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It's Not Easy Being Green!
- A look at the limitations of some renewable energies

"Some day we will harness the rise and fall of the tides
and imprison the rays of the Sun"
Thomas Edison 1847-1931

What are *Renewable Energies*? *Inexhaustible* or *infinite* sources of energy are fundamental and include solar, wind and tidal energy, but renewables also includes sources that can be replenished naturally on a short timescale. This allows for the inclusion of biomass like wood and other vegetation but not the fossil fuels of coal, oil and gas which take millions of years to form. Harnessing the Earth's renewable resources is not a new idea. For centuries mankind has put the waters that flow in rivers and the winds that blow over the land to good use. Boats have used sails since the time of the ancient Egyptians and historically wind turbines have been used to pump water and grind corn.

Mr Cameron's short-lived micro turbine

Today renewable energies are closely linked to the challenges of climate change. These so-called 'green' energies are seen as a key tool in reducing greenhouse gas emissions like CO_2. Increased levels of industrialisation in countries like China and India, and rising world population has led to a dramatic growth in global energy consumption in the past fifty years. In the period from 1971 to 2002 the total world demand for energy rose from 5,536 MTOE (Mega Tonnes of Oil) to 10,345 MTOE [1]. This is slightly faster than the rate of world population growth over the same period which swelled from 3.8 billion to 6.2 billion [2]. This is happening to a backdrop of increasing oil prices as demand surges, and decreasing energy security and stability as we become dependent on foreign supplies.

All of this adds up to make renewable energy an attractive package; for the environment and economy. The issues of climate change are rarely out of the public eye. Recently, the traditional red, blue and yellow of the main political parties have been turning green as each competes for the label of the environmental choice. The leader of the Conservative Party, David Cameron demonstrated his credentials as the 'green' candidate when he installed a micro-wind turbine on the side of his London house earlier this year. The turbine lasted a week before it was removed and some experts feel that political stunts like this one, can contribute to public confusion surrounding renewable energies. Others feel that the term 'green' energies can be misleading and that the benefits of renewables aren't as obvious as people might think.

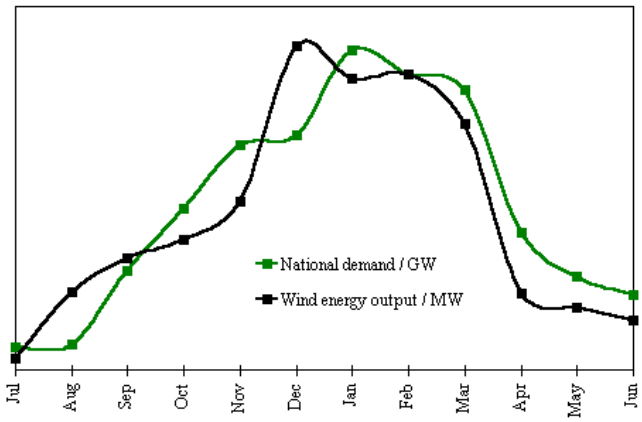


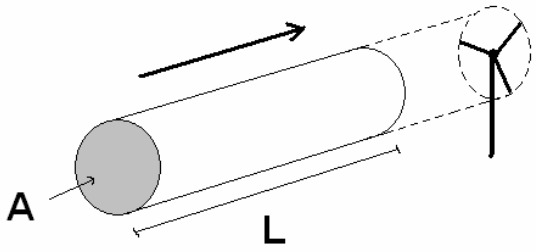
Figure 1 Wind energy output matches the peaks and troughs in national demand

Wind, as a source of renewable energy is now an established technology. An intermittent energy source, wind currently doesn't supply enough of Britain's energy for fluctuations in output to become a concern. As Britain's wind power capacity is increased it is thought that local fluctuations can be compensated by distributing wind farms widely; both on and offshore. Britain is ideally situated for large scale wind projects, sat as we are in the path of the strong North Atlantic prevailing winds. An important factor that makes wind such a viable option is that our annual wind patterns match national energy demand, with stronger winds coinciding with the winter consumption peak.

Last month, the Centre for Alternative Technology (CAT), calling on over thirty years of experience in sustainable and ecological technologies, published their vision for the future of British energy supply, placing wind energy at the heart of their policies. They believe that half of Britain's energy could be supplied by tapping just 14% of the offshore wind potential [3.]. At the moment there are 148 onshore and 6 offshore wind farms operational throughout Britain. These have a combined power capacity of 2293.89 MW [4.]. A further 37 wind farms are currently under construction that will increase capacity to 3648.09 MW. Add to this several large farms approved off the coasts of Kent and Cornwall and the governments intent to make wind energy a major part of Britain's supply becomes clear.

Not only are the government supporting large scale wind farms but they also see small scale micro-turbines as a way of meeting CO_2 emission targets. Through government support and some high profile individuals, like Mr Cameron, leading the way, the micro-turbine has become this seasons 'green' fashion must have. However, despite the popularity of micro-turbines there is evidence that they are not as effective at reducing emission as people might think. In fact CAT, while keen to 'inspire, inform, and enable people to live more sustainably' [5.], would not recommend fitting a micro-turbines to houses in most instances. As Figure 3 shows, the power output of a turbine scales with the cross-sectional area of the rotating blades and the cube of wind speed. This is why locating the turbines becomes so important when factors like height above sea level, nearby trees and buildings can all affect wind speeds and dramatically reduce the power output. Not only would turbulent airflow affect energy production but the moving parts can also cause vibrations that can lead to structural damage.

Figure 2 Power Output from a Wind Turbine



Average velocity of air: u
Average density of air: ρ

Mass of air in the cylinder : ρAL
Kinetic Energy of this volume of air:
$\frac{1}{2}mu^2 = \frac{1}{2}\rho ALu^2$

This volume of air passes through the turbine in a time period T=L/u

Giving,

Power Output = $\frac{1}{2}\rho Au^3$ Watts

A recent article in The Guardian suggests that micro-turbines could in fact add to overall CO_2 emissions. Reporting on a study by The Building Research Establishment Trust that compared the power output of turbines situated in the built-up urban environments of Manchester and Portsmouth and the more remote Shetland Islands port of Lerwick. The report found that two thirds of the turbines in Manchester and one third of those in Portsmouth produced an overall net increase in CO_2 emissions over their lifetime [6.]. Any gains made during operation were more than offset by the impact of building, installing and maintaining the turbines. The data for Lerwick was more favourable. A direct comparison shows that the output from a turbine in a city would be less than 150 kWh a year which is 2% the average household energy consumption in contrast to roughly 3000 kWh in Lerwick; an impressive 40% of household energy consumption.

It's not just small scale energy production that has come under criticism. Large wind farms sited in remote and isolated locations are seen as a scar on untouched landscapes. As well as the aesthetic impact there are concerns about the effects of wind farms on local wildlife and ecosystem. Existing infrastructure will usually be insufficient and new long distance transmission lines will be needed. This can result in lengthy and costly disputes with landowners over routing these lines. Jesse Ausubel, Professor of Environmental Science at Rockefeller University, also raises concerns about the huge areas of land needed to meet global energy demand through renwables like wind. To satisfy US energy demands at 2005 levels would require wind farms covering an area equivalent to the states of Texas and Louisiana [7.]. This is an extreme example as it is unlikely that the US would ever try to source all of its energy from wind farms but the data does indicate that even to achieve modest renewable energy targets would require large amounts of land to be developed on. As Ausubel puts it, '*part of being green is that you cause minimal interference with the landscape*'.

Another boom industry is bio-fuels, which are derived from biomass. The easiest way to extract energy from biomass is just to burn the raw product for instance wood fires. This is not very sustainable since it takes a long time to replace trees. A better option is to use dedicated fast growing energy crops. A

lot of efforts are currently being made to replace at least some of the fuel used in transport by bio-ethanol and bio-diesel which is produced by fermentation of starch and sugar crops like sugar cane, corn and barley and by chemically possessing oilseeds. Bio-fuels are favoured by governments for several reasons but again some experts feel that we are depending too heavily on a new technology, whose full effects are not yet known. The economic arguments for bio-fuels are clear. Although they are more expensive per gallon than traditional fuels the gap will close as increasing scales of production drive down the costs while gasoline prices seem set to rise.

In theory bio-fuels should also reduce green house gas emissions like CO_2 since any carbon released was recently absorbed from the atmosphere by the energy crops, unlike fossil fuels which release ancient carbon. However there are some greenhouse gas emissions due to the production and this can drive down the overall green balance of bio-fuels. Farm machinery running on conventional fuels and the fermentation process release CO_2. Also the use of chemical fertilizers can be incredibly harmful. Some reports about the energy balance of bio-fuels indicate that more fossil fuel energy is used during production than the final output energy. An article in the National Geographic compares the energy balance of different bio-fuels [8]. Corn ethanol produced in the US outputs 1.3 units for every unit of fossil fuel energy used in production. Bio-diesel produced in Germany performs slightly better giving 2.5 units of energy. While these examples suggest the energy balance tipping in favour of bio-fuels, their production is still heavily reliant on the input of fossil fuels and therefore they don't really offer the move away from traditional fuels people hoped for. However there are examples of bio-fuel production that do offer a good opportunity like sugarcane ethanol produced in Brazil. A strong emphasis on efficiency has resulted in an output of 8 units of clean energy and equates to a reduction in greenhouse gas emission of 56% over production and use.

However even the benefits of these energy crops are questionable, say some experts. Reports have indicated that 18% of global greenhouse gas emissions are caused by change in land use [9]. As demand for energy crops increases agriculture will be expand onto uncultivated land. This will include some of the world's most important carbon sinks, releasing huge amount of CO_2 into the atmosphere. In Europe this might be valuable set aside land, while in developing countries the risk is greater as the rainforests are threatened and peatlands are drained to make way for bio-fuels. Campaigners believe that when these emissions are taken into account bio-fuels come at a heavier environmental cost than traditional ones. Combine these concerns with fears of increased food prices and the loss of biodiversity from growing acres of single crops it is not surprising that there are now voices calling for a suspension of bio-fuel production.

As it has been discussed, relying to heavily on one resource could be as damaging as fossil fuels and the real solution is to use a variety of renewable resources. A great example of how renewable energy resources can complement each other is Bio-fuelled Wind Systems [10]. These combine conventional wind farms with biomass based energy storage. Already the problem of wind intermittency is overcome by using compressed air energy storage (CAES) where energy is used when wind power output is high, to

compress air and store it in sealed caverns. During periods when the wind is insufficient to meet supply, the output can be topped up by mixing the compressed air with small amounts of natural gas and burnt to generate additional power. This is a system that is already used, but replacing the natural gas used with biogas produced from energy crops grown locally improves the system. Not only are the greenhouse gas emissions reduced but transport costs can also be cut. The use of energy crops grown locally on a small scale also gives farmers an incentive to support the development which should mean less opposition to transmission lines.

There will always be the 'not in my back yard' argument against new development but when the opposition to renewable energies is coming from the same people who lobbied for a move away from fossil fuels this is worrying. It seems that the technologies that will allow us to lessen our dependence on fossil fuels and achieve a more sustainable supply of energy already exist, but further developments might be needed before renewable energy can truly be thought of as 'green' energy. There are plenty of examples of how renewable resources can be tapped cleanly and efficiently and these must serve as a model to future policies.

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