electricity from wind farms onto the Irish grid. Additional wind power would be so unmanageable that grid failures would be inevitable.

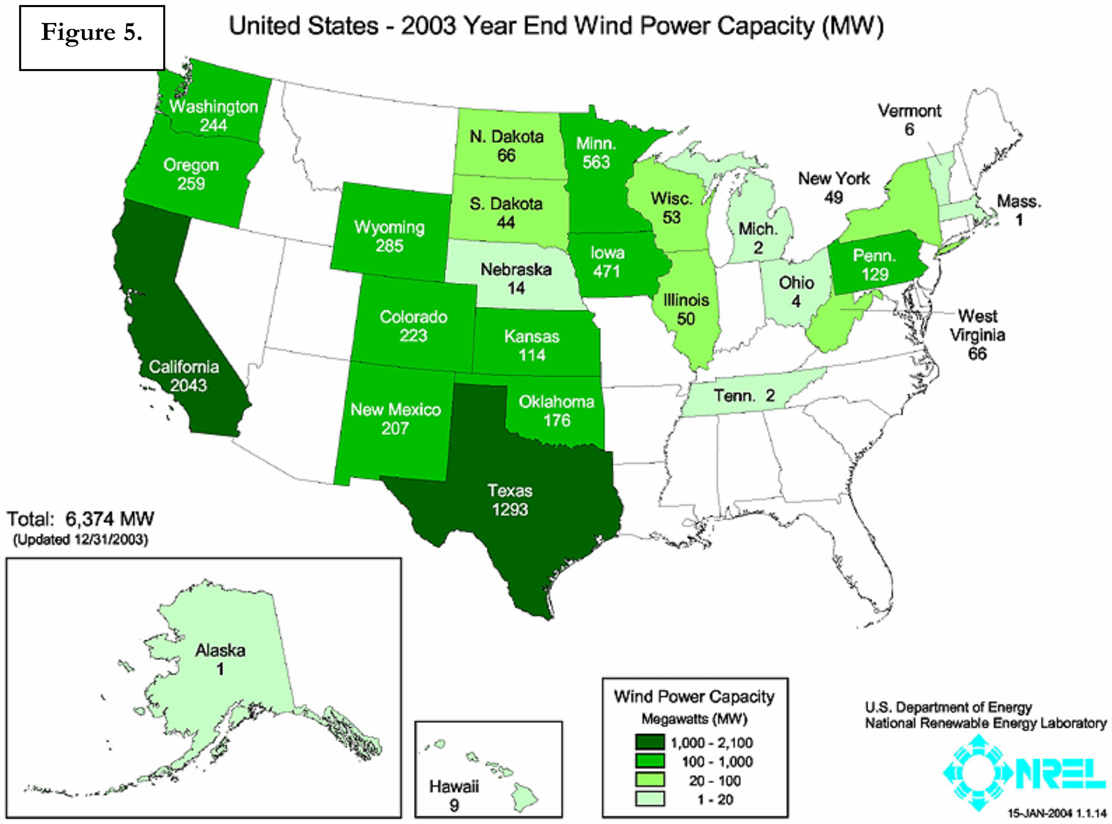
The UK has a similar problem. The Interconnector with France could not handle the dumping of a power surge. Hence, large use of wind power in the UK would cause damage to components of the UK grid and frequent power cuts throughout the UK. Indeed, the UK grid is being upgraded to withstand the problems caused by the intermittent operation of the existing wind farms. Some other countries have similar problems. For example, the dumping of power from one coast of the USA to the other would be difficult because of the distance.

Sec. 12 - Managing supply risk

As earlier explained, power stations operate spinning standby to match electricity demand to supply. In addition to this, other power stations operate spinning standby to manage risk of supply failures. There is a risk of failure of a base load power station or the transmission system from it. Such failures would cause power cuts in the absence of the additional spinning standby.[27]

Wind farms only provide power when the wind is strong enough and not too strong. Hence, wind farms increase the risk of supply failures. Indeed, they give the certainty of supply failures when the wind is too strong or not strong enough.

Figure 5.



The increased risk of supply failures from wind farms is insignificant when there is small contribution of electricity to the grid from wind farms. All the output from the wind farms forces thermal power stations to operate spinning standby that can cope with the risk.

But the problem of managing the risk increases disproportionately as the risk increases. Electricity is not wanted in the same amounts everywhere, and electricity is lost when it is transmitted over long distances. The additional risk management difficulties require additional spinning standby when the risk of supply failures is very large. Otherwise it would be impossible to match supply with demand throughout the grid when a large supply failure occurred.[28] This is demonstrated by the needed amounts of spare capacity shown in **Table 2** and **Figure 4**.

Additional power stations must be built and operated on spinning standby (using their additional fuel and providing their additional emissions) to manage the increased risk of power cuts from supply failures when wind power contributes more than 20% of the potential electricity supply.[29] Indeed, this limit is the reason why the UK target for 'renewable' electricity generation is 20%: the UK generates hydropower (mostly in Scotland) so wind power will not reach the 20% limit if the target is met.

This problem has been realised in California – that has more wind power than any other U.S. State (see **Figure 5**) – although its wind power contributes much less than 20% of its electricity supply. Some 13,000 wind turbines produce more than one percent of California's electricity. (This is about half as much electricity as is produced by one nuclear power plant.) The wind farms were constructed instead of thermal power stations (or instead of re-opening mothballed Californian nuclear power stations), and excess capacity in adjacent States was used to overcome the need for the wind farms to have backup. But California obtained a power crisis when that excess capacity was consumed by the adjacent States. Hence, California has inadequate spare capacity for the needed additional risk management associated with its small use of wind power. This has resulted in California needing to continuously apply scheduled voltage reductions (known as 'brown outs') around the State as an alternative method to manage the risk of power cuts from supply failures.

Summary and Conclusion

Wind farms are expensive, polluting, environmentally damaging bird swatters that produce negligible useful electricity but threaten electricity cuts.

About Richard S Courtney

Richard S Courtney is a Member of the European Science and Environment Forum (ESEF) and acts as a technical advisor to several UK MPs and mostly-UK MEPs. He is Chairman of the Southern Region of a Trade Union (BACM-TEAM) affiliated to the UK's Trades Union Congress. He was the Vice-President of BACM-TEAM from 1995 until May 2000, and he was also a Member of the Executive of the Federation of European Energy Industry Executives throughout that time. Having been the contributing Technical Editor of *CoalTrans International,* he is now on the Editorial Board of *Energy* & *Environment*. His present work mostly consists of providing commissioned advice to national governments, although he has recently conducted research studies of energy interactions at sea surface.

Richard is a respected authority on energy issues, especially clean coal technology. He has been the Senior Materials Scientist of the UK's Coal Research Establishment, has served as a Technical Advisor to the European Coal and Steel Community (ECSC), possesses several patents, and has published papers in many journals including *Nature, Microscopy* and *Filtration*. He is the author of the chapter on coal in *Kempes Engineers Yearbook*.

His scientific achievements have obtained much recognition. The British Association for the Advancement of Science appointed him as a Member of the Association of British Science Writers in recognition of his "clear presentation of scientific information to politicians". The UK's Royal Society for Arts and Commerce appointed him as a Life Fellow in recognition of his "services to British industry". PZZK (the management association of Poland's mining industry) gave him an award in recognition of his "services to Europe's industry". He has broadcast on radio and TV around the world in response to requests from several media companies, notably the BBC, and he lectures around Europe.

His knowledge of energy and environment issues is widely respected. He has been called as an expert witness by the UK Parliament's House of Commons Select Committee on Energy and also House of Lords Select Committee on the Environment. UNESCO commissioned a paper from him on Coal Liquefaction. An Expert Peer Reviewer for the UN Intergovernmental Panel on Climate Change (IPCC), in November 1997 he chaired the Plenary Session of the Climate Conference in Bonn at the joint request of the European Academy of Science, the Science and Environment Project (USA), and the Europaische Akedemie fur Umweltfragen e.v. (Germany). In June 2000 he was one of 15 scientists invited from around the world to give a briefing on climate change at the US Congress in Washington DC, and he then chaired one of the three briefing sessions.

Richard is also an Accredited Methodist Preacher. He is a founding Member of the Christ and the Cosmos Initiative that explores the interactions of religious and scientific ideas. The Initiative started in the UK but became active in 28 countries.

Richard avoids confusion about him in his scientific and religious activities by rarely citing his academic achievements, but his material science qualifications include a DipPhil (Cambridge), a BA (Open) and a Diploma (Bath). He may be contacted at:

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