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The Arithmetic of Renewable Energy

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Global warming is the central problem of our age. In order to solve it, western society must make a serious attempt to switch from fossil fuels. There are other reasons to move away from petroleum: first, a reliance on oil is dangerous when so much of it lies buried in politically unstable countries and, second, (at some point in the future) oil supplies will start to run dry. Nevertheless, climate change, and the fate of our grandchildren, is the pressing issue.

What practical steps should now be taken? Many people have faith in renewable energy sources such as wind, solar and wave power. The first of these is the best currently available.

The sheer enormity of the UK's future energy problem, however, is not widely understood.

Where does energy currently go?

Energy use in the UK falls into four main categories. The largest, at one third of all energy used in this country, is transport. It consumes approximately 55 million tonnes of oil per year. Next at a little under 50 million tones per annum comes domestic household use – for things like heat and light. Then comes energy used in the Services sector. It totals 30 million tonnes. Finally, approximately 20 million tonnes a year of oil-equivalent are consumed in Industry.

Since 1970, these proportions have altered markedly. While industrial energy consumption has dropped, the rise of the car in our society has seen energy use on the roads almost double.

How can we replace petrol in cars?

These numbers make clear that the key long-term issue is how to replace the fossil fuel that is currently burned in car engines.

In the year 2004, there is only one practical way to run motor vehicles in a green way. They have to be powered by hydrogen. The Liberal Democrats have, in fact, called for subsidies for cars of this sort.

What is not widely appreciated is that hydrogen is not a source of energy. It is a carrier of energy. Yes, cars can, and should, be made to run on hydrogen fuel. But, to be clean, the hydrogen has to be made with renewables-based electricity. Today, hydrogen is made from fossil fuel, which defeats the purpose.

What would it take to run all of Britain's transport, in a truly green way, with hydrogen? It is possible to do an illustrative calculation*.

The answer is disturbing. What is required is approximately 100,000 new wind turbines. If sited off-shore, this would mean an approximately 10-kilometre-deep strip of wind turbines encircling the entire coastline of the British Isles. If sited on-shore then an area larger than the whole of Wales would have to be given over to wind turbines.

Given technology as it stands, there is only one non-fossil-fuel alternative -- nuclear power.

Although that leads to other long run concerns (particularly how to deal with radioactive waste), nuclear power stations could in principle provide the necessary green electricity to produce the hydrogen to fuel the UK's transport needs. However, again the number is striking. As the appendix shows, it would require approximately 100 nuclear power stations.

Conclusion

Transport is the single biggest energy user in the UK. On average, we all consume one tonne of oil in this way every year.

To replace this with cars that run on hydrogen -- powered without any fossil fuel -- would take a revolution in society. Given the most effective renewable sources, there are two ways to do it.

One is to construct 100,000 new wind turbines. The other is to build 100 new nuclear power stations.

The UK has painful, but vital, choices ahead.

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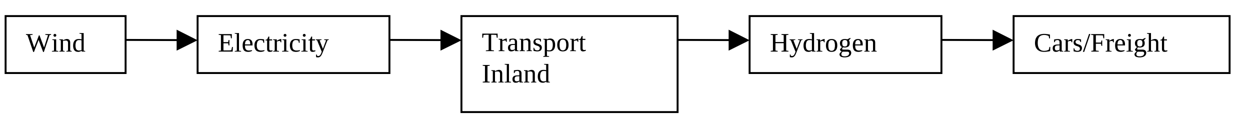
*** Appendix: The technical calculation**

How many wind turbines are needed to supply all the energy for today's UK transport needs?

The following is a calculation of the number of wind turbines required to provide enough energy to fuel the UK's transport today. This calculation is based on the premise that we use wind turbines to generate that energy which in turn is used to generate hydrogen and then the hydrogen is used to power vehicles. The wind turbines are likely to be offshore and the most efficient way to transport the energy inland is as electric power. Once inland, the electricity can be used to electrolyse water into hydrogen at locations across the country. New vehicles would be required that were capable of storing and burning the hydrogen.

The energy chain would look like this



<u>Calculation</u>

From DTI 'UK Energy Sector Indicators 2003' DTI publication 6339/6.0k/02/03/NP, chart 11.8.
The UK annual consumption of transport energy:

= 54 (MTOE) Million Tons Oil Equivalent.
Note: this has been steadily increasing.

The conversion of electric power into hydrogen (an energy store) and then back into motive power is approximately 50% efficient, ref. Ulf Bossel 'The Hydrogen Illusion'. Ulf Bossel is founder and organiser of the European Fuel Cell Forum, based in Switzerland.

So renewable energy required = 54 / 0.5 = 108 MTOE.

*Converting units to average daily MW = 108*1000*11.63*1000/(365*24) = 143,000 MW*
Conversion factor of 11.63 taken from ref DTI 'UK Energy in Brief, November 2000'

Today typical wind turbines are 2MW power. Let us assume larger, 3MW, units are developed and installed for this application.

Number units required = 143,000/3 = 47,794 units.

The wind only blows part of the time. Using an average capacity factor of 50% gives the approximate number of wind turbines required 47,794/0.5 = 96,000 units of 3MW size.
Call it 100,000 units as an approximation.

Where would the UK put them?

To keep the wind turbines out of sight and in a reasonable windy area, let us assume they are placed offshore and strung around the periphery of the entire country. What approximate density, given a rectangular band of turbines, is then required?

The straight line distance north to south = 680 miles (ref road map)
Straight line distance east to west = 200 miles
Periphery = 2(680+200) = 1760 miles = 2800 km*

Number per km = 100,000/2800 = 36 units / km

Wind turbines create blockage to the wind and have to be spaced apart to ensure the wind is undisturbed for neighbouring wind *turbines. AEA report for Greenpeace 'Sea Wind East' argues that a spacing of 0.5km is required. In other words, there are two per linear km. Therefore a band of wind turbines 18 deep would give the required 36 wind turbines per km. This represents slightly less than an approximately 10 km deep strip of wind turbines around the periphery of the UK.*

If on shore, how much land is required ?
100,000 units at 4 units per square km means 25,000 square km required. Total UK land area = 244,000 square km. For example, the area of Wales = 20,000 square km.

In conclusion

- *Approximately 100,000 wind turbines (each 3MW) would generate enough electricity to manufacture sufficient hydrogen to provide the power for today's UK transport needs.*
- *A reasonable spacing of these around the coastline of the UK (2,800km long) would require a band of wind turbines approximately 10 km deep.*

Alternatives

This calculation shows how dispersed renewable energy is: you need a lot of equipment over a large area to collect the energy for today's needs. Wind turbines are the most effective renewable technology available and are being installed widely. Other renewable energy forms such as bio-fuels, wave power, solar are also dispersed forms of power and require big installations to get the large quantities of power for today's needs. Fundamentally, their power per unit size is much worse than equivalent fossil fuel powered machines. Nuclear power is another alternative which is free from CO2 production.

110,000 MW of power could be generated within 100 nuclear power stations each of 1,100MW generating capacity. Ref Sizewell B (the UK's most recent nuclear station) has a generating output of 1,200MW.