Meeting future UK energy demand – what can renewables offer?

In the light of climate change, dwindling oil and gas supplies, and controversy over nuclear power, Peter Smith looks at the scope for expanding the supply of renewable energy in the UK.

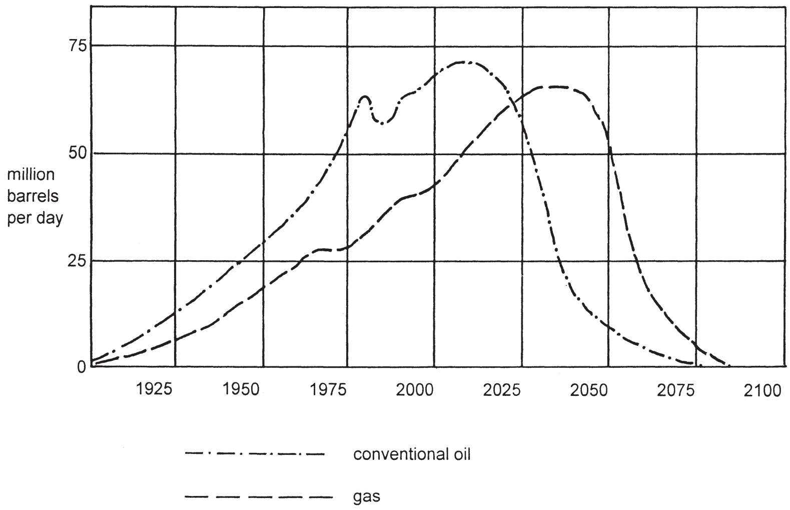

Figure 1 - World production of oil and gas (1900-2100)

Two extremely serious problems are rapidly climbing the political agenda: climate change and depletion of oil and gas supplies. Both are set to have dramatic consequences for the planet well before the middle of this century.

The evidence is increasing that climate change is not only happening but is likely to be worse than had been predicted as little as five years ago. Observations in the last couple of years indicate that the Arctic, Greenland and Antarctic ice sheets are melting faster than before. In tropical areas, the incidence of the strongest categories of hurricanes is increasing, while other reports indicate increased melting of the permafrost. More extensive computer modelling – in particular a novel study published in January 2005 which utilised the power of 90,000 PCs[1] – has shown that the climate system could be more than twice as sensitive to human emissions of greenhouse gases than previously thought.

Meanwhile, as Figure 1 shows, projections of the reserves of oil and gas indicate almost all will peak before mid-century, with conventional oil sources likely to peak before 2010. Against this background, all international energy agencies predict a steady increase in energy demand until at least the end of the century. Hence, as these peaks are reached, there is bound to be increased price volatility which could be exacerbated by conflicts and terrorism.

For the UK, the energy issue is especially pressing due to the decommissioning of the majority of the nation's nuclear plants over the next two decades coupled with the rapidly dwindling indigenous gas reserves. The latter is particularly problematic in the short term as gas storage facilities in the UK currently have only 11 days' reserve capacity.

So can the world achieve a major cut in CO_2 emissions over the coming century while accommodating moderate growth in energy demand? Research carried out at Sussex University and published in November 2004 offers one possible solution. This produced a scenario assuming an increase in energy demand at net 1% per year, but constrained to prevent atmospheric levels of CO_2 climbing above twice the pre-industrial level. They concluded that this would require global CO_2 emissions to be reduced by 80% by 2100, and this in turn would require renewable energy to supply 80% of the world's energy. The scenario shows heavy reliance on solar and biomass closely followed by wind.

A low carbon energy scenario for the UK

Could the UK draw 80% of its energy from renewables? Here I present a sketch in outline of a low carbon energy scenario. This scenario is based on the assumption that the energy driving the economy will increase at 1% per year to 2100. Any increase in economic growth above this will be achieved through improvements in energy efficiency. At the same time, we need to achieve an 80% reduction in CO_2 by that date, so what will this mean in terms of renewable energy? Table 1 illustrates the scale of the challenge. We will have to have installed clean technologies to the scale of nearly three times the total energy demand of 2004.

Table 2 shows the possible distribution of cleaner technologies by the end of the century. The UK is blessed with the most vigorous tidal regime in Europe, so it is not surprising that marine energy is the largest contributor. Solar energy and energy from biomass come next. Solar energy is where the most dramatic technological breakthroughs are likely.

Marine energy

The two main types of marine energy are tidal and wave.

The EU has identified 42 sites around the UK suitable for underwater turbines which could harness tidal currents or streams. Blue Energy Canada has suggested that the tides around Guernsey could provide a peak of over 20 gigawatts (GW), a potential the island is now exploring. Taking account of the load factor it is estimated that tidal streams could provide around 9 GW of electrical capacity. The Department of Trade and Industry has suggested that the Pentland Firth alone could deliver about 7 GW.

The problem with tidal energy is that it comes in great surges when the grid does not necessarily need it. There are three answers to this. First, different tide times around the UK coast can even out the troughs – Severn, Mersey, Morecambe Bay, Solway Firth, Pentland Firth, Humber, Thames etc. Second, there is the option of energy storage. In an estuary like the Bristol Channel it would be possible to construct pounds to retain the high tide to compensate for the slack periods of the tide. A better answer is augmented pounds, that is, higher than the high tide limit. Off-peak power can be used to pump water as a reserve to generate at peak times.

Table 1 – UK primary energy scenario to 2100

Year	% from renewable energy	Total energy (exajoules or EJ)	Renewable energy (exajoules or EJ)
2004	4	8.75	0.35
2020	20	12	2.4
2050	50	16	8.0
2100	80	26	21

Table 2 – Possible distribution of low carbon technologies in the UK in 2100

Energy source	Generation in 2100 (EJ)
Marine (wave & tidal)	8.5
Solar (photovoltaics & thermal)	4.0
Biomass (energy crops)	4.0
Wind (on & offshore)	3.3
Hydro (dams & run of the river)	1.0
Coal with CO_2 sequestration	5.2
Total	**26.0**

Figure 3 - Limpet wave generator, Scotland

The third option is to use off-peak power to produce hydrogen via electrolysis. The hydrogen could produce power via a grid-size fuel cell. The technology of fuel cells is progressing rapidly, mainly driven by vehicle manufacturers.

The oldest technology to exploit tidal energy is the tidal barrage. The strongest case for a tidal barrage in the UK is in the Thames estuary. There is considerable low-lying land around the Thames basin, especially where the Thames Gateway housing project is proposed. Not only could a barrage generate huge amounts of power (by a combination of underwater turbines, wind turbines and wave turbines), but it could also protect London from increased storm surges.

Where there is a good tidal range and a shelving beach, this is ideal for tidal impoundment. The favourite is the 3-pool system, as shown in Figure 2, which allows power to be generated either to even out the troughs or to generate according to the most favourable spot price at peak times.

A small example is under review off Swansea but a much larger project is under discussion for North Wales. It is 9 miles wide by 2 miles across and would produce 432 MW. Being constructed of loose rock and rubble, it is a much cheaper option than estuary barrages.

An environmentally friendlier alternative to the barrage is the tidal energy bridge with vertical rotors between the supports. It is ideal for estuaries and tidal channels and preserves the integrity of the intertidal zones which pleases the wading birds. It has a very high energy density, claimed to be over 192,000 kWh/m2/yr. It can also double up as a road and rail link. The most promising site is the Bristol Channel, which could produce around 6-8 GW of capacity; more if combined with impoundment storage flattening the sinusoidal curves. Another option is the suggested Lake District relief bridge from Heysham to Barrow-in-Furness where there is a rapid tidal race.

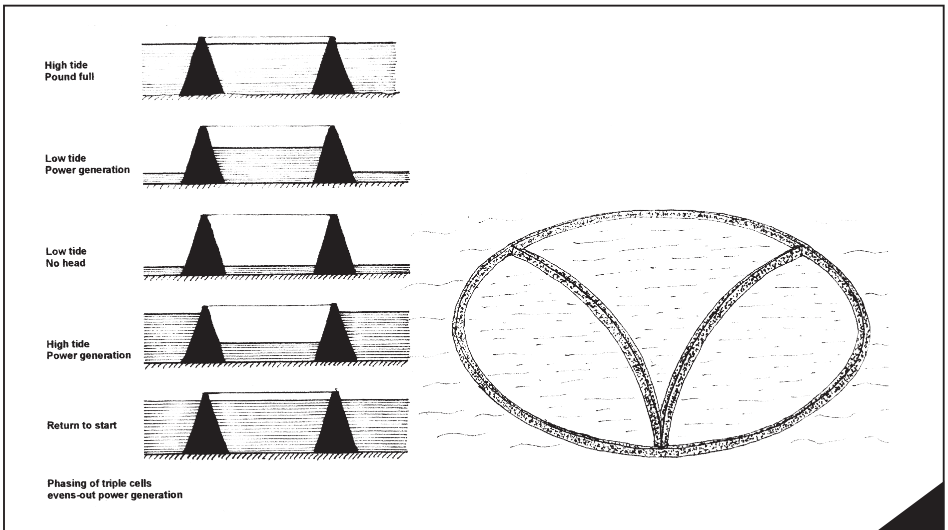

Figure 2 - Three-pool tidal impoundment

In addition to exploiting tidal energy, the UK is well endowed with wave energy. There are two main types: shore-based and offshore.

The Limpet (Figure 3) is a shore-based demonstration prototype in Scotland delivering about 500 kW to the Isle of Islay. It is based on the Oscillating Water Column principle.

The first offshore demonstration project in the UK is the Pelamis, consisting of flexibly linked 3.5 m diameter cylinders. The joints contain pumps which force oil through hydraulic electricity generators through the action of the waves. This project produces 750 kW. The manufacturers aim to build a wave farm covering one square kilometre and delivering 30 MW of power (enough for about 20,000 homes). The first commercial installation is off Portugal at a size of 2.5 MW.

Overall, the total potential for tidal and wave technologies for the UK is approximately 60 GW, taking load factor into account.

Solar energy

Solar photovoltaics (PVs) are not currently cost effective within a bare-knuckle energy market, which is why they are so scarce in the UK. However, in Germany there are large subsidies for all scales from the domestic to the industrial. Their renewable energy law pays about 35p/kWh to domestic consumers and a little less to industrial scale producers. Hence it recently launched its *second* 100,000 homes PV programme. It is also commercially attractive to build huge PV farms, e.g. the 18 MW at Arnstein installed in 2004. Meanwhile the UK has just pulled the plug on grants under both the Major Photovoltaic Demonstration Programme and Clear Skies programme, while the small amount of PV manufacture carried out in the UK is virtually all for export, mostly to Germany.

But things will change. The development of PV technology is not linear but exponential. Thin film and nanotechnology will transform the market within 5 to 10 years, and so will the entry into the market by Chinese industry.

Biomass energy

Biomass can be derived either from waste or from the cultivation of short rotation crops. There are three main ways of converting biomass to energy:

- Direct combustion
- Anaerobic digestion of organic waste to produce biogas
- Landfill gas conversion

The EU expects its members to be producing 6% of its energy from biomass by 2010 and 20% by 2020.

The UK government estimates that 500,000 hectares could be devoted to growing oil seed crops and a similar area for wheat and root crops for bio-ethanol for transport. Rapid rotation crops can be used for direct combustion.

The anaerobic digestion of farm waste is becoming increasingly popular at the scale of the individual farm. Germany so far has 1500 such plants. It produces biogas useful for heating and providing electricity.

The accessible energy content of waste in the UK is about 10 PJ or 100 MW. The processing of municipal sewage and farm waste has the greatest long-term potential for producing biogas.

Wind energy

The UK has the best wind energy regime in Europe but despite this, we are well behind several other EU countries in utilising the resource, as Table 3 clearly shows.

Table 3 – Wind power capacity installed in EU-25 countries by end 2004

	Installed capacity in 2004 (megawatts or MW)
Germany	16,629
Spain	8,263
Denmark	3,117
Italy	1,125
Netherlands	1,078
UK	888
Others	3,105
EU-25	34,20

However, there is a catch-up programme under way, notably including offshore turbines. The two major offshore schemes presently operational in the UK are North Hoyle off the North Wales coast and Scroby Sands off the Norfolk coast. The main advantages of offshore machines are that they have much less of a visual impact and can be much larger than onshore generators. Large 5 MW turbines are being installed in the north of Scotland. The ultimate theoretical size of turbines is 12 MW.

In the second round of wind energy proposals there is a project now seeking consent for a 1000 MW wind farm off the coast of Kent comprising 270 turbines, which could supply a quarter of London's electricity. It should be operational by 2011. Other schemes on this scale are also planned.

However, wind power has limited potential because of its variability. It currently has an average load factor of 27%, that is, the actual power delivered to the grid as a percentage of the rated peak output.

Coal with storage of CO_2

In Table 2, I attributed 5.2 EJ to coal with underground storage of CO_2 in exhausted or nearly empty oil and gas deposits. Currently Norway is a leader in the development of technologies in this field.

China and India together are considering building as many as 800 coal-fired power stations over the coming decades. It is of critical importance, therefore, that Western nations collaborate in the development of the technology to strip and bury the carbon, otherwise the planet will be in very serious trouble indeed.

Conclusion

At the heart of the government's dilemma is its belief in the divine right of the market, brought down from the mountain by Margaret Thatcher. Her government's *coup de grace* was the abolition of the Department of Energy. Since then the Labour Party has been obedient to the principle that energy policy is not the business of government.

In a recent hard-hitting article in *The Observer*[2], former Energy Minister Brian Wilson was sharply critical of the government's myopic perception of the energy crisis that awaits the nation in the next decade, especially the growing reliance on electricity from imported gas. As Wilson puts it, "*It is fatuous to maintain that government does not have a substantial role to play in determining our energy strategy*". It is also fatuous to believe that wind energy alone can fill the gap left by the near demise of the nuclear capacity by 2020, bearing in mind its low load factor.

With the huge threat of climate change and the growing reliance on energy imports, there has never been a greater need for a rigorous energy policy to promote the full range of renewables. A good start would be a new Department of Energy led by a Secretary of State.

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This article is based on a presentation entitled 'A Convergence of Crises' given to the Cambridge Societies in October 2005 (Essex Branch) and April 2006 (Sheffield Branch).

Notes and references

1. Stainforth, D. et al. (2005). Uncertainty in predictions of the climate response to rising levels of greenhouse gases. Nature. Vol 433, pp. 403-406.
2. Wilson, B. (2005). Government must take up the reins of power. The Observer, Business Focus, p. 4, 2nd October.