Mirage and oasis

Energy choices in an age of global warming

The trouble with nuclear power and the potential of renewable energy

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lifestyles must become sustainable

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communities need power and influence

nef (the new economics foundation) is a registered charity founded in 1986 by the leaders of The Other Economic Summit (TOES), which forced issues such as international debt onto the agenda of the G7/G8 summit meetings. We have taken a lead in helping establish new coalitions and organisations, such as the Jubilee 2000 debt campaign; the Ethical Trading Initiative; the UK Social Investment Forum; and new ways to measure social and environmental well-being.

Nuclear power is being promoted as the answer to climate change and energy insecurity. But, as a response to global warming, it is too slow, too expensive and too limited. And in an age of terrorist threats, it is more of a security risk than a solution. Instead, the characteristics of a flexible, safe, secure and climate friendly energy supply system apply to renewable energy. In comparison, it leaves no toxic legacy and is abundant and cheap to harvest both in the UK and globally.

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Summary

Individually renewable energy sources like wind, solar and geothermal could, in theory, meet all of the world's energy needs. But the jump from theory to practice would face many obstacles. Practically, however, a broader combination of renewable energy sources, tapped into with a range of micro, small-, medium- and large-scale technologies, and applied flexibly, could more than meet all of our needs.

Better still, they have the ability to create new access to energy supplies for millions of people around the world who currently lack basics, such as lighting or the ability to cook without inhaling lethal indoor smoke.

There are three major reasons why a rapid uptake of renewable energy in the UK is vital:

1 Climate change means we need to drastically reduce our reliance on fossil fuels.

2 One of the greatest unacknowledged threats to the UK economy is the imminent peak of global oil production, which will send already-high oil prices, much higher, and create a severe economic shock of large but unpredictable proportions.

3 Britain's stock of nuclear power stations is aging and will progressively close over the coming two decades. Compared to most renewable sources, replacing them with new nuclear stations is prohibitively expensive (and the costs of nuclear have been potentially underestimated by nearly a factor of three according to this report); it suffers from the unsolved problem of nuclear waste; and represents an unacceptably high security risk in terms of the threat from terrorism.

The UK has an over-abundance of resources to meet the Government's target of cutting greenhouse gas emissions and increasing the uptake of renewable energy. Without even taking account of savings from effective measures for energy conservation and increased efficiency that reduce demand, wave power could provide around 15 per cent of UK electricity demand.[1] Tidal power could provide approximately 6.5 per cent.[2] The UK has 40 per cent of the total available wind energy resources in Europe – theoretically enough to meet the country's electricity needs eight times over.[3]

The Government set a target for the UK that 20 per cent of electricity needs by 2020 should be met by renewables, the great majority of which would come from wind power. But even given the current limiting structure of the national grid system and the nature of demand, a combination of offshore and onshore wind could provide up to 35 per cent of the UK's electricity.[4] Micro wind generators might provide a further 10–15 per cent of the electricity needed at household level, rising in prime locations up to 80 per cent.[5] Solar cells, though currently still expensive, are thought to be ultimately capable of providing 5–10 per cent of the UK's electricity needs, with solar thermal units providing around half of a UK household's annual hot water requirements.[6]

The potential of getting energy from a decentralised system of very small-scale, microgeneration from renewable sources has been overlooked. But, apart from its low cost and climate friendliness, it has other particular advantages:

- Reducing the total supply capacity needed within networks, and reducing the need for peak provision in electricity networks, which is one of the biggest planning headaches for utility managers.
- A better guarantee against blackouts through the reduction of power system losses; and the ability to adjust supply to match demand.
- Much less power lost during transmission and major energy efficiency gains.
- Automatic provision of diversity in terms of power and location, which therefore reduces the vulnerability of the system and increases the security of supply.
- Speed of installation – units can be installed far more quickly than a central station or transmission and distribution line; and modular systems mean great potential for scaling up.
- Lower financial risk than large stations or transmission and distribution lines.
- Better inoculation against price fluctuations in fossil fuels through the renewables-based mix.
- Good proximity to place of use – units can be installed where the power is actually needed.[7]
- Micropower provides local choice and control, the option of relying on local fuels and spurring community economic development. [8]

In the current debate some argue that nuclear power could happily co-exist with renewables. But there are limited resources available and there is a real danger that nuclear will continue to 'crowd out', cleaner, renewable alternatives. The Government's own Performance and Innovation Unit's energy review commented that, "A sustained programme of investment in currently proposed nuclear power plants could adversely affect the development of smaller scale technologies."[9]

If just around one third of the UK's electricity customers installed 2kW microgen PV or wind systems it would match the capacity of the UK nuclear programme.[10] But in order to realise the full benefits of renewable energy and microgeneration a number of key steps must be taken:

- A fundamental shift of public support away from fossil fuels and nuclear power, to renewables and microgeneration – to remove anti-renewable distortions and enable them to play 'catch up'. It should apply both to the rollout of renewables and to research and development (R&D). In 2004 the House of Lords 'deplored' the *"minimal amounts that the Government have committed to renewable energy related R&D (£12.2 million in 2002–03)*. By comparison, as long ago as 1989–90, the DTI (Department of Trade and Industry, previously Department of Energy) alone funded nuclear research to the tune of £164 million in 1989/90. It was still £17 million in 2000/01.[11]

- Current total funding for renewables should at least match that which was made available to the nuclear industry during its period of peak research and construction.
- Selection of energy options based upon a comprehensive assessment of benefits, that takes account of economic and non-economic factors (see conclusion).
- Local authorities to set targets for the uptake of certain microgenerators and to allow them as 'permitted developments' on a par in the planning process with, for example, satellite dishes.
- A full range of fiscal incentives including, for example, stamp duty concessions for buildings with renewables and tax allowances on renewables investments.
- An obligation for all electricity suppliers to purchase electricity from microgenerators.

A note on method

Any research on energy issues encounters an information problem. Much data lacks clear comparability or is not available at all. Commercial confidentiality and government secrecy due to the historical sensitivity of certain sectors, such as the nuclear industry, are also common problems. To minimise such difficulties we have based our calculations of the underestimation of the costs of nuclear power mostly on publicly available government statistics, even where these figures too may be imperfect. The literature on renewable energy sources makes it clear that, in terms of meeting human needs for energy, there is no theoretical limit on what they can provide. Different scenarios for the uptake of renewable energy are quoted throughout the report. But it should be noted that the only real limit to their potential would appear to be our imagination and the political will to mobilise resources.

Overview

"The sources of renewable energy, such as the sun, wind and tides, are inexhaustible, indigenous and abundant, and their exploitation, properly managed, has the potential to enhance the long-term security of the United Kingdom's energy supplies and to help us cut carbon dioxide emissions."

House of Lords, Science and Technology Committee 2004[12]

nef's 2004 report, *The Price of Power*, published to coincide with the Ashden Awards for Sustainable Energy, highlights that there is potentially more than enough renewable energy available globally to meet all human needs.[13] It also focuses on the enormous contribution that small-scale renewable technologies can make towards poverty reduction. This report covers different ground, but it is worth remembering why this is the case.

In a paper written for the United Nations 2003 conference on renewable energy José Goldemberg, explains how, "The enhanced use of renewables is closely linked to poverty reduction, since energy services can: a) improve access to pumped drinking water, clean water and cooked food, b) reduce the time spent by women and children on basic survival activities (such as gathering firewood, fetching water, and cooking) and, c) provide lighting that permits home study, increases security and… reduces deforestation."[14]

The theoretical potential for solar, wind, geothermal, hydro, biomass, and energy from the oceans is around 2.3 million times greater than current human use. Obviously nothing like this potential can actually be achieved, but even the much more limited potential to tap into these sources from known technologies could still increase our use by a factor of 120.[15]

Yet in Britain, with existing nuclear power stations gradually being phased out, there is concern that renewable energy can neither replace redundant nuclear reactors, nor meet Britain's obligations to reduce its greenhouse gas emissions.

This report looks at the relative costs and benefits of nuclear power compared to renewable energy sources, with an emphasis on the potential contribution of microgeneration from renewables.

It excludes the enormous contribution that energy efficiency, conservation and demand management could make in building a secure and sustainable energy supply, because these issues are covered in great detail elsewhere and they alone could well abate any need for new nuclear capacity. As the Energy Savings Trust said in 2002, "With reasonable advances in energy efficiency and renewables, it is clear that a carbon reduction of 30 per cent or more can be achieved even with the expected rate of closure (of nuclear power stations)."[16]

The role of micro-renewables has, though, been under-examined.

The conclusion this report reaches is that, against every meaningful criteria, whether to do with cost, security, or environmental friendliness; with flexibility; or with the potential for guaranteed long-term supply and job creation, the appropriate renewable energy source wins every time.




Britain is committed to reduce its greenhouse gas emissions by 60 per cent by the year 2050. Without either extending the lifespan of existing nuclear generators, or building new ones, nuclear's share of energy supply is set to fall considerably by the 2020s.

The ability of renewable sources to lower greenhouse gas emissions and contribute to a secure energy supply has been downplayed, even though many are abundant in Britain. Sources like wind power are belittled as being 'intermittent', requiring additional capacity to compensate when weather conditions 'switch them off'. But, even in this case, research from the Oxford Environmental Change Institute says that an optimal mix of intermittent renewables, whose performance varies according to time of day and season, together with domestic combined heat and power (dCHP) could provide most of Britain's electricity and obviate the need for nuclear power.

Combining the different strengths of offshore and onshore wind, wave, tidal, and solar energies in a decentralised system creates a reliable and secure supply. It means that there is new hope that renewables can match 'real time electricity demand patterns', making them a genuine alternative to conventional fuels and superior to nuclear power whose unchanging output cannot respond to fluctuation of demand.

Recent research by the Government's Sustainable Development Commission is particularly positive about the contribution that wind power can make. Their report, *Wind Power in the UK,* asserts that the UK has more than enough potential wind power to meet current renewable energy targets, and that, "technological advances mean there are no limits to the amount of wind capacity that can be added to an electricity system", and that in a huge leap forward compared to other electricity sources there is, "no need for dedicated 'backup'".[17] They point out that as fossil fuel prices go up and wind turbines become cheaper to build, "Wind power may even become one of the cheapest forms of electricity generation over the next 15 years."

But wind is only one renewable energy supply that Britain can tap into on a large scale:

- Wave power could provide around 15 per cent of UK electricity demand.[18]
- Tidal power could provide approximately 6.5 per cent.[19]
- The UK has 40 per cent of the total available wind energy resources in Europe –theoretically enough to meet the country's electricity needs eight times over.[20] Excluding sensitive and difficult ocean terrain, a study by the former Central

Electricity Generating Board (CEGB) concluded that the energy potential from offshore wind was roughly equal to total UK electricity supply at the time the study was carried out, further underlining for how long the potential of wind power in the UK has been neglected.[21]

- Practically, however, the Government has set a target for the UK that 20 per cent of electricity needs by 2020 should be met by renewables, the great majority of which would come from wind power. Structural limitations of the national grid system suggest that a combination of offshore and onshore wind could realistically provide a maximum of 35 per cent of the UK's electricity.[22]

- However, claims from entrepreneurs bringing micro-wind generators to the domestic market suggest that wind could further provide 10–15 per cent of the electricity needed at household level, rising in prime locations up to 80 per cent.[23] And, major energy suppliers are set to provide low-cost rooftop wind turbines capable of powering TVs, fridges, lights and computers.[24]

- In theory, power generated from solar photovoltaics (PV) could provide thousands of times more energy than the world currently uses. According to the Solar Trade Association, the solar radiation received by the UK each year is equal to the output of 1000 power stations.[25] But PV is the most expensive of renewable sources, though in the medium to long term its costs are likely to fall substantially. Solar cells are thought to be ultimately capable of providing 5–10 per cent of the UK's electricity needs, with solar thermal units providing around half of a household's annual hot water requirements in the UK.[26]

There are three major reasons why a rapid uptake of renewable energy is vital:

1. Climate change means we need to drastically reduce our reliance on fossil fuels.

2. One of the greatest unacknowledged threats to the UK economy is the imminent peak of global oil production, which will send already-high oil prices, much higher, and create a severe economic shock of high, unpredictable proportions.

3. Britain's stock of nuclear power stations is aging and will progressively close over the coming two decades. Compared to most renewable sources, replacing them with new nuclear stations is prohibitively expensive, suffers from the unsolved problem of nuclear waste, and represents an unacceptably high security risk in terms of the threat from terrorism.

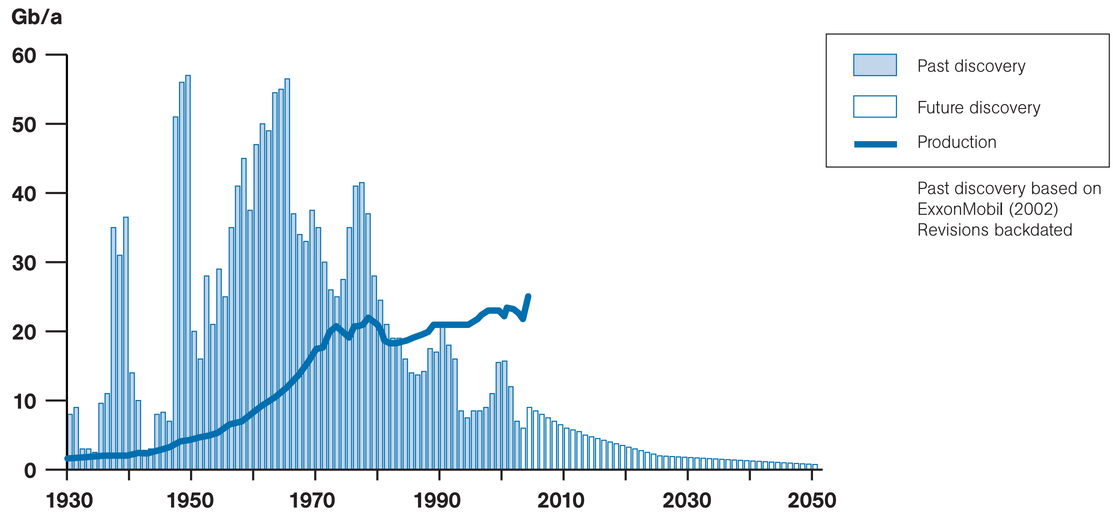
The structure of this report

The climate challenge is set out briefly and clearly below, as the subject itself is examined extensively elsewhere in the literature of, for example, the Intergovernmental Panel on Climate Change (IPCC). The problem of peak oil is then described at slightly greater length, while the majority of the report addresses the potential of renewable energy in general and of microgeneration in particular. It goes on to examine the issues concerning nuclear power, comparing its costs and potential with renewables, and calling for a more coherent and comprehensive assessment of energy options for the UK based on the full and real costs of the different sources and technologies.

The climate challenge

Under the Kyoto Protocol, the UK is committed to reducing greenhouse gas emissions by 12.5 per cent by 2010, compared with 1990 levels. Acting independently, the Government also committed the UK to achieving a 20 per cent reduction in CO_2 emissions by 2010, and a further 60 per cent cut by 2050. Much of the rest of this report reinforces the conclusion of the 2004 report by the Science and Technology Committee of the House of Lords which says, "The exploitation of renewable energy sources – abundant and inexhaustible – will assist in controlling emissions, and will in turn assist the United Kingdom to meet its environmental commitments."[27]

Figure 1: Rising demand-driven oil production departs from new discoveries of oil



As production goes up, driven by rising demand, a growing gap emerges between production and new discovery. Recurring price shocks, recessions dampening demand and price is increasingly likely, with "terminal decline setting in and becoming self-evident by about 2010", according to analyst Colin Campbell. Source: Colin Campbell, Association for the Study of Peak Oil, 2005.[28]

The climate challenge, though, is now well understood. Stories feature in the national media about global warming on an almost-daily basis. Far less appreciated, however, is the threat posed by the pending moment of 'peak oil' production.

The future for oil

> *"Can I tell you the truth? I mean this isn't like TV news, is it? Here's what I think the truth is: We are all addicts of fossil fuels in a state of denial, about to face cold turkey. And like so many addicts about to face cold turkey, our leaders are now committing violent crimes to get what little is left of what we're hooked on."*
>
> Kurt Vonnegut, author *In These Times*, 10th May 2004

In April 2005, energy analyst and chairman of a Wall Street energy investment company, Matthew Simmons, also an adviser to President George Bush, said that the Middle East has much less oil than its government officials claim. He warned that oil prices could hit $100 a barrel within three years. As a result there would be a domino effect of economic collapse.[29] Britain's economy would inevitably be one of those dominos. The reason: the approach of 'peak oil'.

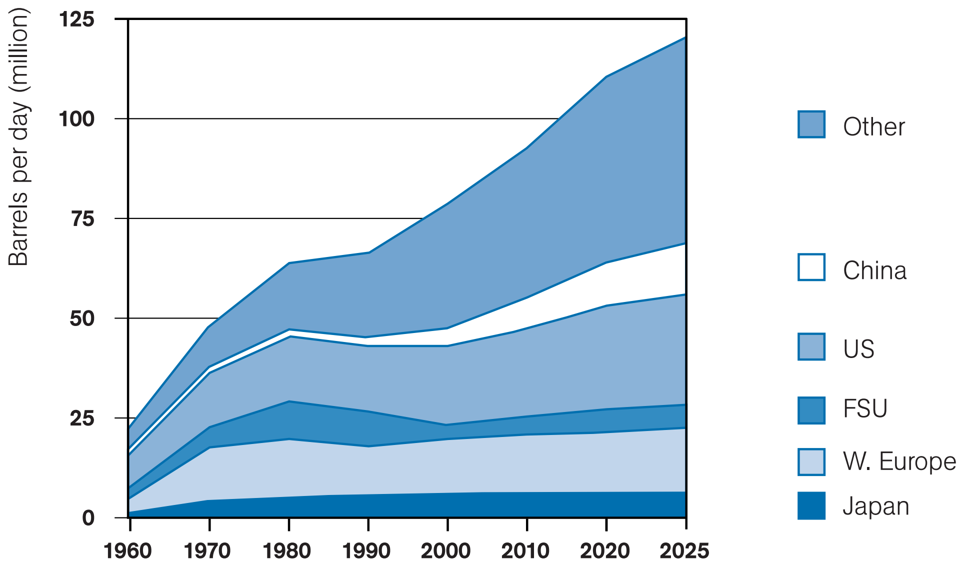
Peak oil – a threshold that some believe we have already crossed – is described by a report for the US Department of Energy in February 2005 like this:

> *"Peaking is a reservoir's maximum oil production rate, which typically occurs after roughly half of the recoverable oil in a reservoir has been produced. In many ways, what is likely to happen on a world scale is similar to what happens to individual reservoirs, because world production is the sum total of production from many different reservoirs."*[30]

Such a practical description belies the almost unimaginably large impact of such an event, as the same report goes on to explain:

> *"The peaking of world oil production presents the US and the world with an unprecedented risk management problem. As peaking is approached, liquid fuel prices and price volatility will increase dramatically, and, without timely mitigation, the economic, social, and political costs will be unprecedented.*

Figure 2: World petroleum consumption from 1960 and projected to 2025



Source: Robert L. Hirsch, SAIC, Roger Bezdek, MISI, Robert Wendling, MISI (2005) Peaking of world oil production: impacts, mitigation, & risk management, US Department of Energy, National Energy Technology Laboratory

> *Viable mitigation options exist on both the supply and demand sides, but to have substantial impact, they must be initiated more than a decade in advance of peaking."*

A range of estimates puts it between 2003 and 2020. Colin Campbell, one of the most experienced oil industry analysts, a former vice-president of Fina and chief geologist of Amoco, puts the point in 2006 but adds that, "The real issue is not the actual date of peak production but what happens during the decline of production. I think we are in for an extended period of restricted economic activity. I do not think that we will adjust very smoothly."[31]

In a 2004 report, *Strategic Significance of America's Oil Shale Resource,* the otherwise obscure Office of Naval Petroleum and Oil Shale Reserves connected to the US Department of Energy put some startling facts on record for the government of the world's largest energy user. It points out that no major new oil field discoveries have been made in decades and that, "World oil reserves are being depleted three times as fast as they are being discovered." As existing fields are used up, reserves are not being replaced. The oil company Shell's embarrassment over exaggerating its oil reserves merely underlined the fact that, in light of this trend, "Oil reserves of individual oil companies must therefore continue to shrink." The report also points out that, "The world may be facing shortfalls much sooner than expected", as none of the predictions of oil peak are beyond 2020. The fact that "a practical supply limit will be reached and future supply to meet conventional oil demand will not be available" is set to hasten the onset of inevitable competition among consumers (and nations) for ever-scarcer oil resources.[32]

The method of predicting oil peak was devised in the 1950s by M King Hubbert, a Shell geologist, who correctly predicted that the point of peak US domestic oil production would be about 40 years after discoveries peaked around 1930. In Britain, North Sea oil discoveries peaked in 1973 and production peaked in 1999.

According to Chris Skrebowski, editor of *Petroleum Review*, "Governments are always excessively optimistic. The problem is that the peak, which I think is 2008, is tomorrow in planning terms."[33]

UK energy facts

1 An average UK household consumes between 3,000 and 7,500 kWh of electricity per year.[34]

2 Energy in UK represents 3.3 per cent of GDP.

3 There are 164,000 people directly employed in the energy industry, representing 5 per cent of industrial employment), and many more are employed indirectly.[35]

4 Energy used broken down by sector in the UK (2003) looked like this:[36]

- The transport sector – 33 per cent
- The domestic sector – 28 per cent
- The industrial sector: – 20.5 per cent
- The commercial sector – 6 per cent
- Non-energy use – 7.5 per cent

5 The main fuels used by final consumers in 2003:

- Petroleum products – 46.5 per cent
- Natural gas – 34 per cent
- Electricity – 17 per cent[37]

6 Of UK electricity supply in 2003 99.5 per cent was home produced and 0.5 per cent was from imports net of exports;. 0.75 per cent of home-produced electricity was exported.[38]

7 Fuel used to generate electricity in the UK (output):

- Gas – 38 per cent
- Coal – 35 per cent
- Nuclear – 22 per cent
- Other fuels – 3 per cent
- Oil – 1 per cent
- Hydro – 1 per cent
- Imports – 1 per cent[39]

8 Total electricity generation from renewables in 2003 amounted to 10,649GWh. All renewable sources provided 2.67 per cent of the electricity generated in the UK.[40]

9 Of the renewable energy produced in 2003, 79 per cent was turned into electricity. Biofuels dominate in terms of input, but hydropower, which loses less power in conversion, dominates in terms of output.

10 Between 2002 and 2003 there was an increase of 11 per cent of renewable sources in electricity generation. Compared with 5 years earlier, there has been an 80 per cent increase helped by 139 per cent growth in the use of biofuels and a 47 per cent increase in the use of wind.

Others believe the future is even starker. According to Jeremy Leggett, a solar energy pioneer and author of *Carbon Wars*, “It is possible to replace oil, gas and coal completely, however the shortfall between current expectation of oil supply and the actual availability will be such that neither gas, nor renewables, nor liquids from gas and coal, nor nuclear, nor any combination thereof, will be able to plug the gap in time to head off economic trauma.”[41]

The world’s known oil reserves will be exhausted in between 32 and 37 years if the recent upward trend in production continues (see Table 1). The difference depends on which estimate for is used for reserves – 1,050 billion barrels or 1,150 barrels at the end of 2003 – and whether one considers the trend since 1970, or more recently over the last 20 years. Also according to BP, the world has only another 60 years of natural gas.

The need to diversify supply in a manner that does not increase the vulnerability of our energy system to, for example, terrorist attack, is further underlined by the low level of energy reserves held in the UK. The shift to gas means a less polluting fossil fuel, but it also increases dependence on foreign supplies. In a 2004 report, the House of Lords points out that, “The United Kingdom currently has gas storage facilities equivalent to only 14 days’ supply, compared with an EU 15 average of 52 days” and urges “the Government to address this issue urgently”.[43]

Table 1: Year of oil exhaustion

	Stocks 1,050 bn b	*Stocks 1,150 bn b*
1970–2003 trend	2040	2042
1984–2003 trend	2037	2039

Sources: BP Statistical Review of World Energy, International Petroleum Monthly, World Oil[42]

Renewable energy technologies: an overview

"At the heart of the White Paper is the Government's target that 10 per cent of the United Kingdom's electricity should be generated from renewable sources by 2010. Beyond 2010, the Government have set an 'aspiration' of 20 percent by 2020… a dramatic change in the rate of introduction of renewable generating capacity will be required if the Government are to come anywhere near their target for 2010."

House of Lords, Science and Technology Committee 2004

In 2003, renewable energy sources accounted for over three million tonnes of oil equivalent (Mtoe) out of the UK's total energy use of 158 Mtoe. Most of this was in the form of electricity: heating and transport still depend almost entirely on fossil fuels.[44] The scope for growth in the UK is enormous as renewable energy contributed 3 per cent of the UK's total electricity supply in 2003, compared to EU averages of 5.8 per cent and 15.5 per cent respectively for 2001.[45] Electricity generation from renewable energy (outside large hydropower) and waste was 5.5 TWh in 1996 rising to 12 TWh in 2001.[46]

Some attempts to cost reaching the UK target of 20 per cent of electricity from renewables by 2020 have been criticised for failing to appreciate the potential of new contributions to supply, such as offshore wind, and for assuming a high cost of insuring against the intermittency of renewable supply systems. On the latter point, a better, more decentralised supply system could, however, radically reduce the need for such measures.[47]

According to the renewables industry, it employs 8,000 people in the UK and is set to increase dramatically, with estimates that 25,000 jobs will be created in the power sector alone by 2020.[48] In the US, where official attitudes to climate change are more dismissive, the number of jobs in renewables is nevertheless projected to grow to 1.3 million by 2020, with the PV roadmap projecting 150,000 in PV alone. In Europe, one million PV jobs have been projected by 2010, and two million jobs by 2020.[49] Figures from the European Commission are more conservative, but still predict that 900,000 new jobs will be created in renewable energy systems by 2020.[50]

PV

Power from solar cells, known as Photovoltaics (PV) is among the most expensive of the renewable energy options. It involves the direct conversion of solar radiation into electricity via a semiconductor device or cell.[51] In spite of high costs, uptake of PV is growing. There was a 70 per cent increase in PV capacity in the UK in 2002 compared to 2001. The cumulative installed PV generation capacity increased by over 50 per cent during 2002, reaching a total of 4.14MW, rising again to 6.0MW in 2003. Much of this increase is due to the rapid expansion of the grid-connected market and targeted support from government.[52] A Photovoltaic Demonstration Programme offering grants for small-, medium- and large-scale installations, was encouraging new projects.[53] Disappointingly, the Government has now reportedly withdrawn support for the programme.[54]

The carbon efficiency with which PV systems generate electricity could increase by a factor of six.[55] Similarly, unit costs are set to fall by up to a factor of seven by 2020.[56] PV systems have dropped in price to between one-third and one-fifth of their cost in 1980.[57] Globally the market is growing at 40 per cent per year in terms of installed capacity installed.[58] The worldwide market is similarly driven by improvements in materials and technology, but mainly by programmes to introduce the technology to markets and as a result of government incentives.[59] The Government aims to have 6,000 roofs in the UK fitted with solar panels by this year, compared with a target in Germany to have 140,000 and Japan nearly 400,000.[60]

Active solar heating

Active solar heating employs solar collectors to heat water mainly for domestic hot water systems but also for swimming pools and other applications.[61]

In the UK in 2003 an estimated 63.4GWh of active solar heating for domestic hot-water generation replaced gas heating; and in the less obvious case of swimming pools, an estimated 102GWh of generation replaced a mixture of gas, oil and electricity.[62]

Small-scale hydro

Generators of up to 10MW can utilise ‘run of river’ and do not require massive dams or create the ecological threats synonymous with large hydro projects.[63] Schemes belonging to companies with a capacity below 5MWe are classified as small-scale and typically are used for either domestic and farm purposes, or for local sale to electricity supply companies.[64]

The estimated UK accessible resource for new small-scale hydropower is 3.9TWh/yr.[65] Generation from small-scale plants in the UK in 1997 was estimated at 159GWh rising in 2001 to 210GWh.[66] The Nepalese Government has identified sites capable of generating 80,000MWe (roughly equal to the present peak load of India).[67] Small hydropower can be very cheap, with costs as low as $0.03 per kWh. Typically, after 15 to 20 years, when high up-front capital costs are written off, plants can achieve even lower costs, because systems commonly last for 50 years or more without major maintenance or operating costs.[68]

According to the International Energy Agency by 2003, only five per cent of global hydropower potential had been exploited through small-scale sites. South America has exploited only seven per cent of its potential, while in the Pacific and in Africa, less than five per cent of the potential has been developed.[69]

Wind

Allan Moore spent 30 years building and installing nuclear, coal, gas and other power stations before moving to wind. Now he is chair of the British Wind Energy Association and head of renewables at National Wind Power. He is planning to invest nearly £1 billion in wind power over the next 10 years. According to him, the problem about the current debate over wind is a lack of sense of proportion, "In the 17th century we had 90,000 windmills in Britain. They were a part of life. What we're looking to do is install perhaps 4,000, making 5,000 in total. Roughly half will be onshore and half offshore. If 4,000 turbines sounds a lot, compare Germany, where last year alone they installed more than 2,500MW of capacity and now have 7,000 turbines."[70]

New research from Stanford University has shown that low-cost wind energy is more widely available than previously thought, and can generate more than enough power to satisfy the world's energy demand.[71] Researchers found appropriate locations in all areas of the world, together capable of producing 72TW. A single TW is roughly equal to the power generated by over 500 nuclear reactors. The researchers comment that, "capturing even a fraction of those 72 terawatts could provide the 1.6 to 1.8TW that made up the world's electricity usage in 2000."[72]

Global installed capacity from wind was some 17GWe in 2000, more than three-quarters of it in OECD countries.[73] It then rose dramatically to 24GWe in 2001[74] and has leapt again by the end of 2004 to 47GWe.[75]

The average global costs for wind-powered generators are between $0.04 and $0.07 per kWh on land and $0.07 to $0.12 per kWh offshore. At the best onshore locations, wind power costs less than $0.03 per kWh.[76] The cost of wind-generated electricity has fallen dramatically in the United States over the last 15 years – from $0.35 per kWh in the mid-1980s to $0.04 per kWh in 2001.[77]

According to the Department of Trade and Industry (DTI), in the five years up to 2002, onshore UK wind capacity grew by a factor of 1.66, while electricity

Fferm Wynt Moel Moelogan (Moel Moelgan Wind Farm), Wales

The struggles of hill farmers are well known, but the solutions are often hard to come by. Faced with decreasing incomes, rising suicide rates, the impact of the foot and mouth disease, as well as long-lasting restrictions of the Chernobyl nuclear disaster, three hill farming families in Wales realised that their livelihoods and life styles were no longer viable options either for them or for future generations. They decided to come together as a co-operative to try and find ways of diversifying their income.

They found the solution literally blowing in the wind. Despite all the hardship they faced, they realised that as hill farmers they owned some of the best and most productive wind-power sites in Europe and all they needed to do was to make use of this potential. It was not an easy road to go down, though, and the learning curve was steep. With no background in the wind industry, they set out to develop, finance and build a wind farm that would not only provide income for them, but would also pay back to the local community.

After a five-year struggle learning the ropes and raising the necessary finance, the first wind farm was finally erected in September 2002. This was not only a success for the project, it also demonstrated the support it had gained in the local community. On the day, around 200 people were expected to come, but instead 1,500 people showed up to support and congratulate the project, turning it into a huge celebration with a party-like atmosphere. One participant called it a "Glastonbury without the music".

To date, the project has not only received the Ashden Award, but has also gained support from many local and national organisations. It is also a great inspiration for others in a similar situation. In close consultation with the local community, the project has now got permission for another nine wind farms to be built under the project name Ail Wynt, meaning 'second wind'. This time even further community involvement is built into the process and bonds are available to the local community, with a forecasted annual return of eight per cent, as well as an added bonus in 'windy' years.[78]

generated from wind grew by a factor of 1.88 over the same period. The difference is attributed to technological improvement and the better siting of wind farms.[79]

It is estimated that the growth of the offshore wind power industry has the potential to bring up to 76,000 new jobs to the UK.[80] Because of the higher costs of installing turbines offshore it is expected that those machines will be larger than onshore versions, at around 2MW and above.[81] The UK's offshore wind resource is vast, capable of providing more than the UK's current demand for electricity.[82]

Geothermal

Global installed geothermal electric capacity has been growing steadily, from some 3.9GWe estimated in 1980 to almost 8GWe in 2000. Energy efficiency is 97 per cent for geothermal CHP, but only 7–10 per cent for electricity production. However, because it operates 24 hours a day, it can provide important base-load capacity.[83]

The costs of geothermal-based electricity generation are very site specific – its cost reduction potential is hard to address on a general level. But it is expected that geothermal electricity could play a significant role in the future energy balance of Asia and of Central and South America. The share of geothermal power in total installed capacity is already over 10 per cent in the Philippines, El Salvador and Nicaragua.

Aquifers containing hot water can be found in some parts of the UK, at between 1,500 and 3,000 metres below the surface. This water can be pumped to the surface and used, for example, in community heating schemes and there is currently one such scheme operation in the UK.[84]

Biomass

It has been estimated that the energy capacity installed in the UK to tap into biomass could rise from 200MW as of 2002 to 4000MW by 2020.[85] Globally, biomass-to-electricity capacity was around 35GWe in 1999. Most of the capacity is in OECD countries, but some 3GWe is in South and Central America, in particular Brazil, which had 2GWe.[86] Biomass power plants are currently limited in size to between 30MW and 100MW, depending on fuel sources and geographical context, although they can be made much smaller.[87] Although, presently the number of plants in the UK is limited, the Government is committed to the development of a bio-energy industry and support is available to developers through a range of programmes.[88]

Landfill gas

Installed capacity from landfill gas is estimated to be set to more than double from 400MW in 2002, to 1,000MW by 2010.[89]

Wave and tidal

Britain has huge potential for wave and tidal power, and one scenario from the Performance and Innovation Unit looks at a rise to 50MW of installed capacity by 2010 rising to 1,000MW by 2020.[90] Commercial markets are undeveloped in the UK, but in May 2005 it was announced that the world's first commercial wave power station is to be built in Portugal by a Scottish company, in an agreement to build three machines generating 2.5MW to be followed by a further 30 by the end of 2006.[91] The Carbon Trust estimates that the potential world market for wave and tidal power alone will be worth about $225 billion, between now and 2050.[92]

Microrenewable energy: flexible, secure, clean and effective

"The choice is clear: if a minority of powerful nations continues to favour an economic system underpinned by centralised technologies and vulnerable supply lines, they will need to protect it at enormous expense and risk to our civil liberties. On the other hand, if we shift to a decentralised world economy based on equitable and efficient use of renewable energy sources, and re-localised supply systems, we will have communities that cannot be easily threatened and, most importantly, which threaten no one else."

Paul Allen, Development Director, Centre for Alternative Technology[93]

Thomas Edison had small-scale, localised power in mind when he built the world's first power plant, Pearl Street Station, in New York in 1882. He had a vision of a decentralised energy industry with dozens of companies generating and delivering power close to where it was to be used, and even putting systems in factories and people's homes. In 1907, 59 per cent of American electricity came from small-scale generation.[94]

Today, there is no single definition of what constitutes microgeneration. Under the Energy Act 2004, the Government broadly defines microgeneration as generating capacity below 50kW for electricity or 45kW thermal,[95] based upon either biomass, biofuels, fuel cells, photovoltaics, water (including waves and tides), wind, solar power, geothermal sources, or a combined heat and power system.[96]

The London Mayor's *Energy Strategy*, published in February 2004, aims for 7,000 domestic solar panels and small wind turbines to be installed within London by 2010.[97] The terms of the Energy Act compel the Secretary of State to prepare a strategy to promote microgeneration, and commit to taking into account the contribution that microgeneration can make to:

- "Cutting emissions of greenhouse gases in Great Britain.
- Reducing the number of people living in fuel poverty in Great Britain.
- Reducing the demands on transmission systems and distribution systems situate in Great Britain.
- Reducing the need for those systems to be modified.
- Enhancing the availability of electricity and heat for consumers in Great Britain."[98]

'Decentralised energy' is the system of energy delivery for which microgeneration is best suited, and is defined as electricity production near the point of use. This, however, is irrespective of size or technology. Typical decentralised renewable energy technologies include PV systems, small hydro, on-site wind power and localised geothermal production.[99]

The Energy Act 2004: Microgeneration

(1) The Secretary of State…

(a) must prepare a strategy for the promotion of microgeneration in Great Britain; and

(b) may from time to time revise it.

(2) The Secretary of State…

(a) must publish the strategy within 18 months after the commencement of this section; and

(b) if he revises it, must publish the revised strategy.

(3) In preparing or revising the strategy, the Secretary of State must consider the contribution that is capable of being made by microgeneration to:

(a) cutting emissions of greenhouse gases in Great Britain;

(b) reducing the number of people living in fuel poverty in Great Britain;

(c) reducing the demands on transmission systems and distribution systems situated in Great Britain;

(d) reducing the need for those systems to be modified; and

(e) enhancing the availability of electricity and heat for consumers in Great Britain.

(4) Before preparing or revising the strategy, the Secretary of State must consult such persons appearing to him to represent the producers and suppliers of plant used for microgeneration, and such other persons, as he considers appropriate.

(5) The Secretary of State must take reasonable steps to secure the implementation of the strategy in the form in which it has most recently been published.

(6) For the purposes of this section "microgeneration" means the use for the generation of electricity or the production of heat of any plant…

(a) which in generating electricity or (as the case may be) producing heat, relies wholly or mainly on a source of energy or a technology mentioned in subsection (7); and

(b) the capacity of which to generate electricity or (as the case may be) to produce heat does not exceed the capacity mentioned in subsection (8).

(7) Those sources of energy and technologies are:

(a) biomass

(b) biofuels

(c) fuel cells

(d) photovoltaics

(e) water (including waves and tides)

(f) wind

(g) solar power

(h) geothermal sources

(i) combined heat and power systems

(j) other sources of energy and technologies for the generation of electricity or the production of heat, the use of which would, in the opinion of the Secretary of State, cut emissions of greenhouse gases in Great Britain.

Source: Energy Act 2004, chapter 20, Sustainability and renewable energy sources

The Distributed Generation Coordinating Group describes electricity supply from microgeneration as a mass-market method of producing electricity rather than a 'bespoke' power project. Microgeneration's competitive advantage, in their view, primarily stems from mass production combined with very effective/efficient utilisation of primary resources.[100]

The UK power transmission and distribution network was built to connect a number of large power stations with energy consumers who are predominantly served at Medium Voltage and Low Voltage. Microgeneration uses small generators connected to the Low Voltage network.[101]

There are 29 million electricity customers in the UK. There is a potential for microgeneration for most of these, as the majority of households and businesses could have a small-scale renewable generators installed.[102] According to the Network for Alternative Technology and Technology Assessment based at the Open University, if just 10 million consumers installed 2kW microgen PV or wind systems, that would introduce 20GWe and, "Despite the lower load factors, it could supply as much power as the UK nuclear programme."[103]

Cogeneration using Combined Heat and Power (CHP), although not always renewable, is one path to a 'decentralised', embedded or localised power system. One of the many benefits of production close to the point of use, is that it minimises energy lost through transport and enhances energy-efficiency. Small-scale cogeneration plants, generally under 1MWe, can be used in multi residential dwellings, leisure centres, hotels, greenhouses, hospitals, are simple to install and are flexible.[104] Individual households can use smaller units.[105]

Problems with conventional energy supply

Centralised large-grid systems are expensive. The inititial costs of the wires to ship power are only added to by their inefficiency. According to Ofgem – the regulator for Britain's gas and electricity industries – power lost as heat on the grid costs the UK nearly $1 billion each year.[106] The benefits of a decentralised system using microgeneration, however, are many:

- Reduction of harmful greenhouse gas emissions and particulates.
- Reduction of the total capacity needed within networks.
- Reduction of the need for peak provision in electricity networks, which is one of the biggest planning headaches for utility managers.
- A better guarantee against blackouts through the reduction of power system losses.
- Much less power lost during transmission.
- Major energy efficiency gains.
- Automatic provision of diversity in terms of power and location and therefore security of supply.
- Reduction of the amount of large-scale centralised generating capacity and therefore vulnerability of the overall system.
- Inherent modularity and therefore potential for scaling up.
- Ability to adjust supply to match demand.
- Speed of installation – units can be installed far more quickly than a central station or transmission and distribution line.
- Lower financial risk than large stations or transmission and distribution lines.

Table 2: Potential – the capacity (GWe) and energy (TWh) assumed in scenarios for the penetration of microgeneration:[107]

	2010		2015		2020	
Scenario	**GWe**	**TWh**	**GWe**	**TWh**	**GWe**	**TWh**
Low	0.37	0.96	1.19	3.07	2.23	5.65
Mid	1.23	3.22	4.06	10.36	7.92	19.41
High	2.48	6.48	8.26	21.15	15.78	39.22

Source: DTI 2004

- Better inoculation against price fluctuations in fossil fuels through the renewables-based mix.
- Zero or very low environmental footprints and impact.
- Few or no permitting requirements.
- Good proximity – units can be installed where the power is actually needed.[108]
- Micropower provides local choice and control and the option of relying on local fuels and spurring community economic development.[109]

The benefits of a high microgeneration scenario in the UK are estimated as a possible net benefit of £35 million per annum.[110] The major cost of providing kWh from any prime mover is related to the cost of fuel. Microgenerators have zero or very low fuel costs because they either run on renewable energy or they run as mCHP.[111]

Capacity from microgeneration can easily be added to the power system. The speed of installation represents a sea change in thinking about how 'fixed' network capacity is. For example, according to the Distributed Generation Coordinating Group, about a million gas-fired boilers are installed every year in the UK. If half of these boilers were micro combined heat and power (mCHP) with 1.5kWe capacity, then 750MW of capacity would be installed or around 15MW per week.[112]

When microgeneration coincides with energy demand peaks, it reduces the total capacity needed within networks. Adding microgeneration to the low voltage network could remove the need for new network capacity.[113] Microgeneration also uses primary renewable energy sources more efficiently than large-scale power stations, transmissions and distribution systems.[114] There is little or no environmental impact from most microgeneration in terms of visual intrusion and harmful emissions, and unlike nuclear, it has no long-term implications, for example, in terms of waste storage or contamination, visual intrusion or decommissioning costs.[115]

Work commissioned for the DTI suggests that a high-microgeneration scenario could save 29.4Mt CO_2e. Taking a CO_2 value of between £5 and £10/t CO_2 provides an annual value for emissions saved of £142–285 million that is without also considering other reduced pollutants such assulphur dioxide, nitrogen oxides and particulates from fossil fuels.[116]

Barriers to entry

There are, however, entry barriers to microgeneration in the UK that need to be overcome. The power system was not designed to enable the easy connection of microgeneration, or to encourage competition in energy 'off-take' and 'supply'. The Distributed Generation Coordinating Group points out that the New Electricity Trading Arrangement (NETA) and 'Competition in Supply' were not designed with microgeneration in mind. Worse still, energy subsidies have emerged over time to favour a centralised energy model.[117] In particular they highlight these 'unfair' obstacles to microgeneration, which will need to be overcome to catalyse the market:

- Considering that the majority of microgeneration is competitive with other forms of electricity supply, current institutional arrangements for electricity trading do not reward microgeneration equitably.
- Current institutional arrangements mean that only Licensed Electricity Suppliers (LES) can take the output from microgeneration.
- Market failures occur in terms of cost allocation when microgeneration exports power onto the LV (Low Voltage) network.
- It is wrong for electricity from microgeneration to be charged full delivery costs when it is exported 'over-the-fence' to neighbouring sites because it does not put the same burden onto the transmission and supply system as other forms of generation.[118]

Importantly, the Performance and Innovation Unit's energy review commented that, "A sustained programme of investment in currently proposed nuclear power plants could adversely affect the development of smaller scale technologies."[119]

The technologies

Biomass

The use of biomass as a source of heat is as old as civilisation itself and can be described as a way of extracting energy from organic matter of recent origin. It can be used to generate heat in individual dwellings as well as part of a community-heating scheme. The main sources for biomass include agricultural wastes and residues, organic wastes from animal husbandry, and energy crops, such as sugar cane and corn. It can be used as a fuel directly to produce bio-energy for electricity or heat, or be converted into biogas or liquid biofuels.

Even though it is not 'infinite' as a resource, biomass is classified as renewable, since it can be replaced at the same rate as it is produced. This makes it different from fossil fuel, which takes millions of years to evolve. It is also virtually 'carbon neutral', since the amount of carbon it produces when burned equals the amount it absorbs while growing. The carbon emissions associated with transport of the fuel should be taken into account, however, and it is therefore most efficient when sourced locally.

Biomass often replaces electricity, peat or oil as fuel for heating homes, and is generally used in four main ways:

- Stand-alone stoves (heating for a room)
- Stoves with back boilers (domestic hot water)
- Ranges (cooking)
- Boilers (connected to central heating and hot water systems)

The automated systems are generally more expensive, but the fuel can be cheaper to buy. Despite that these new boilers and stoves burn cleanly, the Clean Air Act prohibits their installation in many urban areas. Organisations, such as the Green Alliance, are urging for a revision of this Act to take into account new technology.[120]

Biomass

Biomass for biodiversity

Much of the woodland in the East Midlands has been left unmanaged or under-managed, as the timber is considered low quality and therefore of low value. What has been little understood is that it can provide wood fuel for the local area. This opportunity is now being explored by the Rural Energy Trust and Rural Energy Ltd, initiated by a co-operative consisting of around 20 Leicestershire farmers, who have started diversifying as 'heat entrepreneurs'.

The benefits have been multiple, in terms of increased income opportunities for struggling farmers, the provision of local jobs, as well as benefits for biodiversity. The management of previously neglected woodlands acts to enhance their biodiversity value, protect the soil, create habitats for wildlife and improve the cycling of water minerals and energy. The increased demand for wood fuel is also expected to stimulate new woodland planting which can complement soil sequestration of atmospheric carbon dioxide.

The introduction of biomass also has the potential to decrease fuel poverty in the area. Despite the high installation costs of wood-burning boilers, they are expected to lower fuel bills due to low running costs. These can be as low as half the price of oil equivalent energy and half the average domestic gas tariff.

The benefits of locally sourced energy are already evident. When the Woodland Trust started restoring Martinshaw Wood in East Midlands by removing non-native trees, the wood didn't have to travel far. Instead it ended up as wood chips for the wood-burning stove in the primary school down the road, providing heating for both the school radiators and the swimming pool. Andy Sharkey of the Woodland Trust said: "We're doing work to improve the biodiversity of the wood, which is our main aim, and as a spin-off from that our timber has ended up heating a school just down the road. Wood-chips are a renewable-energy source, which help combat climate change. All of it makes good environmental sense."[121]

Solar energy

Solar for London

Solar for London was set up in 2002, to provide people with information, practical assistance and help with the installation of solar energy systems. The main focus is on solar water heating, as it can reduce people's fuel bills as well as making long-term contributions to reducing CO_2 emissions. Hot water is estimated to account for about 20 per cent of a home's energy needs, and since solar water heating can supply around 50 per cent of the yearly hot water needs, this mean that a solar water system can take care of around 10 per cent of the annual energy requirement.[122]

Solar energy

Power from the sun can be utilised in three main ways:

- Passive heat
- Solar thermal
- Photovoltaics (PV)

Around 282 small-scale solar PV systems are currently feeding into the UK grid.[123]

Solar thermal

Solar thermal implies a system that converts solar energy into hot water by absorbing sunlight to heat liquids in collectors fitted to the roof. A thermal system can provide around 50 per cent of the year-round water demand and can work alongside a conventional water heater to provide for shortages. The UK Government has provided little support to make solar thermal an economic option, but around 42–50,000 homes have solar thermal systems installed, which, taken together, deliver 50MW of thermal output. The technology is considered mature in design, but volume efficiencies could make it possible to reduce the costs by up to 20–30 per cent.[124]

Solar photovoltaics (PV)

PV or solar cells are semiconductors that convert solar energy directly to electricity and can be used in many different ways and on many different scales, ranging from calculators to office buildings. PV will work in any weather as long as there is daylight, though for installation on a house, a south-facing roof is more efficient and shading can also affect output.

Even though it has high capital costs associated with it, PV is still a worthwhile technology as the operating costs are minimal, and the technology is evolving rapidly with decreasing costs as a result. The Energy Savings Trust has estimated that a south-facing roof can collect about 20,000kWh/yr of energy, which is equivalent to six times more electricity than a typical home will use in a year. Not all energy, however, is converted into electricity in a PV system. In general, PV is about 10–20 per cent efficient. It generates no greenhouse gases and a 2kWp system, which could be installed on many roofs, could generate about 1.7MWhe/year or half the average electricity use of a typical home.[125]

Micro-hydro

Waterpower is perhaps the oldest method of harnessing renewable energy and has been used for many centuries, but it is only with recent technology that it has become more efficient and is now a viable option even for properties with limited natural water supply. Micro-hydro is generally defined as under 100kW and is a particularly good option for houses with no mains connection, but with access to a micro-hydro site. It is essential, however, to get a professional assessment for each individual site.

Small-scale hydro systems generally offer reliable power with very low running and maintenance costs. They can be sized to meet individual or community needs, and can be operated and maintained by trained local staff. The UK already holds a huge dormant opportunity in terms of micro-hydro, with tens of thousands of disused water mills spread across the UK that could be redeveloped as small-scale generators. It has been estimated that if the small-scale hydro-electric power from all the streams and rivers in the UK could be tapped, it would be possible to produce 10,000GWh per year. This would be enough to meet just over three per cent of the UK's total electricity needs.

While hydro systems do not create any pollution when they are operating, there are some environmental concerns to take into account and large-scale dams with

Micro-hydro

South Somerset Hydropower Project

Scattered across Britain, there are tens of thousands of disused watermills, reminders of when they used to be an important feature of a local economy. Now forgotten and neglected, they have lost their importance, but there is increasing hope that many of them are now reviving their status in local economies, but this time as generators of energy.

In 2001, a group of watermill owners in the South Somerset area came together to start exploring the possibility of transforming their sites into micro-hydropower stations. They performed feasibility studies and secured some funding to get the project going, with strong backing from the South Somerset District Council. Little information was available on the sources of equipment, the economics, or the technical problems of installing hydropower, but these problems were overcome through collaboration and with help of the organisational, engineering and practical skills of all the members.

One of the mills in the scheme, Gant's Mill, dates back at least 900 years. It has adapted to society's many changing requirements, from a corn mill and a silk mill, to a fulling mill, washing and processing locally woven cloth. As such, it was a centre for the prosperous local woollen industry. Now it has become a centre for hydropower, with a new turbine and electricity generator installed in 2003, designed to produce up to 12kW of electricity in continuous operation fed into the local grid.[126]

hydro power stations are often highly controversial for this reason. Smaller-scale projects are therefore increasingly seen as a more viable option, but a number of issues still needs to be addressed, such as to ensure that fish and plant life are not adversely affected and to insulate for noise.[127]

Micro wind

Wind turbines convert wind power into energy through aerodynamic blades that harness the wind to turn a shaft inside a generator. Depending on size, they can be used to generate energy for anything from batteries for caravans and boats, to small communities, as well as producing large quantities of energy at competitive prices for the national grid. Despite the fact that the UK has 40 per cent of Europe's total wind energy resource, the majority remains untapped.

Due to wind constraints, the current models of wind turbines are mainly designed for rural use, or on the edge of towns. Small-scale turbines are particularly useful for remote off-grid locations, where conventional methods of supply are expensive or impractical. There are currently just over 400 small-scale wind systems feeding into the UK national grid.

Micro-wind turbines have in the past been considered to be small turbines used to charge 12V or 24V batteries, for low voltage household lighting or caravans, for example. The UK industry is already considered a world leader in micro-turbines for off-site battery charging applications. A new generation of micro-turbines that can be mounted to rooftops, however, will soon be commercially available at competitive prices and are expected to revolutionise the market. The turbines are no bigger than a TV aerial or satellite dish and one of the models estimates a yearly output of around 4,000kWh, thereby displacing approximately 1.6 tonnes of CO_2 per year.[128]

Micro wind

Micro wind turbines for schools[129]

Schools are not only ideal places for teaching new generations more sustainable ways of living, but they can also serve as sources of that same knowledge for the rest of the community. This opportunity is now being seized in Fife, Scotland, where five primary schools are piloting micro wind turbines by the Edinburgh company Renewable Devices. The first turbine was installed in May 2004 at Collydean Primary School in Glenrothes.

The micro wind turbines are small enough to fit on a roof, and generate minimal vibration. They have a rated output of 1.5kW and the manufacturers anticipate that each turbine will generate 4,000kWh of electricity per year. This could translate into a yearly reduction of the electricity bill of around £250. This is the first time this kind of turbine has been installed on buildings in Scotland, but if the pilots are successful, the scheme could be rolled out to include houses and other buildings.

While many are unaware of the benefits of micro renewables, this pilot has gained substantial support both locally and regionally. For the primary school children the logic is simply 'child's play'. At the launch of the first turbine, one pupil said: "Putting up a wind turbine saves money and energy. Not only that, but our environment is also being

Ground source heat pumps
Geothermal energy implies making use of the energy contained in the heat of the earth's crust. In the UK, the soil maintains a constant heat of around 11–12°Celsius. The system works like a refrigerator in reverse by feeding a coil into the ground. It is not a renewable source in the strictest term, as it requires 25 per cent electricity to work, but this is balanced by the fact that it produces more units of heat than the units of electricity needed to power it.

Such systems can offer considerable savings on heating bills but while the only expense is to run the pump, the fitting can be disruptive and expensive and is best installed when a new property is built. The technology is widely used in rural areas in the US but so far only around 200 to 300 domestic systems have been installed in the UK.[130]

Combined Heat and Power (CHP)

Combined Heat and Power (CHP), also known as cogeneration, is the production of electricity and heat in one single process for double output streams. CHP is not a renewable by definition, but systems are increasingly making use of biomass fuels, which puts them in this category. It can achieve up to 90 per cent efficiency, as it makes use of waste heat that is normally lost in conventional electricity generation. In conventional systems, only an average of 35 per cent of the energy potential contained in the fuel is converted to electricity.

Micro combined heat and power (mCHP) in its commercial form is still under development, but has the potential to revolutionise the domestic market. It entails thermally driven systems that are designed for up to 10kWe, which means that they are timed to meet demand for hot water and heating rather than power. The peak heating and electricity demand are also closely aligned, so the power generated will be displacing the peak power demand, whether on-site or exported. In this way the power units will displace the need for fossil-fuel-intensive and expensive back-up options.

mCHP not only offers a great option for homeowners, but it could also contribute to a large share of the UK's energy needs. The Green Alliance estimates that if just one quarter of all the one million or more gas boilers that are replaced every year were mCHP, this alone would deliver half the Government's Energy White Paper's domestic sector carbon reductions and provide 5.5GWe generating capacity – equivalent to 40 per cent of the UK's nuclear power capacity.[131]

The prospect of nuclear power

A generation has grown up in Britain during a time in which the nuclear industry was assumed to be sliding slowly into a radioactive grave. Many have forgotten how and why the future of a once optimistic energy sector became so tarnished.

For that reason it is necessary to revisit the industry's journey from post war promise, to new millennium white elephant, and why it is that nuclear power is now back on the political agenda. If recent events are indicative, any renewed official enthusiasm for nuclear power will face significant obstacles.

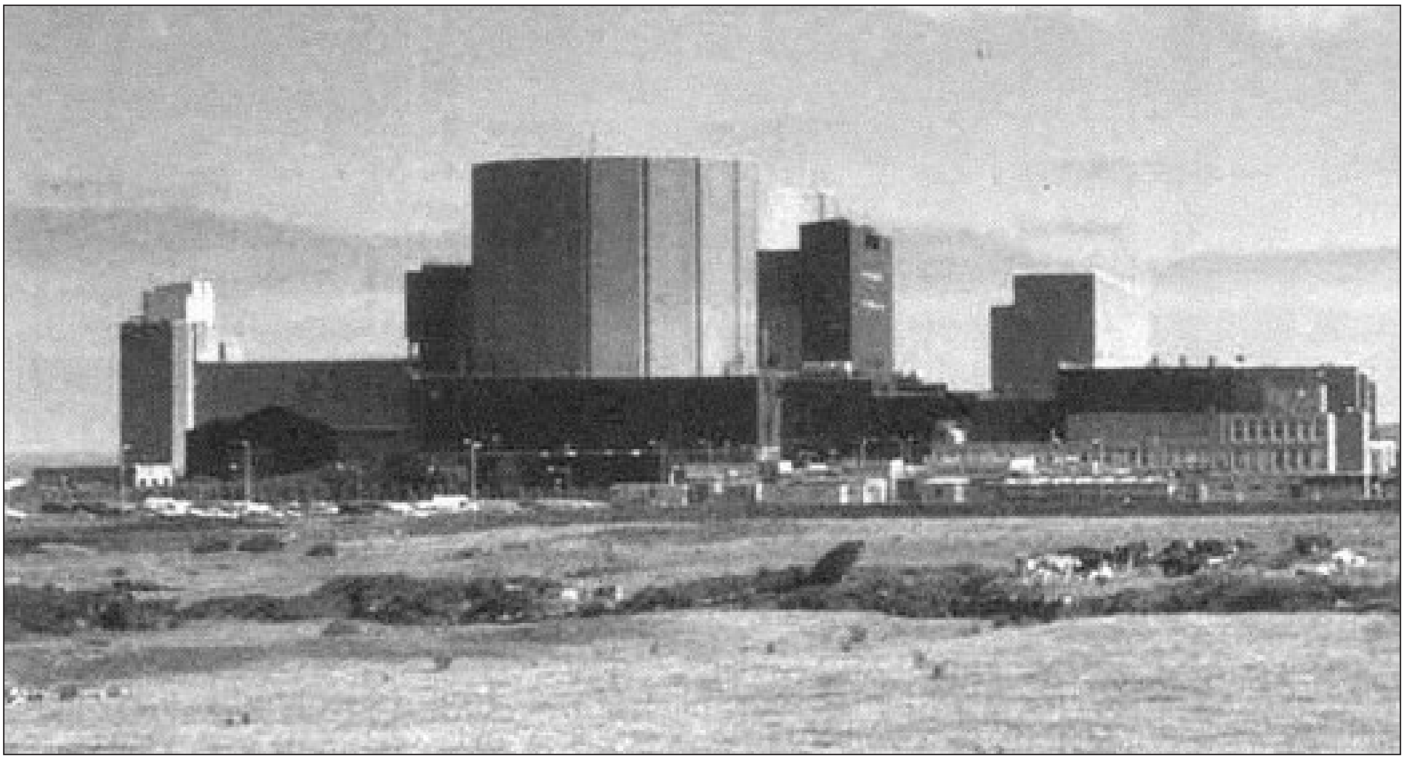
Days after Labour Government officials seemed to be reopening the nuclear door, news emerged of a leak of 20 tonnes of plutonium and uranium dissolved in nitric acid at the Thorp reprocessing plant in Sellafield. Classified on the International Nuclear Event Scale as a 'serious incident', it was a poignant reminder of the Windscale reactor fire – whose scale and impact were kept secret from the British public for 25 years – that led to the plant being renamed Sellafield. The contemporary leak resulted in calls from the EU Commission for tougher safety standards. Soon after, it was reported that the Nuclear Decommissioning Authority wanted Thorp to shut for good. This was due partly to the fact that it was a loss-making operation, and partly because the controversial nature of reprocessing is seen within the industry as a potential barrier to winning the argument for a new generation of reactors.[132]

Discovered in the 1930s, nuclear fission was later pioneered in the 1950s by the United States, the UK, France, Canada and the former Soviet Union as a way of supplying electricity.[133]

The UK's first nuclear power station was Calder Hall in Cumbria, a Magnox gas-cooled reactor, which came on stream in 1956. Several of these aging Magnox reactors are still in operation. The design was also exported. DTI proudly cites the stations built in Italy and the one in Japan, which is still operating. They omit to mention that North Korea's current controversial nuclear programme is based on these same early generation British-designed Magnox plants.[134] France used similar technology early on then later followed the US focus on water-cooled reactors. In the 1960s Britain went on to develop advanced gas-cooled reactors before opting for pressurised water reactors (PWRs) in the 1970s.

Their development is instructive for the current debate about the potential of nuclear power to ward off climate change. A public inquiry into the UK's first PWR, Sizewell B in Suffolk, ran from January 1983 to March 1985 and it wasn't until 14th February 1995 that it began operations. Prime Minister, Margaret Thatcher planned to build a whole series of new nuclear power plants, but as the DTI observes, "Since Sizewell B, no further nuclear reactors have been built or ordered in the UK."

When plans to privatise the electricity supply sector were announced in 1988, nuclear power was left out of the proposals. High capital costs of construction, decommissioning and waste disposal were the main reasons. But the other problem that beset the nuclear sector then, and still does today was, according to the DTI, the serious "uncertainties over the costs" of financing new stations.



Wylfa Power Station – one of the oldest still-functioning Magnox reactors similar to the design used by North Korea to develop their nuclear programme

In 1994, the Government undertook a *Review of the Future Prospects for Nuclear Power in the UK*. After analysing the "economic and commercial viability of new nuclear power stations", it concluded that public support, or 'subsidy', for building new stations would constitute a significant and unwarranted intervention in the market.

In 2000, the final explicit subsidy to nuclear power was removed and replaced with an obligation on UK energy utilities to buy three per cent of power from renewable sources.[135] There are 31 operating reactors at 14 powers stations currently in the UK (see Table 3).

The Government's Performance and Innovation Unit (PIU) published a review of UK energy policy in February 2002. It concluded that new sources of low cost, low carbon energy should be developed. It called for renewables to play a central role, and left the nuclear option open.[136]

In February 2003, the Government published its Energy White Paper *Our energy future – creating a low carbon economy*.[137] It sets energy efficiency and renewable energy as Government's priorities. The White Paper says that, "While nuclear is currently an important source of carbon free electricity [note: this is actually untrue], the current economics of nuclear power make it an unattractive option for new generating capacity and there are also important issues for nuclear waste to be resolved." Consequently and clearly ruling out the prospect of any future public subsidy, the DTI notes that, "In common with all generation options, the initiative for bringing forward proposals to construct new nuclear plant lies with the market and the generating companies."

So it was with an impressive ability to override an apparently glaring contradiction that the Government came to the aid of the financially crippled nuclear sector in 2002, supporting British Energy with a £650-million credit facility. The European Commission challenged the UK Government under its rules prohibiting state aid to industry in an action that has yet to be finally resolved.[138]

The timescale for nuclear phase-out suggests all Magnox reactors would close by 2010 and, with some exceptions, Advanced Gas-Cooled Reactors (AGRs) by 2020. This would mean nuclear power's share of generating capacity falling from its current level of 23 per cent to 7 per cent.[139]

Table 3: Power stations in the UK.

BNFL Magnox	*Capacity MW*	*Published Lifetime*
Calder Hall	194	2003
Chapelcross	196	2005
Sizewell A	420	2006
Dungeness A	450	2006
Oldbury	434	2008
Wylfa	980	2010
British Energy	*Capacity MW*	*Published Lifetime*
Dungeness B	1110	2008
Hartlepool	1210	2014
Heysham 1	1150	2014
Heysham 2	1250	2023
Hinkley Point B	1220	2011
Hunterston B	1190	2011
Sizewell B	1188	2035
Torness	1250	2023

Source: DTI

In April 2005, the Government launched the Nuclear Decommissioning Authority (NDA), to manage the task of cleaning up the contamination left on the sites of the 40 nuclear reactors that have operated in the UK. Very conservatively the costs are estimated at tens of billions of pounds over the coming decades.[140] The transfer of assets and liabilities from British Nuclear Fuels (BNFL) to the NDA is considered to remove 'polluter pays'-type obligations from BNFL. As the State is providing an advantage to a company, the EC considers that it falls into the category of potentially prohibited 'state aid'. An in-depth inquiry has been instigated.[141]

Current development plans

Currently there is no active programme of new nuclear build anywhere that electricity-generating markets have been liberalised.[142] In the US no new nuclear power stations have been ordered for over 25 years. In Europe, Germany, Belgium, the Netherlands and Sweden are committed to closing existing plants. Only one is being built in Western Europe in Finland. If new build were to happen, the Westinghouse Advanced Passive 1000 (AP1000) reactor is apparently the most likely candidate.[143] A Government review of 2002 says that 20 years would be the minimum timeframe to develop a programme using this technology, ruling out any role for nuclear in cutting carbon emissions to control global warming in the period in which the scientific consensus dictates that action is essential.

In an attempt to escape the private sector's deep antipathy toward the economic uncertainties of nuclear power, British Energy is reported to be talking to city institutions about the possibility of private funding for a nuclear-power building programme. Contrary to past official assurances that there would be no new subsidy to nuclear, the Treasury is reportedly considering tax breaks for private companies willing to support a new-build programme. Such an approach would partly circumvent the Government's reluctance to use public cash directly, and British Energy's lack of resources.[144]

British Energy is currently banned from operating any newly built stations until 2010, because of the settlement terms resulting from its brush with the European Commission after the Government's credit bail-out. According to news reports, bankers have told British Energy at London meetings that the "huge initial costs of building nuclear stations, coupled with volatility in the power market makes funding impossible" without government reform.[145]

The 2002 review

One of the problems of dealing with the strictly economic aspects of choosing an energy path is the opaqueness of figures offered by the nuclear industry. The 2002 report by the PIU lists these reasons why the industry's figures about the costs at which it could generate electricity should be questioned:[146]

The industry is over-optimistic about reducing costs through 'learning and scale effects'.

- The former because necessarily strict regulation to do with the inherent dangers of nuclear materials means that it is unrealistic for the industry to 'learn' substantially from its mistakes; a mistake in nuclear power terms might be disastrous.
- Even where possible 'learning effects' will be less for nuclear than renewable because, "Long lead times for nuclear power mean that feedback from operating experience is slower."
- The latter 'scale effects' would also be constrained because, compared to the scale benefits for renewable technologies, "The scope for economies of large-scale manufacturing of components is less."

The industry is over-optimistic about construction costs:

- It claims that it can achieve costs below the bottom of the range given in an assessment of nuclear's potential by the International Energy Agency. But such an outcome would depend on:
    - Achieving very high operating availability.
    - A series build of 10 identical reactors.
    - Short construction times; and regulatory stability.
- The technology proposed for a new series of stations is the AP 1000 which:
    - Is yet to be built anywhere in the world.
    - Carries 'first-of-a-kind risks'.
    - Comes at a time when no new stations have been ordered in OECD Europe since 1993.
    - Performance will be difficult to guarantee at proposed levels.

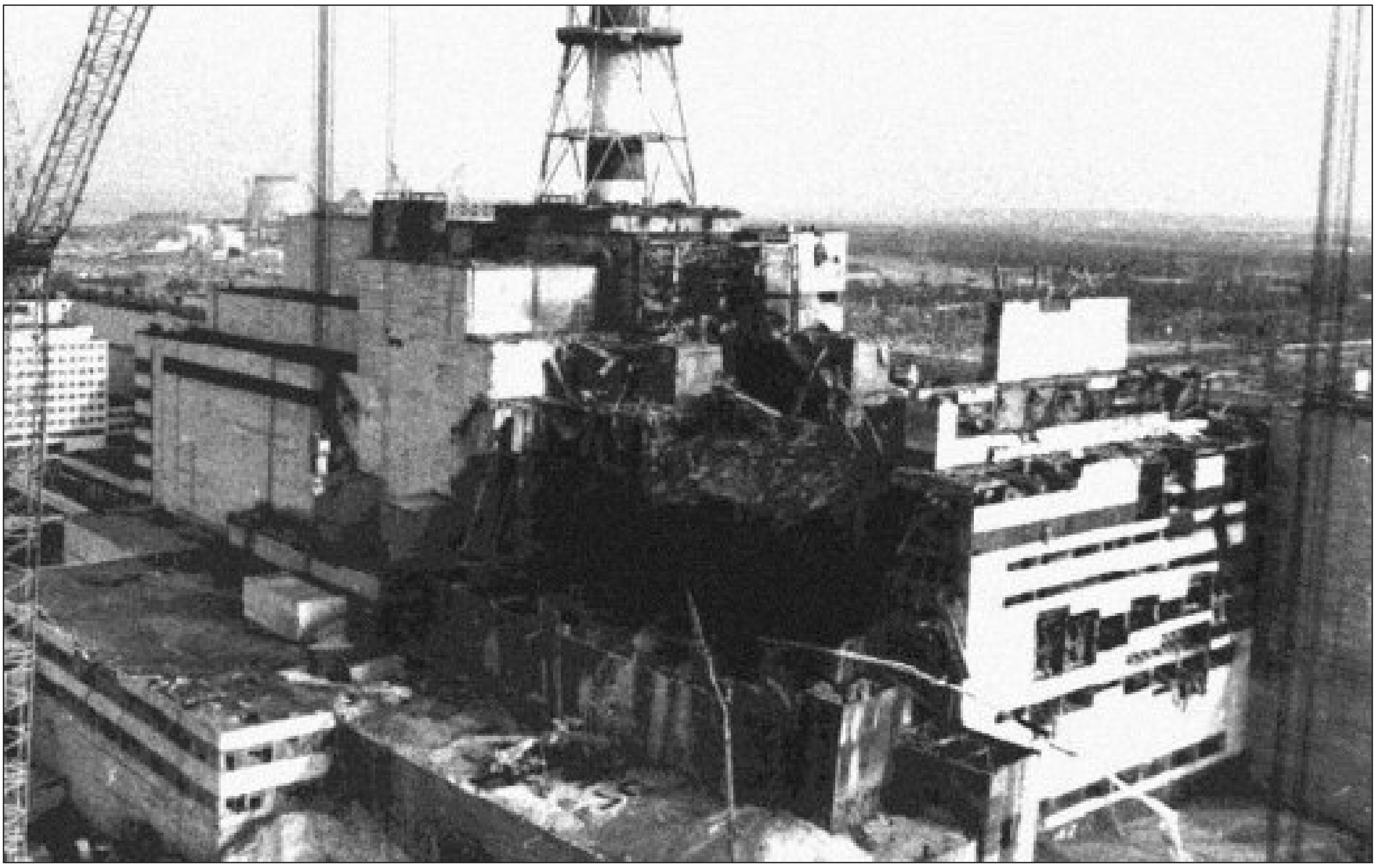
The earliest that new nuclear capacity could be introduced means it can't tackle climate change

- Twenty years was considered to be the earliest that a new generation of nuclear reactors of this type could be introduced, whereas the scientific community say that action to reduce greenhouse gas emissions is urgent with the next decade.

Given the sceptical tone of the PIU review and the clear recommendations of the recent Energy White Paper in 2003, the question the industry has to answer is, what, if anything, has changed in the intervening period to justify re-opening the nuclear box?

Costs and hidden emissions

One of nuclear power's main problems is that it has proved incompatible with any kind of market system for energy. Its high, unpredictable costs and unknowable



The Chernobyl nuclear power station – costs still rising

and potentially uncontainable liabilities deter investors. Its inflexible method of power generation renders the industry largely incapable of responding to changing market conditions by varying output. The bailout of British Energy in 2001 was attributed to a fluctuating market price that went below nuclear power's operating cost, and to which the sector could not respond by simply switching reactors off.[147]

Even the World Nuclear Organisation happily concedes that when the external costs of various fuel cycles are studied, the cost of wind power is up to four times cheaper than nuclear power.[148] With reference to the same methodology, however, they say that the external costs of nuclear – those not to do with immediate generating costs – are much lower than most fossil fuels. However, specialists in the measurement of ecological footprints say that the footprint of nuclear power is at least equal to many fossil fuels. Footprint analysts Best Foot Forward comment, "The losses through Chernobyl alone suggest a footprint per nuclear energy unit larger than that of fossil fuel. Life cycle studies of nuclear energy also reveal the fact that a substantial amount of pollution is produced in the production and processing of nuclear materials and the construction of power stations."[149]

According to the US-based Nuclear Information and Resource Service, the fossil fuel intensive processes involved in uranium mining, conversion, enrichment, transport and construction of power stations, mean that, "Nuclear power produces direct and indirect emission of 73 to 230 grams of CO_2 per kWh electricity."[150]

The problem of insurance

> *"Swiss Re believes that one of the most perilous shortcomings in traditional property insurance and reinsurance concerns inadequate nuclear risk exclusions."*
>
> *Nuclear risks in property insurance and limitations of insurability,* Swiss Re (2003)

The nuclear power industry is underinsured. The limited insurance it does have is effectively subsidised by public funds. The nuclear industry is unable to get commercial insurance cover and governments have had to step in, taking on the burden instead. This is a substantial, and largely hidden subsidy to the industry.[151]

In several countries, law sets the maximum liability for any nuclear facility. Under the Canadian Nuclear Liability Act, the limit for an installation is CAD$75 million and is underwritten by the Federal Government.[152] In the United States, coverage for a 'catastrophic nuclear accident' is set in law under the Price-Anderson Act of 1957 at a much larger US$9 billion, although this too has been labelled 'inadequate'.[153] Arguing for the industry to meet more of its own insurance costs, Senate Democrat and chair of the Senate's Transportation, Infrastructure and Nuclear Safety subcommittee Harry Reid said, during negotiations to renew legislation for the insurance programme, "We cannot allow nuclear power plants to operate without adequate insurance."[154]

The September 11 attacks on New York and Washington raised fears about the vulnerability of nuclear installations to attack. In response, American Nuclear Insurers, which administers the industry's collective insurance pool, limited the industry individual operator's liability to $200 million. In the US, such a government-backed insurance programme for industry is considered unique to nuclear.

To put these figures into context, the Ukraine estimated in 1998 that, up to that point in time, it had lost between $120 and 130 billion thanks to the Chernobyl disaster over a decade earlier, whilst neighbouring Belarus estimated its economic loss at $35 billion. Of course the damage from that one incident spread much wider and, for example, still effects the hill farmers of Wales today.[155] Figures released in 2004 in response to Parliamentary questions by Labour MP Llew Smith, showed continuing damage to sheep farming in the UK from the fallout from Chernobyl.[156] In North Wales restrictions remained at 359 farms covering 53,000 hectares;[157] in west Cumbria in England, near Sellafield, 9 farms were still affected covering 12,100ha;[158] in Northern Ireland, in Counties Antrim and Londonderry, 153 farms covering 8,752ha were still affected;[159] and in SW and central Scotland, 14 farms covering 16,300ha remained affected.[160]

In terms of the international communities' ability to respond to the major nuclear accidents, the Chernobyl case is instructive. A limited plan to manage the contaminated accident site was pulled together in 1996 known as the International Shelter Project. It was estimated to cost $758 million, not including the costs of actual fuel removal or the decommissioning and decontamination of the site. G7 nations pledged to contribute $300 million towards the $758 million cost, topped up by a further $37 million from 40 other countries, together less than half the total.[161]

The insurance circumstances of the nuclear industry represent a double subsidy. First, installations are underinsured, and second, the state ultimately picks up the bill. As the retired Royal Navy Commander Robert Green, (who navigated nuclear strike aircraft during two decades of service) observed, "No commercial insurance company has ever insured either nuclear-powered merchant ships (which were all economic failures) or electricity generation plants, because a worst-case accident, like the 1986 Chernobyl reactor explosion, cannot be ruled out."[162]

The insurance industry's deep antipathy towards the nuclear sector was underlined by a call in 2003 from Swiss Re for contracts to be rewritten and laws to be changed to explicitly remove any exposure of the insurance and reinsurance sector to the nuclear industry.[163]

Questions of supply and cutting greenhouse gases

People rarely consider the question of finite resources in relation to nuclear power but uranium is in limited supply. Given current nuclear output one estimate from a body representing the renewables industry suggests that uranium reserves will be depleted in around four decades.[164]

But even the International Atomic Energy Agency (IAEA), a UN body that promotes peaceful uses of nuclear power, cites known conventional, recoverable resources of uranium at 4.6 million tonnes – enough to last only another 85 years at the rate of use in 2002. It also observes, "The period for which resources are sufficient decreases the more nuclear power is assumed to grow in the future."[165]

Another question is whether, even with a major building programme, it could make much difference in terms of global greenhouse gas emissions. The IAEA's 2004 review of the sector looked at two different scenarios. In the first, in which no new nuclear stations beyond those already planned get built, "Nuclear power's share of global electricity generation decreases after 2010 to 12% in 2030, compared to 16% in 2002" meaning that its relative contribution to fighting global warming falls also. However, ironically, nuclear power's potential relative contribution to reducing greenhouse emissions is even worse under the IAEA's more optimistic high-growth scenario.

This is because the model takes account of the fact that in order to pay for a major nuclear building programme there would have to be high economic growth, which would still be largely powered by even faster growth of fossil-fuel use. Hence the conclusion that under the high nuclear growth scenario "generation steadily increases by a total of 46% through 2020 and by 70% through 2030", but, "overall electricity generation increases even faster than nuclear power, causing nuclear power's share of overall electricity to decline. By 2030 the nuclear share is down to 11%".[166]

Fast-breeder reactors are meant to solve the problem of limited uranium supplies, but they require much higher energy 'investments'. As the UK Atomic Energy Authority wrote in 1989, "In practice, it is now not clear how [the use of fast breeders] would be achieved on an expanded global scale without encountering basic plutonium shortages, not to mention serious problems with waste disposal, power plant decommissioning and nuclear weapons proliferation."[167]

If fuel supply was not a problem, there is another one. Margaret Thatcher, as Prime Minister, planned ten new nuclear power stations and managed only one. In the context of declining oil and gas output, to meet unmanaged energy demand, would require an unfeasibly enormous programme of new building. According to one estimate between 2015 and 2040, 1,700 stations would be required.[168] Add to that the new demand to provide the energy necessary for the global economy to grow at two per cent beyond 2015, and another 5,000 stations would be needed. Based on this estimate, over the 25-year period up to 2040, approximately five new stations would need to open every week. There would be real problems in finding suitable sites outside earthquake zones where the cooling water would not harm the marine environment. And given that most stations take ten years to build, work would have to start almost immediately.[169]

Another estimate comes from the US-based Nuclear Information and Resource Service (NIRS): to meet the IAEA's high-growth scenario for nuclear power, an average of 115 power stations of 1000MW would need to be constructed annually, with a new station opening approximately every three days.[170] A report on the *Future of Nuclear Power*, recently published by MIT says that to increase nuclear power's share from 17 per cent of world electricity to just 19 per cent by 2050 would mean nearly trebling nuclear capacity. Between 1,000 and 1,500 large nuclear plants would have to be built worldwide.[171]

Even a report produced in 2004 by the IAEA to mark the 50th anniversary of nuclear power conceded that it could not stop climate change. In an interview, Alan McDonald, an IAEA energy analyst, admitted that, "Saying that nuclear power can solve global warming by itself is way over the top."[172]

Security

Global reinsurance giant *Swiss Re* cites three scenarios for nuclear terrorism in the post 9/11 world:[173]

1. A radiological dispersal device, otherwise known as a 'dirty bomb'.
2. Attack or sabotage on a nuclear installation.
3. An 'improvised nuclear device', either taken from military sources or 'home made'.

All imply long-term contamination and extremely high costs in both human and financial terms.

So far, no convincing response has been given to this key security question, which explains the nervousness of the insurance industry. There are fears that the degree of new security measures necessary to address such concerns, could, in themselves, represent a victory for terrorism and lead to a police state. There is also the problem of materials 'leaking' to supply the market for state-sponsored nuclear proliferation.[174]

One recent estimate put the cost to BNFL of providing security against terrorism, including armed police, at £50 million per year. This is roughly the same as the total amount recently allocated to a new wave and tidal development fund in the UK, to be spread over several years.[175]

Chernobyl demonstrated what happens when a reactor core is penetrated without first having shut down safely. Private nuclear industry calculations are understood to have shown that the effect of a plane being flown into the intermediate-level waste stores at Sellafield could result in 3,000 deaths within two days of the attack.[176]

With the industry arguing the case for their own renaissance in the context of climate change, there is another, ironic, potential obstacle. The challenge of finding appropriate sites for new wind farms is dwarfed by the task of choosing sites for new nuclear reactors. Given public opposition, a common official fallback position is to advocate building new reactors at existing nuclear sites. However, following the sector's notorious 'dilute and disperse' approach to waste management, nearly all nuclear plants are to be found on the coast. But, as observed in a newsletter produced by Defra, "With sea levels rising sue to climate change, this does not seem to be a good location."[177]

Waste

Britain has over 10,000 tonnes of radioactive waste, set to increase 25-fold when current nuclear facilities are decommissioned. Most high- and intermediate-level waste, around 90 per cent, is in 'unconditioned form', not held in a form suitable for long-term storage.[178]

The total amount of nuclear waste in the UK, including waste generated over the next century from existing power stations and their decommissioning, is 470,000 cubic metres when conditioned and packaged – enough to fill the Royal Albert Hall five times over. The nuclear waste volumes can be divided as follows:

- High level waste – 2,000 cubic metres
- Intermediate-level waste – 350,000 cubic metres
- Low-level waste – 30,000 cubic metres
- Spent fuel – 10,000 cubic metres
- Plutonium – 4,300 cubic metres
- Uranium – 75,000 cubic metres[179]

On average, people in Britain live only 26 miles from a major radioactive waste site, including power plants and military bases.[180]

A recently released consultation document from the Committee on Radioactive Waste Management (CORWM), based on an investigation of different options over a period of 18 months, recommends that waste should be either buried underground or stored temporarily in facilities above ground in anticipation of better technologies. No recommendation, however, is forthcoming on where these sites should be located.[181]

The high cost of waste management was a factor in another controversial government decision to do with the industry. In order to help meet waste management costs, in late 2004 the UK Government reversed a 30-year-old policy to not store foreign intermediate-level nuclear waste on British soil. But where the new waste from Japan, Germany, Italy, Spain, Sweden and Switzerland will be stored is unclear. Many observers believe that the current storage site at Drigg, near Sellafield in Cumbria, is nearly full.[182]

Both sides are calling for a new debate about disposal of nuclear waste. Along with the question of security and cost, waste management remains a thorn in the industry's side. For example, the UK Government faces court action from the European Commission for safety failures and for having no reliable figure for the amount of plutonium and uranium contained in waste tanks at Sellafield. The problem goes to the heart of the technology: murky water in the tanks and radiation prevent proper inspection of the content of the holding tanks. When the problem came to light, *The Guardian* commented that, "The European court of justice could in theory levy unlimited fines on the UK for failing to comply with Euratom safeguards to prevent diversion of nuclear material for military purposes."[183]

Spin

Shortly after Margaret Thatcher became Prime Minister she announced a plan to build ten new nuclear power stations. In spite of her extraordinary grasp on power in Britain, as mentioned above, just one was commissioned. With peculiar symmetry, shortly after Tony Blair was re-elected in 2005, a Whitehall plan was leaked, appearing to allow for a series of ten new nuclear power stations. In the event, according to former ministerial advisor Tom Burke, it turned out to be merely one of countless options papers produced 'like confetti' for incoming ministers.[184]

But the return of nuclear power to public debate didn't just happen. It was carefully engineered. Over the course of the previous year a range of bodies representing the industry invested heavily in new staff and capacity to engage in a press and public affairs charm offensive. A combination of British Energy, the Nuclear Decommissioning Agency, the UK Atomic Energy Authority (UKAEA) and the Nuclear Industry Association used a range of strategies and newly employed lobbyists to try to revive the industry's prospects.[185] Even **nef** was invited to become part of the charm offensive in the build up to the political party conference season in 2005 by a public relations firm, Grayling Political Strategy, taken on by the UKAEA. In spite of efforts like this, it seems the most important audience is yet to be convinced. This year only 15 per cent of the senior management of Britain's energy utilities expected the current reactors to be replaced.[186]

Public trust in bodies set up to oversee the industry was recently undermined by questions over the composition of a key committee to do with nuclear waste management. One third of the members of the Government's Committee on Radioactive Waste Management were recently reported to have 'serious conflicts of interest', that breached the code of conduct on public committees.[187]

Nuclear power: what are the real costs

"New nuclear capacity cannot contribute significantly, if at all, to the 20 per cent reduction in carbon emissions required between now and 2020. The relevant cost comparison is not with the cost of renewable (or non-renewable) energy sources now, but in around 2020…"

According to the PIU, British Energy (BE) and BNFL estimate the costs of nuclear generation at between 2.2 and 3.0p/kWh. Having criticised the over-optimism of many of their assumptions, PIU proposes a range of 2.2–5.0p/kWh as more realistic, with a narrower range of 3–4p. However, this range appears too low, and unrealistically narrow for new technology that remains untested. Even if the BNFL and BE assumptions are accepted, the 2.2p/kWh figure is the lowest estimate for the *eighth* reactor to be built in a series of new build, which presupposes the construction of seven previous reactors at highest cost; and it is based on a 20-year plant lifetime. Using the PIU's standard assumptions of an 8–15 per cent discount rate and 15-year plant lifetime, even with an optimistic view of the reduction in costs between the first and eighth units, BE and BNFL estimates imply an average cost for all eight reactors of between 3.1 and 4.3p/kWh.

The PIU highlights reasons, beyond vested interests, to believe that these figures are themselves an under-estimate. The following adjustments are based on the PIU figures for sensitivity analysis. However, since these are themselves based on an 11 per cent cost of capital and a 20-year plant life, they are adjusted by +/- 10 per cent to correct and bring them broadly into line with the standard PIU assumptions.

First, BE/BNFL estimates of construction costs are *below the lower end* of the range of IEA estimates for expected construction costs of new nuclear capacity in seven OECD countries ($1,518–$2,521/kW). Based on the PIU's own sensitivity analysis, this suggests an increase in the upper end of the UK cost scale in excess of 1.1–1.3p/kWh. The estimated £100–300 million of additional 'first-of-a-kind' costs excluded from the BNFL and BE figures, if spread across eight reactors, would add up to a further four per cent (approximately) to construction costs, and up to 0.07p/kWh to the overall cost.

It should also be noted that these estimates are based heavily on 'engineering judgements', in which the *lower limits* to the costs of producing certain types of structure are directly estimated. In other words, while the lower end of the range is a minimum, there is much greater potential for upside risk.

Past experience of nuclear power – particularly in the UK – suggests that such risks may be very considerable. Dungeness B, for example, took 23 years to complete instead of 5 years, resulting in a construction period longer than its productive life, while construction costs were more than 400 per cent above the original projection. If this were repeated, it would increase the price per kWh by around 11-12p/Kh. A moderately cautious estimate of potential time and cost overruns (5 years' delay and 50 per cent cost overrun) would increase the upper end of the cost range by a further 1.5–1.8p/kWh.

Sizewell nuclear power station

Together, these considerations suggest additional costs of 0.1–3.2p/kWh, increasing the cost range to 3.2–7.5p/kWh.

BE/BNFL also assume operating availability substantially above the IEA's estimate of the current average OECD lifetime performance (75–80 per cent). Interpreting 'substantially' as a margin of 5–10 per cent, and lowering the assumption to the IEA estimate would increase all costs (including additional costs based on the sensitivity analysis) by 5.3–11.1 per cent. This further increases the range to 3.4–8.3p/kWh.

By comparison, if the industry estimate of 2.5–3.0p/kWh were under-estimated by the same margin as its 1995 estimate (3.5p/kWh) compared with the actual cost (6p/kWh), the true range would be 4.3–5.2p/kWh.

Timing

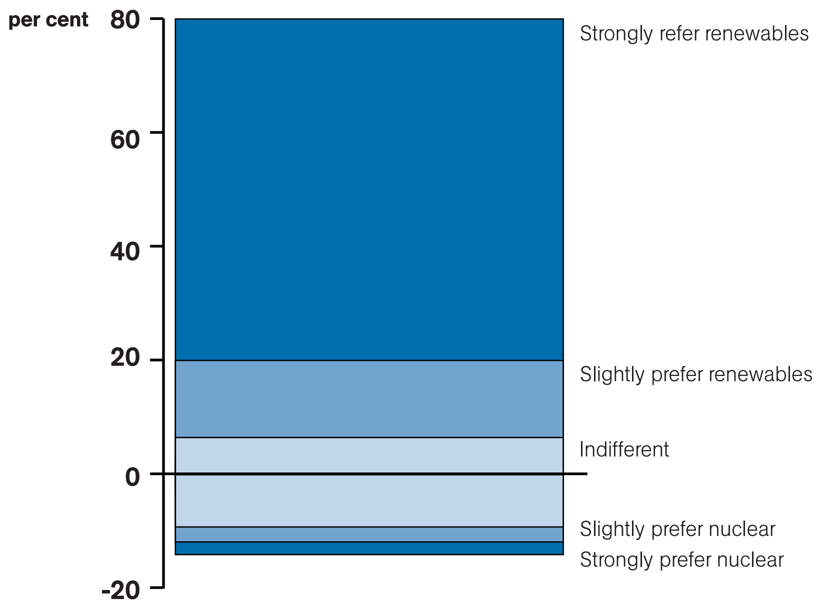
The PIU suggests a planning/construction period in the order of a decade for each nuclear plant – a figure that may prove optimistic in the light of the controversy of planning applications and past experience of delays in construction. This suggests that electricity supply would come on-stream no earlier than mid-2015, even if the planning period began immediately.

However, there is a number of reasons to expect substantial further delays. Recent official briefings suggest that even an initial decision to pursue a nuclear option is far from immediately likely and possibly very far away, if it exists at all. Such an option has been, and remains highly controversial. Popular opinion towards nuclear power is roughly equally divided between supporters, opponents and undecided.[188] The Government's relatively small majority, coupled with the likelihood of a significant backbench opposition to a pro-nuclear policy seems likely to delay matters further. An added complication is the absence of a policy on nuclear waste disposal, and the finding of the Royal Commission on Energy Policy that new nuclear construction should not be permitted until this issue has been resolved to the satisfaction of the scientific community, and the public at large.

In view of these considerations, it seems unlikely that production will begin until at least 2020, and possibly well after this.

This has two very important implications. First, it means that new nuclear capacity cannot contribute significantly, if at all, to the 20 per cent reduction in carbon emissions required between now and 2020. Secondly, it means that the relevant cost comparison is not with the cost of renewable (or non-renewable) energy sources now, but in around 2020 – after any cost reductions resulting from increased economies of scale and learning-curve effects in the meantime.

Figure 3: Preferences between nuclear and renewable energy at equal prices (2002)



Source: MORI (2002) "Renewable Energy Wins Support From British Public"[189]

In fact, the delay could extend considerably further into the future. In 1981, the Monopolies and Mergers Commission (now the Competition Commission), deploring the lamentable performance of CEGB with respect to AGR plants such as Dungeness B, drew the following conclusion:

> *"Again with hindsight it is clear from the views we have received that work on the AGRs has been at the frontiers of technology. The implication of this is that there were many components of the AGR which could not be fully tested before full-scale operation began, nor were relationships between the variables in the design sufficiently understood even to allow simulation of certain potentially damaging conditions. Nevertheless a full-scale prototype AGR was not built before proceeding to the programme. It is the CEGB's policy not to repeat that mistake in the current proposals for the future nuclear programme."*
>
> (Competition Commission, formerly the Monopolies and Mergers Commission, 1981,)

Avoiding this mistake with AP1000 technology might reduce the risk of construction delays (although construction of Dungeness B took a further ten years after the completion of Hinkley Point B). However, it would delay the process by around another ten years, to 2030 or later.

Externalities

The PIU explicitly excludes consideration of unpriced externalities. Taking account of these could add considerably more to the economic cost of nuclear power, and to its financial cost if mechanisms were introduced to price them.

For example, there is the question of the insurance of nuclear installations. This is a cost borne largely by the State, which in the UK accepts liability for insurance costs above £140 million, and therefore an uncounted subsidy. Secondly there is the issue that the limits set on insurance liability, where costs from major nuclear accidents are unlimited, represents a second subsidy. The nuclear industry assumes that these costs are of minimal value, in which case the question remains, why should the nuclear industry not be insured at going market rates, and if the costs really are minimal, why is the industry not prepared to take them on?

The risk of theft of nuclear materials, for example by terrorists, is also ignored. Given the increased level of perceived risk since 9/11, this is a serious omission. Again, it should be included in the calculations, and valued at the commercial cost of insurance against 100 per cent liability for the damage caused. This would add significantly to costs. Additional security costs for storage and transport of inputs and waste could also increase costs significantly.

An indication of the existence of such uncompensated externalities is the public preference for renewable energy over nuclear power, excluding price effects. Asked by MORI in July 2002 about their preferences between the two, if the cost of either option were equal, 72 per cent expressed a preference for renewables, and only 6 per cent for nuclear (see Figure 3).

Energy costs and learning curves

A more positive externality arises from learning effects – the progressive reduction in costs arising from gaining experience in production. However, these effects are relatively limited in the case of nuclear power. While learning effects are typically in the order of 10–30 per cent for each doubling of cumulative production, and 5–25 per cent for the energy sector as a whole the figure for nuclear power is only 5.8 per cent.[190] There are a number of reasons for this:

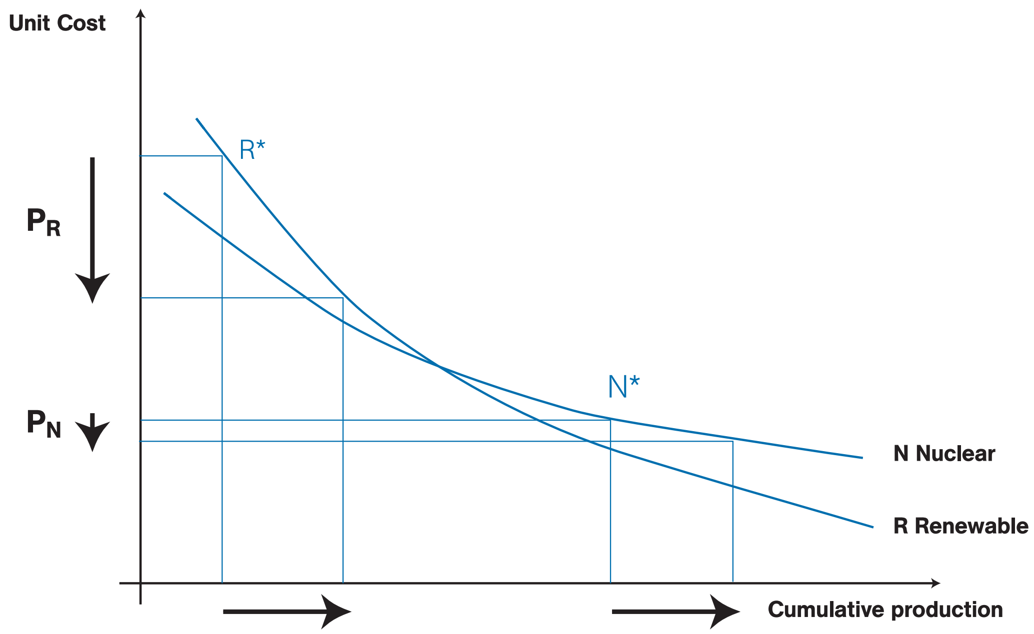
- Nuclear power stations are large, one-off projects, which need to be individually designed according to local conditions. This limits the scope for learning from one case to another, even where the same technology is used.
- The large scale of nuclear power stations means that relatively few units are built; and the scope for standardisation of components is more limited than in most other productive sectors (including energy sub-sectors). The resulting short production runs for components limit the potential for economies of scale through increasing production.
- As the current cases of Iran and North Korea demonstrate, the potential for international sharing of learning is limited by security considerations, and particularly concerns about nuclear proliferation. Such concerns also limit the potential scope for use of nuclear power as an alternative to fossil fuel use globally.
- The gestation period of construction for a nuclear power station is very long – at best several years – and extended still further by an extensive planning and approval process, necessary for safety reasons. This means that, where lessons are learned which could reduce production costs, there is a considerable built-in delay before they can be put into practice.
- Learning is further delayed by the need for rigorous safety assessments of any significant changes in technology or design.

This is a critical issue. The diversification away from fossil fuels is, by nature, a very long-term process. The implications of current decisions for the *future* costs of non-carbon production are therefore at least as important as the effects on current energy costs. The relevant consideration, therefore, is not limited to the immediate effect on energy prices, but the long-term effect into the indefinite future of producing energy from alternative non-carbon means.

By contrast, learning effects for renewable technologies have been found to be much higher – around 18–20 per cent for wind and PV. This reflects the more conventional nature of the production process, at least for wind and solar power, which is based on the production of a much larger number of more standardised units, with considerable scope both for learning and for economies of scale.

However, these headline figures seriously understate the scale of the differences they imply. In the case of renewable energy sources, if costs fall by 18–20 per cent for every doubling of cumulative production, it will take an increase in cumulative production by a factor of around 10 for costs to be halved. In the case of nuclear energy, with a learning effect of 5.8 per cent, costs would be halved only when

Figure 4: Learning curve and cost reductions for nuclear and renewable energy



cumulative production had been increased by a factor of more than 3,000. To underline this crucial point, it means that nuclear power is 300 times less efficient at lowering its costs compared to renewables.

A further issue arising in comparing nuclear power with renewable technologies, and particularly micro-renewables, is the relative maturity of these sectors. Empirical work on learning effects shows that cost reduction is proportional to the change in *cumulative* production. Since nuclear power has been operating on a substantial scale for half a century, new production increases cumulative production by a relatively small amount. Thus the 5.8 per cent learning effect is applied to a relatively small number, limiting cost reduction still further.

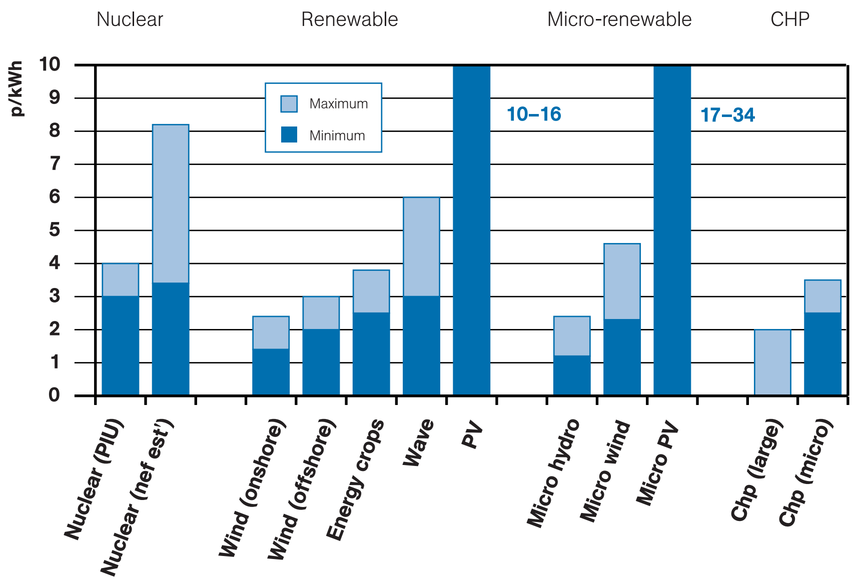
Most renewable technologies (except hydro), have thus far been much smaller in scale – and microrenewables still more so. As well as having much greater potential learning effects, increases in their production are therefore substantially larger relative to cumulative past production, so that these higher ratios are also applied to substantially larger numbers. The result is a much greater benefit in terms of reducing the cost of future non-carbon energy production.

Thus there are two distinct factors, each of which makes this consideration much more positive for microrenewables than for nuclear: first, the nuclear learning curve is shallower than that for microrenewables; and secondly that nuclear is further along the curve, which becomes progressively shallower as production increases (see Figure 4).

In other words, not only would halving nuclear prices require an increase in cumulative production 300 times as great as that for wind or PV, but the much greater production to date means that it would take many times longer to increase cumulative production by a given factor for nuclear than for renewables.

Even further, increasing the production of microrenewable capacity by a factor of 10 is more than plausible; it is probable. Increasing nuclear capacity by a factor of 3000, regardless of strictly limited supplies of uranium, is highly improbable and more likely impossible.

Figure 5: Projected electricity generation cost, 2020



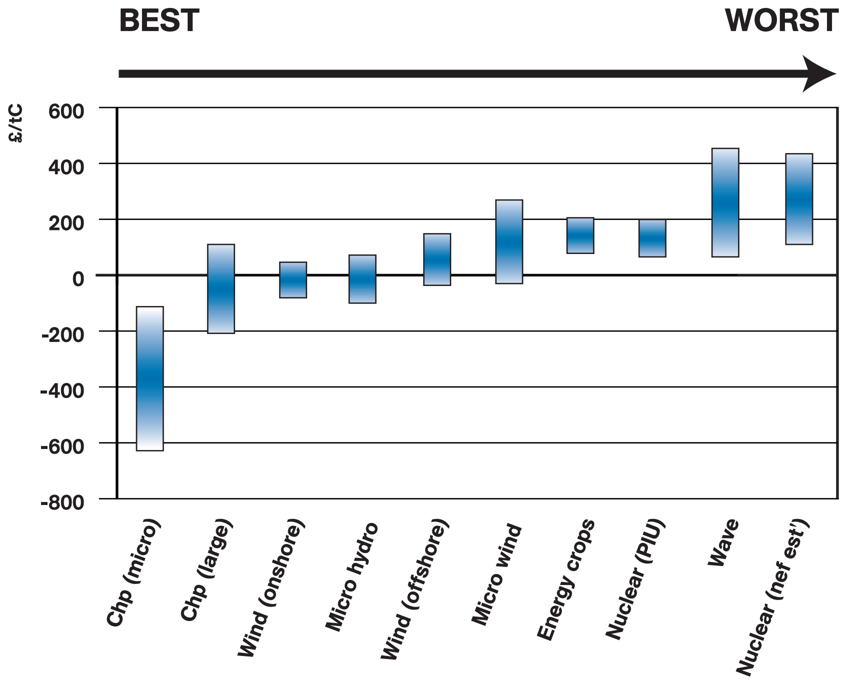
Source: PIU Energy Review (2002); DTI/ofgem (2004) Distributed Generation Coordinating Group, P02a Working Paper Three: The Economic Value of Micro Generation, Technical Steering Group *(except nef/nuclear – nef estimate)*

First it should be noted that the starting point for learning-curve effects, according to our calculations, is that the real cost of any new nuclear generation will be much higher than the industry-quoted figures. In Figure 4 the curve marked N represents the cost of producing electricity from nuclear power at a given level of cumulative production, and R is the corresponding curve for renewables. R* and N* show the current combination of cumulative production and costs in the renewable and nuclear industries respectively. It will be noted both that the N curve slopes down more slowly than the R curve (reflecting the smaller learning effect), and that N* is further along the curve than R*, so that the slope of the curve is still shallower. The result is that if production of renewables in a given year is Q, P_R reduces the cost of production substantially; but the same production from the nuclear sector will reduce cost by a much smaller amount, P_N.

Even though our figures show that renewables already generally represent better value than nuclear on a range of criteria, there is a still further powerful argument for much greater public investment into research and development with regard to renewables and microgeneration. According to analyst Robert Williams, “When new technologies are introduced into markets, their costs tend to be higher than the costs of the technologies they would displace. Early investments are needed to ‘buy down’ the costs of new technologies along their experience, or learning, curves to levels at which the technologies can be widely competitive. In principle, a firm introducing a new technology should consider experience effects when deciding how much to produce and consequently to ‘forward-price’: that is, it should initially sell at a loss to gain market share and thereby maximize profit over the entire production period. In the real world, however, the benefits of a firm’s production experience spill over to its competitors, so that the producing firm will forward-price less than the optimal amount from a societal perspective. That phenomenon provides a powerful rationale for public-sector support of technology cost buy-downs.”[191]

Even based on the PIU’s estimate of 3–4p/kWh for nuclear power, offshore wind (2–3p/kWh) is at least as cheap, and could cost as little as half as much; and onshore wind (1.5–2.5p/kWh) is between 17 per cent and 60 per cent cheaper. Large CHP is also at least 33 per cent cheaper. The cost range for nuclear energy overlaps with those for energy crops and mCHP, which may be slightly cheaper, and with wave power which may be somewhat more expensive. However, the corrected estimates for nuclear provided above suggest that it will almost certainly be substantially more expensive than any form of renewable energy with the

Figure 6: Cost of carbon saving, 2020



*Source: PIU Energy Review (2002), Table 6.1 (except **nef**/nuclear – **nef** estimate; microwind/hydro – **nef** estimates based on DTI/ofgem (2004) P02a WP3)*

exception of photovoltaic (which remains substantially more expensive in the UK) and possibly wave power.

Also included in Figure 5 are estimates for the cost of electricity from microrenewable energy sources. The maximum cost is that estimated by the Distributed Generation Coordinating Group Technical Steering Group in November 2004; the minimum assumes cost reductions of up to 50 per cent by 2020 as a result of learning effects. These figures suggest that micro-hydro is likely to be one of the lowest cost sources of electricity in 2020. While the cost reduction assumption may be over-optimistic in this case, it remains highly competitive even at the maximum level (i.e. with no cost reduction).

The estimate cost range for micro-wind power is broadly comparable with energy crops and the PIU estimates for nuclear power (though well below our estimates for the latter). MicroPV, however, is still more expensive than larger scale PV.

Figure 6 shows the corresponding figures for the cost of carbon savings, in pounds per tonne (excluding PV). This suggests that mCHP saves money as well as carbon, as may large-scale CHP, onshore wind and micro-hydro. Offshore wind and micro-wind power are in the middle of the range. Nuclear power is near the upper end of the scale even on the PIU figures, equal with energy crops at £70–200/tC, and cheaper only than wave power. On our revised estimate for nuclear, the cost rises to a range broadly corresponding with that of wave power (£110–430/tC), though still cheaper than PV (£520–£1,250/tC), and considerably cheaper than micro-PV (£1,450–£3,200/tC).

Figure 7 illustrates the effects of correcting the various sources of under-estimation of the maximum cost of nuclear power. Starting from the BNFL/BE estimate of 3p/kWh, averaging the costs of the first eight reactors adds 1.3p/kWh, as does substituting the IEA range for OECD construction costs, while 'first-of-a-kind' (FOAK) costs add about 0.1p/kWh, taking the figure to 5.7p/kWh. Allowing for delays and cost-overruns could add a further 1.8p/kWh, and lowering the assumed performance to current levels 0.8p/kWh, taking the total to 8.3p/kWh – 177 per cent above the BNFL/BE figure.

Figure 7: The escalating cost of nuclear power (excluding insurance, pollution and terrorist risk)

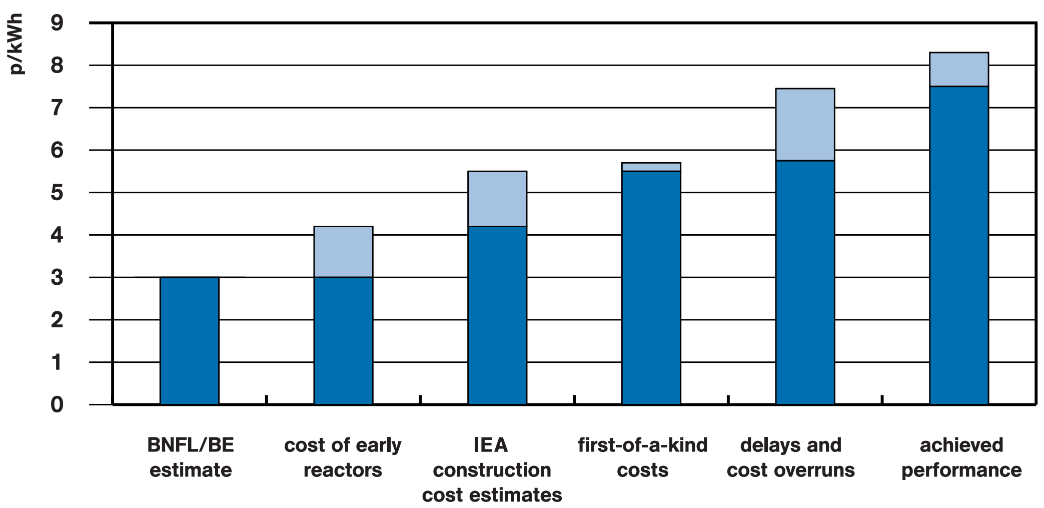


Table 4: Job creation in the energy production industries	
Sector	***Jobs – year / TWh (fuel production and power generation)***
Petroleum	260
Offshore oil	265
Natural gas	250
Coal	370
Nuclear	75
Wood energy	733 – 1067
Hydro	250
Mini hydro	120
Wind	918 – 2,400
Bioenergy (i.e.: sugarcane)	3,711 – 5,392

Source: Goldemberg (2004)[192]

The nuclear industry is highly capital intensive and one of the least labour-intensive methods of energy generation. Due to technological changes, any new cycle of nuclear power stations would employ fewer people than existing plants. Renewable energy, on the other hand, has rich potential for job creation.

The European Commission estimated that the predicted growth in the renewable energy sector would create nearly one million (900,000) new jobs by 2020, with at least 15,000 being created in the UK.[193]

Conclusion

Nuclear power has been promoted as a solution to climate change and an answer to energy security. It is neither. On the one hand, as a response to global warming it is too slow, too expensive and too limited. On the other hand, it is more of a security risk in an age of terror-related threats, than a security solution.

> *"We deplore the minimal amounts that the Government have committed to renewable energy related R&D (£12.2 million in 2002–03); the comparable figure for the US is $250 million for 2004–05. If resources other than wind are to be exploited in the United Kingdom this has to change."*
>
> House of Lords, Science and Technology Committee 2004

> *"Government funding should be focused on energy efficiency and renewables, as they have the highest long-term potential to deliver a low carbon economy at the lowest overall cost."*
>
> The Carbon Trust, Submission to the Government's energy policy consultation, 2002

In spite of newspaper headlines suggesting a come-back for nuclear power, this report finds no substance to claims that it has an increased role to play in a flexible, safe, secure and climate friendly energy supply system. These, in fact, are the characteristics of renewable energy, which is abundant and cheap to harvest both in the UK and globally. Successive investigations by Government and Parliament have come to similar conclusions. The opposite conclusion is only possible if renewable energy technologies are negatively misrepresented, and if the numerous weaknesses, high costs and unsolved problems of nuclear power are glossed over.

The Government is committed to 'evidence-based policy'. This alone should rule out a nuclear comeback. The limited criteria of cost and security are enough to direct the UK down the path of renewable energy. By adding further, meaningful criteria to an assessment of energy choices, such a decision is merely confirmed. It is beyond the scope of this report to carry out a fully comprehensive energy path analysis, but not beyond its scope to recommend that such an analysis be carried out. The energy assessment grid illustrates what such an analysis could include (see Table 5).

Cost and the economic return on investment are issues at the top of many people's lists. Using unadjusted figures most renewables can outperform nuclear power. Using more realistic figures for the cost of nuclear power leaves renewables easily the better choice.

Renewables are quicker to build. They also need less energy pumped in for every unit of power subsequently generated. Because renewables also generate far more jobs than nuclear power, they contribute much more to broad-based economic development both at home in the UK and abroad. Importantly, renewables don't leave a legacy of radioactive waste that endures in the environment for tens of thousands of years.

It is clear that a new wave of nuclear power stations could only be built with some form of large public subsidy. But given that the public purse has limited resources, the Government must make the best investment on the taxpayers' behalf. In this case, the danger is that the huge and unpredictable costs of nuclear power will crowd out vital investment into renewable energy, as it has done for decades already.

In order to re-level the economic playing field for renewables two things are needed. First the Government should remove the existing direct and indirect subsidies to nuclear power that 'feather bed' its prospects. Secondly, in order that they achieve their full potential, public support to renewables should rise to match the levels historically enjoyed by nuclear power.

In a recently issued manifesto the Renewable Power Association (RPA) called for particular fiscal measures that would, it said, deliver the best value for money.[194] These include:

- Extending Enhanced Capital Allowances to all renewables.
- Reducing VAT on wood-fuel boilers and other domestic-scale renewables.
- Introducing Stamp Duty concessions for buildings with renewables.
- Enhancing tax allowances for all renewable investments.
- A Cabinet-level Energy Minister.

A private members' bill on renewable energy, introduced earlier this year by Lord Redesdale, called for *all electricity suppliers to be obliged to purchase electricity from microgenerators.* It went further to require local authorities to set targets for their take up and categorise certain types of microgenerator as 'permitted developments', *"putting them into the same category as swimming pools and satellite dishes."*[195]

On the international stage, there is the need for an *International Agency for Renewable Energy* to represent the sector at the global level and to balance the already existing nuclear equivalents.

An unacknowledged benefit of microgeneration is that it puts people back in touch with where energy comes from. We have taken fossil fuels for granted for too long, and ignored the importance of living in balance with the ecosystems upon which we depend. Renewable energy is a great reminder that also offers us the chance for greater independence. It is possible that nuclear power has only survived for as long as it has because its true costs have been hidden from us, and because its radioactive emissions are invisible.

The potential for a climate friendly, non-nuclear energy supply system has been acknowledged by extensive research carried out across Government, Parliament, the Royal Commission on Environmental Pollution, to the wider research community and civil society. There is now an opportunity and a need to make it happen.

Table 5: Energy assessment grid: Proposed comprehensive energy path assessment grid with estimated, illustrative scores for nuclear and wind (0 is the lowest score, 5 the highest)

Source	***Coal***	***Oil***	***Gas***	***CHP***		***Nuclear***	***Micro/Small***	***Hydro***			***Wind***	***Wave***	***Tidal***	***Solar***	
Factor				*chp*	*dchp*			*Onshore*	*Offshore*	*Micro*				*Thermal*	*PV*
Cost						1		4	3	2					
Supply potential[1]						2		3	5	2					
Security[2]						0		5	5	5					
Climate solution[3]						1		5	5	3					
Energy gain[4]						3		5	4	3					
Waste						0		5	5	5					
Job creation						1		5	5	5					
Flexibility[5]						0		4	3	3					
Independence[6]						2		5	5	5					
Score (weighted)															

1 Considers whether the resource is renewable or not and the ease of access to the resource.

2 Considers the overall security implications of the energy technology, both vulnerability to attack, potential to contribute to wider security problems such as conflict and nuclear proliferation, as well as any negative impact on domestic civil liberties considered necessary for protection of the source/technology.

3 Considers the carbon intensity of the technology but also its potential to effect carbon savings within the timeframe considered necessary.

4 A measure of the energy return on the energy invested.

5 Considers flexibility in terms of sites for installation and supply; nuclear power's score is low because of the limited number of appropriate sites and its inflexible method of generation.

6 Considers contribution to national energy sovereignty; nuclear power's illustrative score is low because of the international nature of the industry.

Glossary

CHP	Combined Heat and Power
CO_2e	carbon dioxide equivalent
GW	gigawatt = 1,000MW
GWe	gigawatt electric power
GWh	gigawatthour = 1,000 MWh
Energy	energy = power x time
kW	kilowatt = 1,000W
kWh	kilowatt hour = the energy of a 1kW device running for 1 hour or a 100W device running for 10 hours
kWe	kilowatt electric power
kWp	peak kilowatt
LV	low voltage
Mt	million metric tonnes
Mtoe	million tonnes of oil equivalent (1 toe = 11,630kWh)
MW	megawatt = 1,000kW
MWh	megawatt hour = 1,000kWh
MWe	megawatt electric power
PV	photovoltaics
TW	terawatt = 1,000GWe
TWh	terawatt hour = 1,000GWh
V	voltage: the force of an electric current, measured in volts
volt	the standard unit used to measure how strongly an electrical current is sent around an electrical system
W	watt: a unit of power

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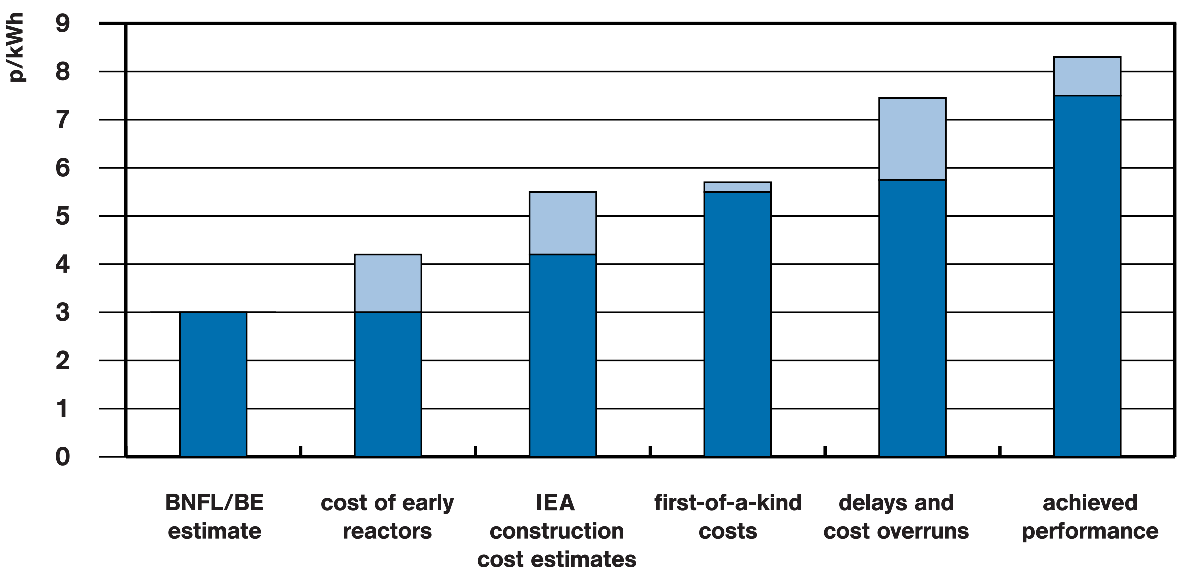
The escalating cost of nuclear power (excluding insurance, pollution and terrorist risk)



According to this report, the true costs of nuclear power have been seriously underestimated. This figure illustrates the effects of correcting the various underestimates. It starts from the UK industry estimate of 3p/kWh. Taking an average cost for the first eight reactors that would be built in a programme of new nuclear power stations, however, adds 1.3p/kWh. So does substituting the International Energy Agency range for typical construction costs in wealthy OECD countries. So called 'first-of-a-kind' costs – inevitable given the fact that any new stations would incorporate substantially new designs – add about 0.1p/kWh, taking the figure to 5.7p/kWh. Allowing for delays and cost-overruns of the sort typical for the industry could add a further 1.8p/kWh, and lowering the assumed performance to levels that have actually been achieved in practice adds another 0.8p/kWh, taking the total to 8.3p/kWh, nearly three times the industry estimate. Tellingly, these costs do not factor in the wider risks associated with nuclear power such as terrorism, the danger of proliferation and accidents.

Written by Andrew Simms, Petra Kjell and David Woodward

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