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UK Energy Policy and the Environment

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Abstract

Climate change is recognized as a major threat to the human future, and it is generally agreed that it is being caused by the increased concentration of greenhouse gases in the atmosphere due to human agency. Carbon dioxide (CO_2) is of especial concern, much of it resulting from the combustion of fossil fuels as a source of energy. The UK Government, in partnership with other Governments in the European Union, has set targets for reducing our dependence on such fuels and a wider global agreement is being sought under the United Nations Framework Convention on Climate Change. The achievement of these targets demands both enhanced efficiency in energy use and the replacement of fossil fuels by nuclear power and 'renewables'. There will need to be a fundamental adjustment in our social attitude to energy use, and a recognition that decades of cheap power are over. At the same time rising costs must not exacerbate the problem of energy poverty. The technical and ethical challenges are substantial.

The Issues

Our ability to harness energy has been a key to human civilization. Fire helped early humans to hunt, allowed them to keep warm in climates they might not have tolerated otherwise, and allowed them to make foods palatable through cooking. Since then, the harnessing of energy to provide heat and electricity and drive engines has been the foundation of our industrial civilization.

But today we are concerned that human emissions of gases produced in the combustion process – especially carbon dioxide – are causing a change in the climate. This is probably the most serious environmental issue that humans face today. Global average surface temperatures have increased by about 0.8˚C over the past century, and the projections are for a further increase of between 1.5 and 3˚C by 2100. There are likely to be substantial changes in rainfall patterns, more frequent extreme weather events and a rise of from 30 to 70 centimetres in sea level. The consequences for global biodiversity, human settlements and agriculture could be profound. That is why Governments are seeking concerted action to limit the increase to 2˚C above the mean temperature of the pre-industrial period.

Climate change results from human augmentation of an important natural phenomenon. The Earth is habitable because trace gases in the atmosphere (water vapour, carbon dioxide, methane and nitrous oxide, together with industrial chemicals called chlorofluorocarbons) create a 'greenhouse effect', allowing radiation from the sun to reach the planet's surface but absorbing some of the longer-wavelength radiation that would otherwise pass back into space. But since the industrial revolution, and especially since around 1900, human societies have been burning 'fossil fuels' (coal, oil and natural gas) on an increasing scale, yielding essential energy but emitting carbon dioxide into the atmosphere. The carbon in these fossil fuels has been locked up in the rocks for millions of years and natural processes such as uptake by green plants and solution in the sea cannot keep pace with the surge in emissions resulting from human activity. That is why CO_2 concentrations have been rising and the natural greenhouse effect has intensified. .

The atmospheric concentration of CO_2 is easily measured, but international action needs to address the impact of the other natural greenhouses gases (notably methane (CH_4) and nitrous oxide (N_2O)), as well as remaining CFCs (which have been banned). Each greenhouse gas has different levels of absorption of the infra-red radiation emitted by the Earth's surface. In setting targets to limit global warming it is the composite measure called 'CO_2 equivalent' that is needed. But at the heart of the debate lies the need to curb the rise in CO_2 emissions, and since this largely results from the combustion of fossil fuels to produce energy, this has been the centre of attention. The central need is to find a way in which human societies can continue to supply themselves with essential energy without incurring the severe risks posed by climate change.

Energy

We use energy in three main ways – as electricity, as heat and as fuel for fixed and mobile engines, including road vehicles and aircraft. Heating of homes, offices and public buildings accounts for the largest single proportion of the UK's final energy demand at approximately 49%, and also the largest proportion of our carbon emissions at 47%. Using heat more efficiently and reducing the proportion produced from fossil fuels is therefore crucial for delivering any UK target, but the scope for a change in heat source is limited: currently only about 0.5% comes from 'renewables' such as fuelwood. One problem is that unlike electricity, heat cannot travel for long distances without significant losses and expense, so most deployment has to be local. Transport is also an important user of fossil fuels and while there is significant scope for gains in efficiency, there are currently few alternatives fuels and this is likely to remain the case for the next decade or so.

For these reasons much of the energy debate has centred on electricity and how we make it. Aside from the fact that power stations account for at least a quarter of our CO_2 emissions, one reason is that the electricity market is more accessible to being steered by the Government. Another is that there are technological solutions that can make a difference. These are discussed below.

Future energy policy

The UK Government has set four goals for the country's energy policy:

- to put ourselves on a path to cut the UK's CO_2 and other greenhouse gas emissions by at least 80% by 2050, with 'carbon budgets' set every 5 years [Climate Change Act 26 November 2008];
- to maintain the reliability of energy supplies;
- to promote competitive markets in the UK and beyond, and
- to ensure that every home is adequately and affordably heated.

The thrust of this paper is to examine how we can meet our irreducible needs for energy while emitting as little carbon dioxide as possible, and at the same time ensuring reliable supplies. It thus covers the first two of the four goals announced by the Government. However the fourth goal is extremely important from an ethical standpoint: there are some places, mostly deprived areas of large conurbations where many households suffer from 'energy poverty', spending 10% or more of their disposable income on heating and lighting.

The most effective way to reduce our national carbon dioxide emissions is to use less energy to achieve the same personal or social benefits. Technology can help, for example by increasing the energy efficiency of light bulbs, domestic appliances and central heating, the insulation of homes and buildings and the fuel economy of road vehicles and aircraft. Personal action can help by sharing transport, switching off appliances and reducing room heating. There are many other examples.

Incentives and regulations can help 'pull through' such developments. The Government has already begun to tighten up regulations for new-build construction, but there is scope for fiscal and financial incentives for even better insulation and for architectural design to minimize heat loss and obtain maximum solar gain. Regulations to require such measures, rather than encourage them, would be welcome, as well as financial help for the installation of solar (thermal and PV) panels and heat-pumps in domestic, public and commercial buildings.

Countering these savings, we are now using more electric and electronic devices, expecting higher standards of living, and assuming more mobility in travelling to work and for recreation and holidays. The overall result has been that our national energy demand has steadily risen over the years. The UK pattern is reflected elsewhere: no major economy has ever achieved significant cuts in energy usage without a corresponding fall in GDP. In the long term a whole change of attitude is required whereby we look for a level of contentment and lifestyle that reflects our need to reduce our impact on the planet, and not measure wealth in terms of GDP.

Achieving the Government targets may be helped by such adjustments and by greater efficiency, but it will clearly also demand major changes in energy supply, with an increasing share being taken by renewables. That now requires discussion.

Energy supply

At present the UK obtains 40% of its energy from natural gas, 33% from oil, 17% from coal, 8% from nuclear and 2% from renewables (wind, hydro, wave, tidal, biomass, solar). Although in recent decades the country was self-sufficient in gas and oil, and mined a good deal of coal, the position is now changing rapidly as the North Sea gas and oil fields are being exhausted. By the year 2020, estimates suggest the UK will need to import about 75% of its primary energy. Reliance on imports raises issues of energy security and the reliability of supply.

By 2030 only around 10% of our gas will come from the UK, and imports will provide 25% from Africa, 22% from Russia, 15% from the Middle East and 15% from Norway. Similarly by 2010 the UK will become a net importer of oil, mostly from the Middle East countries which currently have 75% of proven world resources. Although coal mining is a traditional UK industry, known exploitable reserves in the UK are only 155 million tonnes (at end of 2007), and at the current rate of consumption (if these were the sole source for the UK) these would only last 9 years. Globally the largest stocks are in the USA, Russia and China. We already rely heavily upon imports from South Africa, Poland, the USA and Australia. As for nuclear, whereas in the recent past this supplied over 20% of our electricity, most of our nuclear power stations are moving towards the end of their planned lifetimes and by 2023 only one of the present plants (Sizewell B, until 2035) is planned to be operative.

The contribution from Renewables

Renewable sources of energy are a vital part of this strategy. In 2007 the UK agreed with its EU partners to a binding target that 20% of EU energy consumption should come from renewable sources by 2020. Within that overall target the UK has agreed that renewables should move from providing 1.5% of our energy in 2006 to 15% by 2020. In September 2008 the Department for Business, Enterprise and Regulatory Reform (BERR), in its Renewable Energy Consultation, set a target of securing 30-35% of our electricity from renewables, not only to meet carbon emission reduction targets but to improve the security of energy supply and the reduction of imports. By 2050 the Government seeks to reduce national carbon emissions by 80%. These are extremely demanding targets, and are unlikely to be met unless wind energy developments are flanked by other renewable sources (among which tidal power has evident potential) and by a new generation of nuclear power stations. Even then, some residual use of fossil fuels is inevitable.

Renewable sources differ both in the kind of useful energy they produce (electricity, heat, transport fuels) and their degree of commercial development. Hydro-power, wind power, tidal power, wave power and photovoltaic solar systems produce electricity, as biomass sources can also do. Solar panels and biomass yield heat, and biomass (energy crops) contribute to transport fuel.

Hydro-power.

Hydro-electric power stations were constructed in a number of places in Scotland in the period after the second World War, and there is renewed interest in small-scale hydro-power on fast-flowing rivers. Existing hydro-power contributes about 2.8 GW of electricity. However, while the technology is well established, the scope for further large developments in the UK is limited, and there are real environmental objections to them, although small-scale installations are likely on a number of fast-flowing rivers in Cumbria and elsewhere.

Wind power

By far the greater part of the increase in electricity generation by renewables is likely come from wind power, at least in the short term. For off-shore wind, the Government target is 14 GW compared with the present 1 GW: this would equate to around 3,000 extra off-shore turbines each of 5 MW. Substantial developments are planned in the Solway and Morecambe Bay. The Government is moving towards favouring offshore rather than onshore wind farms, partly because of objections to the latter in areas of high scenic and tourist importance. None the less there is talk of an increase in on-shore turbines from the present 2 GW to 14 GW, involving about 4,000 new 3 MW turbines in addition to the 2,000 turbines already installed. Much of the on-shore development will probably be in Scotland, but some is likely on the West Cumbrian 'energy coast', in Furness, and the Solway Plain.

Tidal energy

The other significant practicable source of power is that of tidal barrages, of which by far the largest, in the Severn estuary, might meet nearly 5% of national electricity demand. Other barrages have been discussed and in Cumbria one across the Solway from Bowness to Annan in Scotland would generate around 180 MW, one on the Duddon estuary a comparable amount and a 'Bridge across the Bay' from near Morecambe to near Barrow might produce 200 MW from a combination of wind power and tidal stream systems, the latter driven by the movement of currents in the same way as wind turbines use the movement of air. Barrages closing off entire estuaries would have a major environmental impact: tidal pools, filled at high tide and releasing the impounded water at low tide, less so, but all need careful assessment.

Solar and wave power

Other renewable systems are at various stages of development. Solar (thermal) panels, using the sun's energy to heat domestic hot water, are being marketed but the pay-back period is long. Photovoltaic (PV) systems, converting solar energy to electricity, are theoretically very attractive because a house or office can be powered directly from tiles or panels on its own roof, selling surplus electricity to the grid while the latter is drawn on at night and on dull days. However PV is currently not financially competitive. Wave power, using the rocking motion of sea waves or the changes in pressure in a vertical cylinder as waves pass over, is still at the development stage and may be expensive to build and maintain.

Biomass

Biomass is any kind of biologically-produced organic matter, including the organic component of domestic, agricultural and industrial waste, wood, grass and fermentable organic matter.

Municipal wastes contain significant amounts of combustible matter and a number of towns burn this as both a means of disposal and an energy source. Wood wastes from industry and wood as a forestry by-product (thinnings and chippings) or wood chips from specially grown short-rotation willow coppice can be used to fuel small power stations, also suitable as the suppliers of heat to combined heat and power (CHP) schemes. Approximately 300 hectares of willow coppice are needed for the sustainable generation of 1 MW of electricity and costs make it desirable for the sources of supply to be both productive and near to the power station. At the other end of the scale, wood is one of the most universal, ancient and sustainable sources of domestic heat and domestic wood burning stoves are now popular and efficient, so that their use is likely to expand substantially.

Organic matter from crops like sugar beet, sugar cane or grain can also be fermented to produce ethanol and other alcohols for blending into vehicle fuels and oils (from oilseed rape or palm oil) and can be used in 'biodiesel'. The EU's draft Renewable Energy Directive includes a binding target for all member states to source 10% of their transport energy consumption (excluding aviation and shipping) from renewable sources by 2020. The UK Renewable Transport Fuel Obligation, introduced in April 2008, requires fuel suppliers to ensure that their road transport fuel contains 2.5% by volume of biofuels, rising to 5% in 2010. This is the main current form of renewable energy used in transport, but vehicles powered through the electricity grid using renewable and nuclear energy may become more prominent in future, as may vehicles driven by hydrogen produced using surplus power from nuclear stations. However there is concern over competition for arable land between food and energy crops. Biofuels should not be imported if this means the loss of locally-produced food in developing countries which already have an inadequate food supply. Within the UK it is questioned whether biofuel production as an energy source is an efficient means of reducing CO_2 emissions when the 'carbon cost' of mechanization, fertilizers, harvesting and the conversion of oilseed to fuel is considered.

Limitations

One drawback in many forms of renewable energy is that the power source is intermittent (wind, wave, solar) and needs some back-up from more traditional forms. Wind farms, for example, typically operate at full capacity for around 28% of the time, their output is unpredictable, and the back-up is normally from fossil fuel-powered stations. There is also increasing resistance to wind farms on land because of their visual intrusion and consequent impact on tourism, and this is a particular concern in Cumbria where so much of the land is designated as a National Park or Area of Outstanding Natural Beauty. Many proposals have been rejected on these grounds. Another problem arises because the locations where natural wind, wave or tidal energy is most available are remote and the national grid system will require substantial (and expensive) extension if these resources are to be tapped.

The fact is that while renewables are benign in terms of substitution for fossil fuels, they are not without environmental impact, and are not universally efficient or economically attractive. Several forms depend on subsidy to be commercially operable: for wind-generated electricity this subsidy is said to total £1 billion annually. Further development may alter this picture, but the current Government targets seem the maximum achievable with current technology.

Nuclear power

Nuclear power is attractive in current circumstances because it emits very little CO_2 (the emissions generated by the construction of a nuclear plant are commensurate with those for building 400 wind turbines generating the same amount of electricity at maximum capacity). It is particularly suited to meeting 'base load' electricity demand (that is, the constant demand throughout the whole 24 hours) since nuclear stations are most efficient when kept running steadily for long periods and can, indeed, achieve load factors of 90%.

However, Britain's nuclear power stations are nearing, or in some cases beyond, their projected lives. Newer pressurized water systems are safer and more efficient than those at present in use in the UK, and the Government recognizes the need for a programme to build a number of them. Construction takes about ten years from planning to operation, and the French company EDF proposes to build four new stations to come on stream by 2017; others would be needed in the immediate years that follow. In the longer term there will probably be a need to move to breeder reactors like (but more advanced than) the one projected at Dounreay that was abandoned by the Thatcher Government. In their use of uranium these are 60 times more efficient than our present thermal reactors. Russia has a BN600 breeder reactor which has been running successfully for over 20 years. Such reactors have the added advantage of being very suitable as the power source for desalinisation of sea water – likely to be of great future importance in arid developing countries with a great need for reliable supplies of clean water. Surplus capacity at nuclear stations could also be used to produce hydrogen from sea water, if this proved an attractive alternative transport fuel.

Future use of fossil fuels

Although the Government is seeking a drastic reduction in the use of fossil fuels, this reduction will be progressive. Petroleum is likely to remain the principal transport fuel for the foreseeable future and gas- or coal-fired power stations are likely to be required as part of our electricity generating capacity, not least as back-up to intermittent renewable sources. There will therefore be considerable interest in reducing carbon emissions from them.

<u>Coal</u> currently supplies about 32% of electricity generating capacity, but this is estimated to fall to around 15% by 2020. Coal is a 'dirty' fuel, generating much CO_2, SO_2 (sulphur dioxide) and particulates ('smoke'). Desulphurisation plant and filters can remove most of the SO_2 and particulates, but investment is needed in carbon capture and storage (CCS) technologies that may reduce emissions of CO_2 by up to 85%. So far (2008) no CCS plant has been put into commercial use, and the small-scale Norwegian prototype has not proved an effective way of reducing atmospheric CO_2.

Coal is favoured commercially because it provides for baseload and peak demands. Efficient boilers can reduce emissions by 20%, and co-firing coal and 20% biomass also reduces net emissions. The development of combined heat and power (CHP) improves efficiency, where what would be waste heat is fed into local domestic and commercial heating systems, but there are limited opportunities for this adjacent to large-scale power stations.

<u>Gas</u> has progressively replaced coal as a power station fuel since 1990 ('the dash to gas'). It is also well established as a fuel for space heating and cooking, and advances in technology continue to produce more efficient appliances. Commercially it was favoured as a fuel for power stations because up to 2006 it was the cheapest fuel for electricity generation, but global demand has considerably increased prices in a highly fluctuating market. Gas power stations are more adaptable than those for coal, being capable of being used not only for baseload but also easily switched into the system to meet peak demands. In future CCS will also be applicable, and because gas power stations can be smaller than coal, they are more adaptable for CHP. They are therefore likely to be preferred.

Energy costs

It is not easy to find definitive studies on the comparative costs of energy, not least because these vary according to location and access to resource. The following table gives representative figures for electricity generation, based on information from *Our Energy Challenge, DTI,* 2006. However, since they were published, there have been significant increases in the costs of natural gas and oil, the effect of which, on purely economic grounds, is to make wind and nuclear generation highly competitive with gas. All other renewable sources, other than micro-hydroelectric, can be assumed to be more expensive.

Generating source	Electricity cost (pence per kilowatt hour)
Gas	2.3
Onshore wind	2.9
Nuclear (including decommissioning)	3.0
Gas (with carbon capture)	3.6
Coal	3.75
Offshore wind	4.3
Coal (with carbon capture)	5.9

The immediate future

Some 20 GW or more of electricity generating capacity will be required to replace retiring coal and nuclear plant (about 30% of current electricity demand). Demand for electric power is currently increasing steadily, as it has been doing in the past, and although there is a strong case for greater efficiency in use there is no sign that this will be sufficient to level the demand growth curve off. By 2020 the falling contribution from nuclear and coal will create a potential gap in supply, even allowing for a significant growth in renewables, and this will need to be filled by natural gas which will come to provide at least 60% of total capacity. Because of the intermittent nature of many renewable sources, there also has to be extra back-up capacity, and this too is most likely to come from gas. About 80% of that gas will need to be imported. At the end of 2007, at current rates of production the UK's reserves were sufficient for only 5.7 years (the figure for the end of 1990 was 12.3 years).

The years to 2020

It is clear that the next eleven years could be crucial if a security of supply of energy is to be achieved. Part of the pattern of these years should be:

- a major effort to improve efficiency in energy use;
- a considerable extension of wind turbines, both on- and off- shore;
- possible construction of at least one major tidal barrage and expansion of tidal stream systems;
- a plan to build new nuclear plant, at least supplying 20% of UK electricity and maybe more;
- construction of no more than the minimal essential amount of new fossil-fuel burning plant – equipped with CCS as soon as proven large-scale technology to capture the CO_2 is available.

There are difficulties with all these proposals. There is considerable opposition to on-shore wind turbines because of their impact on landscape, property values and the tourism industry. The effective cost of generating electricity from wind turbines compared with other sources needs careful scrutiny. There is also still unease or open opposition to nuclear power, partly because recent advances in the safe storage of vitrified high-level wastes have not been publicized adequately. As to coal, some argue that no new plants should be built until CCS is a proven possibility. On the other hand, it has been pointed out one (new) nuclear plant together with one coal plant would produce less CO_2 than two gas-powered plants of the same capacity.

It is widely accepted that the changes in the energy future that are necessary if carbon emissions are to be reduced can only be achieved through continuing Government intervention. The Renewables Obligation guarantees a market for electricity from these sources and the Government believes this will cause electricity suppliers to generate about 14% of our electricity from them by 2015-20. New planning laws are intended to separate decisions on policy towards major types of development (such as power stations) from the evaluation of specific sites, so speeding up the overall process. Proposals for several alternative Severn Barrages have recently been published and a decision on whether or not to build one is likely during 2009. A large Severn Barrage would be a capitally intensive project with substantial environmental impact, but it could provide around 5% of the UK's electricity free from CO_2 emissions. However, we also need to stop thinking of electricity generation only in terms of massive power stations, and instead encourage a wide range of micro-generation: hydroelectric, solar thermal and photovoltaic, wind, heat pumps, tidal stream and wave. All these changes will alter the geographical pattern of electricity generation nationwide, and this means improving access to the national grid for newly built electricity generators, involving both upgrades of the onshore network, and the removal of constraints on grid access, especially for microgeneration by renewables.

Conclusion

The familiar adage 'there's no such thing as a free lunch' applies remorselessly in the energy sector. All modes of energy supply and use have some impact on our shared environment, and if we are to be responsible stewards of the Earth we need always to seek to use its resources as efficiently and sustainably as possible. But in today's world the need to reduce emissions of carbon dioxide, with its potentially disastrous climatic consequences, is seen by many people as paramount. That means a drastic reduction in the use of fossil fuel, especially in countries like the UK which can develop alternatives when many developing countries are more constrained by their relative poverty. It follows that difficult choices need to be made about the adoption of a new generation of nuclear power and the acceptance of renewables, some of which (like major estuarine barrages and large wind farms) would inevitably transform cherished landscapes. In the longer term technological advances that will allow more efficient use of solar energy would be attractive; it is commonly said that the sun sheds every hour more energy on Earth than humanity, even today, uses in a year. Using that abundant natural power cleanly and efficiently would seem an obvious goal. However, experience in California, with substantially more sunshine than in the UK, demonstrates how far we have to go to make this a reality.

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