CPRE Seminar Understanding Wind Power

Background

In understanding wind turbines, as with all engineering facilities, nothing is straight-forward. Statements are made such as "*the wind is free, we must make use of this free energy*". However, there is no such thing as a free lunch and there is a lot of very expensive engineering between the wind and being able to produce electricity from it. This paper attempts to answer the most common questions people have and tries to dispel the many myths that surround wind power.

The title could be **"Understanding Wind Power"** or **"Understanding Wind Energy**". Few people know the difference between power and energy. They shouldn't need to, but very worryingly, decision makers and politicians do not seem to understand the difference!

No-one knows what energy is, but we know what it does. Energy provides the ability to do work. The conservation of energy is one of the most fundamental laws of physics. Energy can neither be created nor destroyed; we can only convert it from one form to others. Power is the rate at which we use or convert energy.

Electricity is something that we take completely for granted, we use it 24/7 and we expect it always to be there on demand. We expect it to be there when we switch appliances on, no matter how many appliances we use and no matter how much electricity we want.

Electricity is the most ubiquitous form of energy. We can heat our houses, cook our food, light our houses, run motors and pumps and run all the electronics equipment that is so vital to our way of life. No other energy source is as useful as electricity, particularly the alternating current (AC) type that comes into our homes and factories. Without electricity we would be in complete chaos; nothing would work. Trains would not run, there would be gridlock on our roads as the traffic lights failed, all shops and filling stations would have to close, to name just a few problems. Within hours absolute chaos would descend.

The National Grid is considered by many engineers to be one of the greatest engineering feats of all time. It has been in existence for over 70 years and has never once failed. The National Grid has been so successful because it was devised, built and operated by scientists and engineers – there was no political interference and it was not driven by Government targets!

The National Grid consists of power stations and the transmission grid (the large pylons we are familiar with) for transmitting the electricity from power stations, which are mainly in the north of England, around the country to the local distribution networks. It carries electricity at very high voltage (400kV and 265 kV). We receive the electricity from the National Grid via a distribution network at much lower voltage, typically 11kV, and it is then transformed down to the 240V supply to our homes. The National Grid maintains a very tight control of the frequency of the electricity, nominally 50Hz (50 cycles per second) because there is a lot of equipment which fails if the frequency is not properly controlled and blackouts would then occur.

The one big drawback of the AC electricity that the grid supplies is that it cannot be stored and therefore the supply of electricity has to closely match the demand for electricity at all times, otherwise the frequency changes. The grid operators control the output of power stations to match the consumer demand.

Three types of power station supply the grid. They perform one or more of baseload, load follow and peak load. Baseload is provided by large power stations which operate at constant power to provide the amount of electricity below which demand never falls. Load follow is provided by power stations which can raise or lower their output to match the daily and seasonal changes in our electricity consumption. Peak load is provided by power stations that can react quickly to sudden increase in demand (such as half-time in the World Cup Final when millions of consumers put the kettle on – or whatever). All these power stations are controllable (despatchable) by the grid operators to ensure supply closely matches demand. Demand is known fairly accurately; it is predictable based on the time of day, time of year and the weather. However, wind power is intermittent, largely unpredictable and uncontrollable. It cannot perform any of the three key functions given above – it is a liability to the grid, having a destabilising influence and making it difficult for the operators to control the grid frequency by matching supply to demand.

Why does the Government have this obsession with wind energy?

The previous Government signed up to the EU renewable energy targets to have 15% of UK total energy (which equates to about 30% of our electricity) from renewable sources by 2020. The aim of Government policy using renewable energy is to reduce CO_2 emissions as given in the Climate Change Act 2008. However the Government didn't know whether the renewable energy target could be achieved, didn't know what the costs would be and didn't know then, and still doesn't know now, whether CO_2 emissions will actually be reduced by using wind power.

What is wind power or wind energy?

It is the conversion of the energy in wind (kinetic energy of moving air molecules) by the turbine blades into rotational energy and then into electrical energy by using a generator. Here are some facts about wind power:

- For physicists and engineers, the natural progression in the development of energy was to use fuel of increasing energy density (the energy in a given volume of fuel). Hence from wind (windmills) to water (water wheels, hydro-power), to coal, oil and gas, to nuclear fission and one day in the future to nuclear fusion.
- Wind is of very low energy density, hence reverting to using wind is against the normal technological progression. Using wind to generate electricity to input to the grid is something scientists and engineers would not do if given the choice. It is a political decision to use wind power.
- Because of the low energy density of wind (moving air), wind turbines are huge. They thus need huge foundations of concrete to prevent them blowing over in high wind. The large size and small output make for very expensive electricity.
- Wind is intermittent and unpredictable – it is never constant. Therefore wind power is intermittent and unpredictable; it has the destabilising effect on the grid discussed above.
- The amount of electricity produced is extremely sensitive to the wind speed. The amount of electrical energy that can be converted from the wind is proportional to the cube of the wind speed. Thus a doubling of the wind speed, results in an 8-fold increase in electricity; conversely, a halving of the wind speed results in 1/8th of the electricity.
- Wind turbines don't work at low wind speed (there is not enough energy in the wind). At high wind speed the blades are stopped to prevent damage and thus no electricity is produced in high winds. You may see the blades turning in light winds, but they are producing little or no electricity.
- Only about 1% of the time do they produce peak (design or rated) output. For about 1/3 of the time they produce less than 10% of peak output and for over ½ the time they produce less than 20% of peak output. On average, about once a week the output of all wind turbines is negligible.
- On average an onshore wind turbine in England produces about 20-25% of the design output – dependent on location. This figure is known as the capacity factor; it

is the ratio of the average amount of electricity produced compared to the peak output. Applicants invariably exaggerate the amount of electricity that will be produced, often by a factor of at least two. This is because they are trying to sell the benefits to decision-makers and the public. They also exaggerate the equivalent number of households (the average household consumption is 4,700kWh/yr) that the wind turbine could supply. Because the electrical output is small, they use equivalent number of households, which is always a much bigger-sounding number. It is a meaningless number because most electricity is consumed by industry and commerce and in fact there is no way of knowing where the electricity will be consumed.
- Because wind turbines are operating in harsh conditions, they have a relatively short life – usually a design life of about 20 years. Maintenance and repair are difficult. The short life and difficult maintenance/repair add to the cost of the electricity.
- They are connected to the low voltage distribution network (the network that is designed to distribute electricity from the National Grid to consumers, not to accept locally generated electricity input) and due to the low voltage, losses can be huge, especially if the wind turbine is remote from consumers. There may need to be a transformer building adjacent to the turbine to deliver the electricity at the required voltage.
- When demand for electricity is highest (cold winter weather), there is usually no wind blowing and the turbines may actually consume electricity rather than produce it.

Where best to site a turbine

- Ideally the turbine should be on a tall tower, because wind speed usually increases with height above ground (known as wind shear). The ideal location is on top of a roundish hill where the air flows smoothly. They should be located away from trees and buildings which cause turbulence. Turbulent air leads to reduced output and increased wear and tear. Hence the effect on the landscape of siting turbines in the optimum location on top of a hill is a big issue. Wind turbines cannot be hidden away!
- They should not be sited close to roads, railways or where people congregate, i.e. not near to schools, hospitals, community centres etc. They can collapse, they can catch fire and spread burning debris, and blades can fail and scatter debris in the form of large fibre-glass shards.
- Access to the site is often a big issue because of the nature of Devon lanes. Large vehicles capable of carrying long and heavy loads are needed, together with a large crane.
- Close access to a grid connection point is needed.
- Ideally they should be sited near to consumers or electricity will be "lost" down the low voltage lines.
- Ideally an anemometer mast should be placed on site for a year or so to monitor the wind speed at hub height, to determine whether the site is suitable and how much electricity is likely to be produced. This is not normally done as it is expensive, time-consuming and requires planning permission. Developers tend to rely on what is known as the NOABL database, which provides an average value calculated over a square kilometre. It can be very inaccurate for any specific location, especially in complex topography such as we have in Devon. It carries a "health warning" that it cannot be relied on. Often developers seem to use guesswork and hope nobody will notice!

Why landowners want wind turbines

There are huge subsidies paid to producers of renewable electricity. Thus big profits can be made at little risk. Let's examine the costs. Conventionally-generated electricity costs the consumer about 12p/unit (kWh) of which the cost of generating the electricity is about 4p/unit. The table below shows the subsidies paid to wind power generators through the Feed-in Tariff (FiT) scheme. It consists of a Generation Tariff subsidy for each unit of electricity generated plus an Export Tariff subsidy for each unit of electricity fed into the network (not consumed by the owner).

Capacity	T a r i f f / u n i t generated	Tariff/unit if all exported
< 1.5kW	35.8p	39.0p
1.5 → 15kW	28.0p	31.2p
15 → 100kW	25.4p	28.6p
100 → 500kW	20.6p	23.8p
500kW → 1.5MW	10.4p	13.6p

The FiT subsidies are guaranteed for 20 years and are inflation linked. The Generation Tariff is paid even if the owner of the turbine consumes all of the electricity produced. For wind farms of over 5MW capacity the subsidy is paid via the Renewables Obligation (RO) scheme.

The table below compares some typical types of wind turbine.

Capacity	Cost	Type of turbine	Blade tip height	Equivalent building height
11kW	£60k	Gaia 2-bladed	25m	8 storey
50kW	£250k	Endurance E3120	35m	11 storey
330kW	£750k	Enercon E33	50-65m	18-21 storey
800kW	£2M	Enercon E44	85-100m	26-30 storey
2MW	£4M	Enercon E82	120-180m	40-60 storey

An approximate economic analysis for an 11kW Gaia with a 20% load factor is now given.

At a 20% load factor the turbine will on average produce electricity at an average rate of about 2kW. **That is not enough to run one modern kettle!** At the commercial rate for electricity of 4p/unit (kWh), the income would be about £2/day = £700/year = £14,000 over the 20 year lifetime. Thus the lifetime income would pay about ¼ of the cost of the turbine. We also need to consider annual maintenance, which typically costs about 1%/year of the value of the turbine (£600) + insurance + interest on the money borrowed to buy the turbine (or lost interest if the owner has the capital to buy the turbine). The turbine clearly needs the huge subsidy, 31.2p/unit, compared to the value of the electricity of 4p/unit, to make it viable.

This calculation can be repeated for each type of turbine. For example the 50kW Endurance turbine costing £250k would, at a capacity factor of 20%, over its expected life of 20 years generate an income of about £70k. An Enercon E82 costing £4M would over its life generate an income of about £2.8M.

It can be seen how uneconomic wind turbines are if they need such big subsidies (up to 8 times the value of the electricity for the smallest turbines). The reasons are the huge size of a turbine, the small amount of electricity produced, the poor capacity factor, the short lifetime and the difficult and expensive maintenance. Clearly no wind turbine would be built without a massive subsidy.

Where does the money come from to pay these huge subsidies? It is passed on to electricity consumers, so all electricity consumers pay it within their electricity bills, but the amount is not revealed. It increases electricity bills for all households, factories, businesses, commerce etc. This increases fuel poverty for many and damages industrial competitiveness and the economy as a whole.

It is often claimed that jobs are created, but are they? Yes, but very few and mainly in construction and maintenance. Virtually all turbines are manufactured overseas – Germany, Denmark, USA, Canada, even Ireland. Real jobs in the real world are destroyed due to rising electricity costs and reduced consumer spending. Industry and commerce have to survive without subsidies but with higher energy costs.

It must be remembered that at the end of their life the turbines have to be removed. The decommissioning costs are large as a crane and large vehicles are again required. Some of the material has scrap value, but the fibre-glass blades are not recyclable and go to landfill. The huge concrete foundations and cables are generally left buried in the ground.

Is wind power clean and green and does it reduce CO_2 emissions?

The assumption has been made by politicians, without any supporting evidence, that wind turbines reduce CO_2 emissions by displacing electricity that would be generated by fossil-fuel power stations. But this is not the whole story.

A lot of energy is needed to manufacture, transport, construct, operate and decommission turbines, and all of these energy-intensive activities are also CO_2 intensive. It has been estimated that typically it takes about 2 years operation of a wind turbine to "pay-back" the energy used in the above processes.

Because the wind is intermittent and unpredictable, there is always a need for conventional power stations to be operating ready to deliver electricity whenever the wind falls. This is known as back-up. Conventional power stations cannot be turned on and off by the flick of a switch. They have to be operating and connected to and synchronised with the grid. They thus have to burn fuel even when they are not delivering electricity and they receive no income for this service. Operating conventional power stations in back-up is a very inefficient mode of operation as the power stations are not operating in their optimum design mode. They burn excess fuel and increased wear and tear ensues. Providing back-up is very CO_2 intensive and can completely negate all the emissions that are saved by wind turbines displacing electricity that otherwise would be produced from fossil fuels. There is evidence from analysis of operation of wind farms in Germany, the Netherlands, Denmark, Ireland and Texas, to show that, due to backup, operation of wind turbines may actually increase CO_2 emissions.

The Government has belatedly recognised the need for back-up power stations. However nobody is going to build such power stations without an enormous incentive because they do not know how much of the time they will be operating without delivering any electricity and without being paid to burn fuel or how much of the time they will be operating at reduced efficiency. They do not know how much income they are likely to earn to cover the investment. Hence the Government is putting in place what is known as a "capacity mechanism" to pay generators to build and operate such power stations. The cost will be passed on to electricity consumers. We will be paying for two electricity systems; one that operates when the wind blows and one that operates when the wind doesn't blow.

The Government is aware of these issues, but refuses to acknowledge the problems because of the need to meet the EU renewable energy target.

Noise

Noise is, quite rightly, the biggest concern of many people when they learn that there is an application for a wind turbine to be sited near to their house.

What is noise? It is unwanted sound. Wind turbines emit two types of noise: mechanical and aerodynamic. Mechanical noise is produced by the rotating machinery in the nacelle and can be reduced by sound insulation and good maintenance. However, aerodynamic noise is produced by the blades cutting through the air at high speed. It cannot be eliminated, but good design reduces the noise. For example, downwind turbines (the blades are downwind of the tower) are noisier than upwind turbines (the blades are upwind of the tower). The distance that the noise travels is also dependent on the climatic conditions (wind speed and wind shear) and upon the topography and the ground conditions.

The Government's position on noise from wind developments is as follows "*Noise impacts are considered within the planning process before a decision is taken on whether or not to grant consent to an onshore wind project. Existing planning guidance states the ETSU-R-97 approach should be used to assess and rate noise from wind energy developments*".

ETSU-R-97 ("The assessment and rating of noise from wind farms") was produced in 1997 by a working group, which recommended that the guidance be reviewed after a year. No review of has subsequently taken place, but wind turbines are now many times larger than in 1997. There have been many complaints about excessive noise from turbines. ETSU-R-97 permits more noise at night than during the day: 43dB of noise is permitted at night in quiet areas. During certain atmospheric conditions the permitted wind turbine noise can be four times louder than the ambient background noise before a wind turbine is erected.

The noise limits are specified so that the characteristic "swish, swish, swish" or "thump, thump, thump" noise, which is much louder than the average noise and is the source of most complaints, is excluded from the noise assessment. Noise limits imposed through planning conditions fail to control the actual levels of turbine noise but rather deal only with the lowest 10% of the noise averaged over ten minutes. This permits the separation distances between turbines and neighbouring dwellings to be reduced.

The objectives of the ETSU-R-97 noise limits were to provide noise levels "*thought to offer a reasonable degree of protection to wind farm neighbours and encourage best practice in turbine design and siting*". No definition of "reasonable" was given and clearly the industry still supports turbines that are not designed to minimise noise and certainly do not use best practice when siting the turbines.

Noise from wind turbines is known to cause ill-health and it can lead to sleep disorders, exacerbating ill-health. Medical experts recommend large separation distances between wind turbines and residential property.

<u>Other issues</u>

The effect of wind tourism is denied by the wind industry, but commonsense tells us that tourists come to rural Devon to enjoy the peace and quiet and the sense of tranquillity.

Common sense also tells us that people looking to buy property in the heart of a tranquil, rural environment will pay much less for a property adjacent to a wind turbine.

Wind turbines have an adverse impact on wildlife such as birds, bats, deer and this is mostly ignored in applications.

<u>Final thought</u>

There is a saying "**The Stone Age didn't end for lack of stones**"; it ended because something much better came along – the Bronze Age. Likewise windmills didn't go out of usage for lack of wind; something better came along. We cannot turn back the clock from the huge benefits to society that the industrial revolution gave us. A modern society that has the resources to care for its citizens and the environment needs cheap, reliable and abundant energy, something that wind power can never provide.