Solving the energy crisis

Neither the nuclear evangelists nor the renewables enthusiasts can take comfort from my calculations

In one respect, Simon Jenkins is right. “Nobody,” he complained in the Guardian last week, while laying out his case for nuclear power, “agrees about figures.” As a result, “energy policy is like Victorian medicine, at the mercy of quack remedies and snake-oil salesmen”. There is a reason for this. As far as I can discover, reliable figures for the total volume of electricity that renewable power could supply do not yet exist. So anyone can claim anything, and anyone does. The enthusiasts for renewables insist that the entire economy – lights, heating, cars and planes – can be powered from hydrogen produced by wind. The nuclear evangelists maintain, in Jenkins’ words, that “even if every beauty spot in Britain were coated in windmills, their contribution to the Kyoto target would be minuscule”. All of us are groping around in the dark.

So, though this is not a scientific journal and though I am not qualified to do it, I am going to attempt a rough first draft, which I hope will be challenged and refined by people with better credentials. Some of my assumptions are generous, others are conservative. This will be far from definitive and, I am afraid, quite complex, but at least, on the day the government’s energy review is announced, we will have something to argue about.

The UK has an installed electricity-generating capacity of 77 gigawatts (GW). Demand for electricity peaks on winter evenings between 5pm and 7pm, when we use some 61.7GW. A recent report by Oxford University’s Environmental Change Institute estimates that if we do everything possible to improve energy efficiency in the home and install mini wind turbines and small "combined heat and power" boilers, we could reduce our demand from big power plants by 25GW, or 40%, by 2050.

I haven't been able to find a comparable study for offices and industry, so my first leap of faith is to assume that the same cut can be applied across the economy. This is likely to be generous. It is now clear that 2050 is too late: drastic cuts - 80% to 90% - in greenhouse gases need to be made by 2030. So my second assumption is that the 40% cut can be spread evenly across time: that we can, in other words, reduce peak electricity demand by 22% by 2030. This means that it falls by 13.6GW, to 48.1GW.

Because wind doesn't blow consistently, wind power cannot replace fossil fuels watt for watt. A paper published in the journal Energy Policy estimates that 26GW of installed wind capacity (which could meet about 20% of current electricity demand) would replace 5GW of fossil fuel plant. Graham Sinden at Oxford University has shown that a more reliable mixture – 43% wind, 52% wave and 5% tidal stream power - could, at the same volume, replace 8GW of coal or gas.

The National Grid company tells me that wind power could directly deliver "at least 20%" of our electricity and remain "economically feasible". Assuming that the same can be said of Sinden's mixture, 20GW of installed renewable capacity will mop up 20% of our reduced demand (48.1GW), displacing 6.2GW of conventional power plant. This leaves us with 41.9GW to find.

Figures from the Energy Technology Support Unit at Harwell suggest that if you build only in places with an average wind speed of at least 7 metres per second, and keep out of national parks, areas of outstanding natural beauty, nature reserves and towns and villages, you could produce a maximum of 58,000 gigawatt-hours (GWh) per year of electricity from onshore wind (a gigawatt-hour is an hour of electricity delivered at a rate of 1GW). If you build only in shallow water with a firm seabed, out of the path of migrating birds and military exercises, and where grid connections are available, you could generate 100,000GWh from offshore wind. These estimates are probably conservative, as wind turbines are already bigger than the researchers envisaged. The same study estimated that 53,000GWh could be produced from wave power and 36,000GWh from tidal stream machines. A House of Lords committee reports that it might be possible to generate 24,000GWh from tidal lagoons. I won't count electricity from sunlight, because it's expensive and isn't produced when we need it most. This means that if we used all the available sources of variable renewable power in the UK, we could produce 271,000GWh of electricity per year.

We have already used up 20GW of installed renewable capacity. Assuming that renewable power is 30% efficient, we can multiply 20 by 8760 (the number of hours in the year) and 0.3, to make 52,600GWh. Subtract this from 271,000 and we are left with

218,400.

Now here comes the biggest leap of faith. I am going to assume that by 2030 a cost-effective energy storage technology has been developed which has a 50% efficiency. The most likely technologies are hydrogen (which can be burnt in gas turbine engines) or a battery system such as the one envisaged in the UK's Regenesys project, which was scrapped last year. Either one would add considerably to the costs of power generation, so investors are likely to become interested only if gas prices keep rising (which is likely) and nuclear operators are forced to carry their own insurance costs (which is unlikely). But if either the market or the government swung behind energy storage then something like half the output from our variable power sources could be turned into a reliable supply of electricity. That means 109,000GWh.

To this we could add 17,000GWh from willow plantations grown on the farmland currently under set-aside, 6,000GWh from farm and forestry waste, 6,000 from hydro power and 5,000 from landfill gas, to give a total for reliable electricity generation from renewables of 143,000GWh. Assuming very conservatively that this is evenly distributed across the year (in reality much of it can be held over to meet peak demand), and that at any one time 85% of it is available, this gives us 19GW of installed capacity. We needed 41.9GW, so our shortfall is some 23GW at peak demand and 34.8GW of total capacity. (The need for spare capacity could be greatly reduced if we managed demand rather than supply, as the great free thinker on energy systems Walt Patterson has suggested.)

This is more than the apostles of renewable energy were hoping to see, but much less than the nuclear proselytes have predicted. It suggests that we could cut our demand for fossil fuel without building new nuclear power stations. But it is still too much: even 23GW will help to cook the planet. So the choice then comes down to this: we make up the shortfall either with nuclear power, as Jenkins suggests, or with gas or coal accompanied by carbon burial (pumping the carbon dioxide into salt aquifers or old gas fields). The first option means uranium mining, nuclear waste and the threat of proliferation and terrorism. The second means insecurity (gas) or opencast mining and air pollution (coal) and a risk (though probably quite small) of carbon seepage.

Neither option looks pretty. I fear I have succeeded not only in writing the densest column The Guardian has ever published, but also in demonstrating that this problem is harder to solve than I had hoped. Is there someone out there who can prove me wrong?