June 2006

Friends of the Earth

Briefing

Nuclear power, climate change and the Energy Review

"Tony Blair's determination to restart nuclear ordering cannot be overestimated. But practical problems are immense and it should be remembered that Margaret Thatcher, elected on a very pro-nuclear agenda, presided over an almost terminal decline in the fortunes of nuclear power in Britain."[1]

UK emissions of carbon dioxide are growing. Indigenous supplies of oil and gas are running out. Industry lobbyists and media commentators are warning that we face an imminent 'energy gap'. They are calling for a new nuclear programme to replace Britain's ageing reactors – so that we can maintain energy supplies and cut emissions. The Prime Minister, Tony Blair, has ordered a review of energy policy and seems determined to encourage the building of new reactors.

This briefing looks at the sort of reactors that might be built in the UK and assesses the importance of a new nuclear programme for maintaining energy supplies and reducing emissions. It considers the likely cost of a new reactor programme and the impact that new reactors would have on nuclear waste and public safety. Finally, it looks at alternative ways of bridging the 'energy gap' and at the impact that our energy choices might have on other countries.

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An 'energy gap'?

A significant part of the UK's electricity generating capacity will be lost over the next twenty years, as coal and nuclear stations are closed for environmental, economic and engineering reasons. As of 2004, the total generating capacity of Britain's power stations was 80 gigawatts (GW), easily enough to meet our peak demand of about 55 GW. This comprised 22 GW of coal, 11 GW of nuclear and 25 GW of natural gas, with the remainder being oil, renewable or hydro-electric plants[2]. By 2010 all of Britain's 'Magnox' nuclear stations, with a capacity of 2.54 GW, will be closed. By 2023, all our 14 Advanced Gas-cooled nuclear Reactors (AGRs), with a capacity of 9.16 GW, are also scheduled to be shut down. Meanwhile, the European Union's Large Combustion Plant Directive will force many coal-fired stations to fit pollution-control equipment. Some older plants may close down instead. Electricité de France suggests that this figure could be much higher, with 19 GW shut by 2016[3]. However Oxera says that only six GW of coal-fired power stations are likely to close by 2020[4].

On the face of it, this suggests that capacity in 2023 may be at least six GW less than required at peak times. Calculations like this have fuelled industry fears and led to calls that a new generation of reactors should be built to "replace nuclear with nuclear". However, the issue is not so simple. Some of the Advanced Gas-cooled nuclear Reactors may not close when scheduled. The oldest, Dungeness B, was granted a 10 year life extension in 2005. British Energy, which owns these reactors, is applying or is expected to apply for similar life extensions for the others, on a case by case basis. Also, more than 31 GW of new power generating capacity is forecast to come on line by 2010. This includes 21 GW of renewable power, mostly onshore and offshore wind. On the other hand, 80% of this proposed new capacity has yet to be given planning permission and only 3% (0.95 GW) is actually under construction[5]. And, of course, we must also consider the scope for energy efficiency.

Clearly, Britain will need some new electricity generating capacity over the next twenty years. But the amount needed and when it is needed is not as clear as nuclear lobbyists claim. Fears of an impending 'energy gap' could prove unfounded.

When could new nuclear plants be built?

The process of approving and building nuclear power plants is complicated and time-consuming. Fourteen years elapsed between the time Britain's last reactor, Sizewell B, was first conceived, in January 1981, and the time it first generated power in February 1995. Roughly half of this time was spent in gaining the necessary approvals[6] and half in actual construction[7].

Nuclear lobbyists claim that changes to planning processes, coupled with new reactor designs, will cut the total licensing and construction time to 10 years and that a first reactor might be in operation by 2015. Other independent experts disagree, saying that a first reactor is unlikely to be operational before 2021[8].

Of course, this is just the timing for the first reactor. Nuclear advocates suggest that the UK should build 10 or more reactors to 'replace nuclear with nuclear'. These could not all be built at once and a construction programme would therefore extend over at least a decade. A new reactor programme involving any increase in nuclear capacity is unlikely to be completed much before 2030.

The Energy Review

In the face of rising carbon dioxide emissions, and under pressure from nuclear lobbyists, the Prime Minister, Tony Blair, announced a new review of energy policy on 29 November 2005[9]. On 23 January, 2006, Energy Minister, Malcolm Wickes launched a public consultation which closed on 14 April[10].

Mr. Wickes aims, following the consultation, to bring forward proposals for further consultation by the summer. Decisions that might pave the way for a new nuclear programme are expected by the end of 2006. In any case, the Government promised, in its last Energy White Paper that: "before any decision to proceed with the building of new nuclear power stations, there would need to be the fullest public consultation and the publication of a white paper setting out the Government's proposals"[11].

Planning for new nuclear build

There is nothing to stop an electricity generator from applying to build a new nuclear power plant tomorrow. To start construction, it would need a number of permissions that could be sought simultaneously:

- **Electricity Act Consent.** This is required under Section 36 (generation) and Section 37 (transmission) of the Electricity Act 1989 and is granted by either the DTI (for England and Wales) or the Scottish Executive. Permissions are required for the construction of new electricity generating capacity over 50 megawatts and recent, non-nuclear experience suggests that the process takes two to three years and may or may not involve a public inquiry[12]. The issues considered during the consent process are[13]:
    - Current energy policy
    - Current planning policy, including plans at local and regional level
    - Environmental and health impacts, including safety, arising from the environmental impact assessment process required under European law.

  It is unthinkable that an application to build a new nuclear power plant would be approved without a public inquiry. In the case of Sizewell B, the public inquiry took 340 days over two years. 50 days were devoted to “policy”, 120 days to the “need and economics”, 100 days to “design and safety issues” and only about 30 days to “local issues”. The Hinkley C inquiry took evidence for 182 days[14]. Since then, some public inquires, albeit not for power stations, have taken even longer. The longest, for the construction of a fifth terminal at Heathrow, took 46 months.

Most of the time at planning inquiries is taken up by the proponents giving evidence and by the statutory objectors, like the Environment Agency, rather than individuals or specialist interest groups. Much of the whole planning process is taken up by the preparation of studies into the proposal’s impacts, the writing of the inspector’s report and then its review by the Government, rather than by the inquiry itself.

- **Nuclear Site License.** This is required under the Nuclear Installations Act (1965 as amended)[15]. It is granted by the Health and Safety Executive (HSE) and is specific to the particular operator, site and operations being undertaken. The licensing process involves lengthy discussions between the operator and HSE to determine that the operations are justified and to develop and refine the operator’s safety management capability and practices until HSE is satisfied that the plant will be run as safely as is reasonably practicable. A senior source in the HSE’s Nuclear Installations Inspectorate (NII) told Nucleonics Week, that “it might be possible to complete the whole process in about three years – from initial request to granting a licence – although this could well increase if problems were found with the safety case during NII’s assessment”. However “for a completely novel design, the resources requirements – and the time taken- could be significantly greater”[16].
- **Waste Authorisation License.** This would be granted by the Environment Agency, under the Radioactive Substances Act (1993). It would authorise any discharges of radioactive materials to the air, rivers or sea as well as the disposal of its solid radioactive waste.
- **Security and transport.** The Office for Civil Nuclear Security and the Department for Transport regulate on-site security and the movement of nuclear materials respectively. They need to approve the procedures of the generator.

The nuclear industry would like to see the approvals process streamlined. Keith Parker, the chief executive of the Nuclear Industry Association, has said that "there have to be some enabling measures to give the right signal to investors. For example, there is no way investors are going to be interested when it takes six years to get planning permission for a new plant, so reform of planning law would be a good start"[17].

The Energy Review therefore includes discussions on changes to planning and regulatory procedures. However, it is not clear that any changes will be agreed. On 21st March, Malcolm Wickes challenged the nuclear industry, saying “you are calling for greater certainty over licensing. You are calling for shorter planning processes. You are calling for the scope of planning inquiries to be restricted. But my challenge to you then is to show me how this might work in practice. How might you achieve these things while still maintaining the same high levels of scrutiny and safeguards we have now?”[18]

One change that is being considered is the pre-licensing of particular reactor types. The Health and Safety Executive (HSE) announced, in January 2006, that it will review the potential for pre-licencing of a new generation of reactors[19]. In essence a particular reactor type might be approved for use, in principle, by the Nuclear Installations Inspectorate before particular sites are chosen. The nuclear industry is calling for this process to start prior to any decision by the Government on whether or not to encourage further nuclear construction. This would enable the constructors of a number of designs, probably the AP 1000 and the EPR, to submit them for review in case the Government proceeds with support further nuclear construction.

In its submission to the Energy Review, Electricité de France also called for the Nuclear Installations Inspectorate to undertake a separate pre-licensing assessment of potential sites. This would therefore speed up any consultation of any actually proposed reactor[20].

However, these and other changes in planning and regulatory procedures will themselves take time to implement, if agreed. They might need new legislation – and scarce parliamentary time. Even if agreed, new procedures will take time to implement. For example, the pre-licensing of a particular reactor might take up to three years. And depending on the changes proposed, other regulatory requirements are likely to come into play, such as the European Directive 2001/42/EC which requires Member States to carry out strategic environmental assessment on certain plans and programmes that they promote.

And, of course, planning and regulatory approval is only one half of the process. Construction itself is expected to take 60 months, or five years. Experience has shown that construction times are often much longer in practice than on paper.

Conclusion

Expert opinion suggests that no new reactors could be built in the UK for at least ten years and that a first reactor will probably not be completed for at least fifteen.

Reforms to speed up the approvals process will themselves take time to implement and may be detrimental to the democratic process and potentially dangerous.

What sort of new reactors might be built?

There were currently 441 nuclear reactors generating electricity in 32 countries around the world[21]. These come in many different sizes and dozens of different designs. To simplify matters, nuclear engineers talk of four broad categories of nuclear reactors that are currently deployed or under development.

Generation I reactors were the first commercial reactors developed in the 1950s and 1960s. They are modified and enlarged military reactors that were originally designed either for submarine propulsion or plutonium production. Britain’s first nuclear power plants, using Magnox reactors, were of this type and arose directly out of the military need for plutonium for nuclear weapons. Military designs were then modified and their size increased to produce greater quantities of electricity. Only four Magnox power plants are still in operation[22].

Generation II reactors include the vast majority of the reactors in commercial operation worldwide. The British Advanced Gas-cooled Reactors (AGRs) and the Pressurised Water Reactor (PWR) at Sizewell come into this category.

Generation III reactors are now being built in some countries, notably Japan. They are mostly supposedly cheaper variants of Generation II designs and include designs like the European Pressurized Reactor (EPR), developed by the French company, Areva, and the AP1000, developed by Westinghouse plc.

Finally, **Generation IV reactors** are currently being developed with the objective of commercialisation around 20-30 years from now, although many see this as optimistic. They include revolutionary designs such as the Pebble Bed Modular Reactor.

Any future reactors built in the UK over the next couple of decades are likely to be third generation reactors, most probably the EPR or the AP1000. That means that they will be a different design to the reactors that currently operate in the UK, or in fact anywhere in the world.

Generation IV

In December 2005 Energy Minister, Malcolm Wicks announced that the Department of Trade and Industry had allocated £10 million (£5 million in 2006-07 and £5 million in 2007-08) to support UK involvement in international research on advanced nuclear energy systems. Much of this is expected to fund UK research on Generation IV designs, as part of a US-led initiative with nine other countries[23]. Six major concepts are being developed. The majority of these incorporate some use of plutonium, requiring a so-called "closed fuel" cycle, whereby fuel used in reactors is reprocessed to extract its plutonium which is then used to make more fuel. This is in contrast to current practice in most countries, whereby used nuclear fuel is repackaged and sent for long term storage or disposal – a "once-through" cycle. It has significant implications for proliferation, particularly if these reactors are widely deployed around the world, as plutonium can be used to make nuclear weapons. The Oxford Energy Group says 'The consequences of the widespread use of Generation IV reactors for nuclear-weapon proliferation and the risk of nuclear terrorism are very serious indeed"[24]. Reprocessing is also polluting and potentially hazardous as its radioactive residues are particularly vulnerable to terrorist attack.

European Pressurized Water Reactor (EPR)

The EPR is a modification of the German and French pressurised water reactors built in the 1980s and 1990s. No EPR has yet been built anywhere in the world. Only one is even under construction, at Olkiluoto in Finland, where formal 'ground breaking' for construction began in September 2005, with opening due in 2009. However, despite the fact that construction only started just over a year ago, technical problems, in particular with the concrete used in the foundations, have already led to a nine month delay in the construction schedule[25].

Despite the design modifications there are still a number of questions over the safety of the EPR. Its supporters claim that: "the new PWRs with a containment dome are proof against a design basis threat that generally includes hijacked airliner crashes"[26]. But documents, submitted in Finland, on the EPR's ability to withstand the impact of a commercial airline are classified[27]. Concerns have also been raised over the digital instrument and control technology that is to be deployed. Similar systems were used in Germany and at Sizewell B and both had problems which impacted upon safety[28].

AP 1000

The AP (for Advanced Passive) 1000 megawatt reactor is a scaled up variant, by Westinghouse, of a previous Westinghouse design, the AP600. Neither has ever been built anywhere in the world, although the designs of both have now been approved in principle for construction in the United States. It is claimed that the AP 600 design has some safety improvement over current reactors but these gains are largely offset by steps taken to reduce its construction costs. The AP 600 design was found to be uneconomic and was transformed into the AP1000, by increasing the power output by 80 per cent while construction costs increased by only 20 per cent. As a result, the AP1000 has a ratio of containment volume to thermal power below that of most current pressurized water reactors, increasing the risk of containment overpressure and failure in a severe accident[29].

Nuclear Fusion

Conventional nuclear technology uses fission, the splitting of atoms of heavy metals, to generate energy. Nuclear fusion merges small atoms to create energy. It is the process that makes the sun shine. For decades, researchers have been trying to start this process in a controlled fashion (uncontrolled nuclear fusion has been possible since the Americans invented the hydrogen bomb). The latest attempt is the International Thermonuclear Experimental Reactor (ITER), a €10 billion (£6.5 billion) project, to be located in France. The technological, environmental and economic problems of fusion technology are huge and maybe insurmountable. The European Union's EURATOM Scientific and Technical Committee recently said it would be twenty years before anyone could say whether fusion will be a viable option for electricity supply in the 21st century[30]. Others suggest that fusion is a "long term energy option", which will not be commercial until the second half of the 21st Century[31].

Conclusion

New reactors ordered for the UK are likely to be of designs that have yet to be built anywhere in the world. Even on paper, these designs appear to be vulnerable to terrorist attack. Supposed safety enhancements appear to be undermined by measures designed to cut costs.

What would be the effect of a new nuclear programme on climate-changing emissions?

Climate change is the greatest environmental threat facing humanity. The burning of fossil fuels and the production of specific chemicals is causing a gradual increase in the global temperature, which in turn is causing sea levels to rise and leading, in different places, both to more droughts, more flooding and more intense storms.

Under the Kyoto Protocol, the UK is required to reduce its climate-changing emissions by 12.5% from 1990 levels by 2008-12. However, the Government has pledged to go further and cut CO2 emissions by 20% of 1990 levels by 2010. Furthermore, it has set a long term target to cut carbon dioxide emissions by 60% from 1990 levels by 2050 in order to lead to a global stabilisation of temperatures.

Evidence suggests that many of the worst effects of climate change could be avoided if the rise in global average temperatures is kept below 2°C above pre-industrial levels[32]. The European Union has set an objective on this basis[33].

To ensure a reasonable chance achieving this target, the concentrations of CO2 in the atmosphere must stabilise at about 400 parts per million in the atmosphere in the longer term[34]. Global emissions must start to fall in the next 10-15 years and halve by around 2050[35]. As the UK is relatively wealthy and emits more than our fair share of the global total, our emissions must fall faster - by about three per cent a year until 80% cuts are achieved on 1990 levels by 2050.

The contribution of nuclear power

Electricity generation using nuclear power does not lead directly to emissions of carbon dioxide or other greenhouse gases. Yet nuclear power cannot be considered to be carbon-neutral. Fossil fuels are burnt in the mining, milling, transport and enrichment of uranium, in the making of fuel rods and in the removal and reprocessing, storage and/or disposal of spent fuel. Nuclear power's contribution to climate change therefore needs to be considered on a life-cycle basis.

This has been done on many occasions and the general consensus is that nuclear power generation emits far less carbon dioxide than electricity generation from gas or coal[36]. Broadly speaking, emissions savings from switching from fossil fuels to nuclear are comparable with the switch to renewable energy but not as great as the savings that can be achieved through by energy efficiency. However, calculations suggest that life-cycle emissions from nuclear power will rise if high-grade uranium ores become exhausted and lower grade ores have to be used[37].

This potential contribution also has to be seen in the context of overall emissions. Nuclear power currently generates about a quarter of our electricity. Yet electricity generation is responsible for less than a third of the carbon dioxide emissions in the UK's inventory. Most of the remaining carbon dioxide emissions result from energy use from heat and surface transport. Carbon dioxide, itself, is responsible for about five-sixths of the emissions in the inventory (the rest being emissions of methane, nitrous oxides and various industrial gases). Meanwhile, emissions from international aircraft and shipping are not included in the inventory at all! If they were, the inventory would be about a fifth larger than it is. As nuclear power can only currently be used for electricity generation, it will be at most a bit player in our strategy to reduce emissions.

The Sustainable Development Commission has recently calculated the effect of two scenarios for the development of nuclear power in the UK[38]. The first scenario involves replacing existing nuclear generation with new nuclear capacity, by building new reactors sequentially from 2015-2024. The second extends this programme till 2034 when the contribution of nuclear power would be double what it is today.

These calculations suggest that replacing existing nuclear power plants with new nuclear plants might reduce overall emissions in 2020 by 2.4 per cent and overall emissions in 2030 by 4.1 per cent. An extended programme to expand the contribution of nuclear power might cut overall emissions by 6.5 per cent in 2030 and 8.1 per cent by 2050.

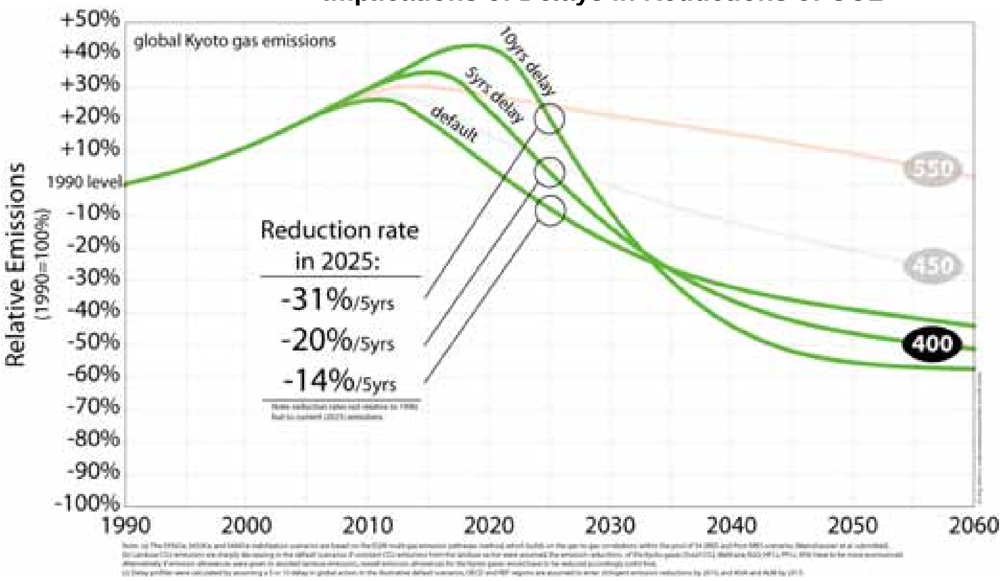
Clearly, energy efficiency and renewable energy will have to be the key means of reducing emissions, even if a new nuclear programme goes ahead.

The timing of nuclear's contribution

The timing of emissions reductions is almost as important as their depth. Carbon dioxide stays in the atmosphere for an average of about 100 years. That means emissions in 2000 will still be having an effect in 2100. Cutting emissions quickly means that the cumulative amount of carbon dioxide in the atmosphere is reduced and overall warming effect minimised. Starting emission savings as soon as possible means that cuts can be made at a slow, steady rate.

Meinshausen has shown that delaying the onset of emissions reductions will mean that deeper cuts will have to be made in later years to ensure a given atmospheric concentration is not exceeded. A delay of ten years will require a 31% cut in emissions from 2022-2027 whereas only a 14% cut will be needed if action is taken now.

Implications of Delays in Reductions of CO2



Source: Malte Meinshausen[39]

As a consequence, priority must be given to technologies that can be implemented quickly. Building new nuclear power plants takes time and energy that will actually increase emissions, albeit marginally, in the years before the plants open. It is therefore an even less helpful contributor than the savings that can be achieved in later years suggest.

How much would a new nuclear programme cost?

"Nuclear Power, which early advocates thought would be 'too cheap to meter', is more likely to be remembered as too costly to matter". The Economist[40]

Electricity in Britain is provided through a liberalised market. Private generating companies decide whether to build power plants. They may then supply consumers themselves or sell the electricity on to another supplier. Not all generators supply consumers and not all suppliers generate their own electricity.

Cost is expected to be a key factor in any Government decision to favour a new nuclear programme. However, the costs of building new power plants have to be seen from the perspective of private investors, as the Government won't build the power plants itself.

Experience to date suggests the private sector is wary of investing in nuclear power. Energy market liberalisation in Britain in the late 1980s stopped the industry's planned expansion in its tracks as the sector was forced to reveal the extent of its financial failings. This phenomenon has not been restricted to the UK. As one trade journal warned in the 1990s "deregulation of the European markets could represent an even bigger threat to the future of nuclear power than anti-nuclear ideologues"[41].

But, today, the nuclear industry is actively promoting itself, claiming once again that it is a cheap option. A report from the World Nuclear Association says that "the economic case favouring new nuclear build is now virtually universal. Nuclear energy today represents an affordable, economically competitive means to meet the world's growing demand for electricity"[42]. However, this view is not shared by many independent financial institutions.

Past UK experience

The UK does not have a good history of building nuclear reactors to time and cost.

- The last time Britain built a series of nuclear power plants, the Advanced Gas-cooled Reactors (AGRs), each was slightly different to the last. They took an average of nearly 13 years from start of construction to first power. Design changes and construction delays lead to increased costs. The costs of the Torness reactor in Scotland soared £742 million to a final cost £2500 million[43].
- Britain's most recent experience was with the Sizewell Pressurized Water Reactor (PWR). It took seven years to approve and another seven to build[44]. Its capital costs rose from £1,691m to £3,700m - £3,810m[45].

Cost over-runs and delays have also dogged other nuclear investments.

- The Thermal Oxide Reprocessing Plant at Sellafield was expected to cost £300m when it was considered at public inquiry in 1977. It was supposed to start operating in 1987, but was completed five years' late. By 1992, costs had risen to £1.8 billion. With the additional costs of associated facilities, including new waste treatment buildings, the total bill reached £2.8 billion[46].
- Similar problems have occurred at the Sellafield MOX Plant (which is supposed to fabricate fuel rods using the plutonium separated during reprocessing). The £460 million plant was completed in 1997 and finally given approval for operation in October 2001. However, today it has still not worked properly and hasn't produced a single MOX fuel element.

As one utility said in 2005, the general rule of thumb is to double any costs estimates from the nuclear industry in the UK[47].

The experience of Britain's private sector nuclear operators has been equally problematic.

- Attempts in 1989, to privatise the nuclear sector had to be abandoned due to lack of interest from the City. Seven years later, following extensive reviews, the Advanced

Gas-cooled Reactors and the Sizewell Pressurised Water Reactor were finally sold off to form British Energy. But the sale only fetched £2.1 billion, despite the fact that the Sizewell PWR alone had cost £3 billion to build and had only entered commercial operation one year before. The older 'Magnox' reactors couldn't be sold and remained in public ownership.

- British Energy survived the rigours of the market for just six years before collapsing spectacularly in 2002. Its inflexibility caused its revenues to fall during a period of low electricity prices. As it became clear that its income could not keep pace with its liabilities, its share-price plummeted to 3.5p (from a high of 744p three years earlier). It was forced to beg for a Government loan of £650 million to avoid going into receivership and was only saved by comprehensive restructuring which was equivalent at the time of a cash payment of about £5 billion[48]. Existing shareholders lost virtually their entire investment.

International Experience.

The UK is not unique in its inability to construct nuclear power plants to time and budget. The World Bank said in 1991 that one reason why it didn't fund nuclear power was that "the cost figures usually cited by suppliers are substantially underestimated and often fail to take into account waste disposal, decommissioning, and other environmental costs"[49].

Since then, a slow down in the construction of nuclear power plants worldwide has meant that less recent construction data is available. However, Japanese experience shows that cost overruns are still likely. General Electric estimated that its new 1300 MW Advanced Boiling Water Reactor would cost $1528 per kilowatt to build. However, when two were ordered for Tokyo Electric Power Company, the costs per kilowatt were $3236 and $2800 respectively[50].

Work has started on the first European Pressurized Water reactor at Olkiluoto in Finland. This 1600 MW reactor, when it was ordered, was estimated to cost between €1500-1800 per kilowatt[51]. However, experts claim that this price is artificially low. The European Renewable Energy Federation (EREF) has complained to the European Commission over the reactor's financing. EREF argues that €710 million of export credit guarantees from the French and Finnish governments and a €1.95 billion loan, at an interest rate of only 2.6%, from the public Bayerische Landesbank and other financial institutions constitute unlawful State Aid. The quoted price for a similar reactor in France is reported to be about 25% higher per installed kilowatt than the cost of the Finnish reactor[52].

Likely costs in the UK

New reactors built in the UK are likely to be either the Westinghouse AP 1000 or the European Pressurized Water Reactor (EPR). Neither of these have been built anywhere in the world, so any suggested final costs are purely theoretical.

Uncertainty over the scale of any future nuclear programme and the type of reactors that might be built makes it very difficult to estimate the likely costs or to compare them with the costs of alternative ways of cutting emissions. Comparison is made more difficult by the very big differences between the economics of nuclear generation and the economics of alternative energy sources.

- Nuclear power plants cost a lot to build but are then relatively cheap to operate. They are expensive to decommission (and no one knows the full cost of managing their long-lived wastes). Wind turbines are also costly to build but cheap to run. Conversely, gas-fired power plants are fairly cheap to build and decommission but comparatively costly to operate.

- Costs of all power plants fall if larger plants are built and if they are built in series. But, to stand a chance of being cost effective, nuclear reactors have to be bigger than gas-fired plant and much bigger than wind turbines. As a result, the scope for reducing costs by building a large number is lower.

- Nuclear power plants cannot easily vary their output or be switched off. They produce a constant supply of electricity regardless of whether it is needed or not. This means their operators cannot take advantage of short-term variations in the price of electricity. By comparison, hydro-electric plants can vary their output within a few minutes and can take advantage of short-term price changes. Gas-fired plants are not as flexible as hydroelectric but can still vary their output on a daily basis. Conversely, nuclear power plants are, in theory, able to predict their output and can sell their electricity years in advance.

- Nuclear power plants, gas and coal-fired plants and some renewable sources of energy rely on a centralised national grid to distribute electricity around the country. The costs of new grid investment and the loss of electricity as it is moved around the country need to be included in the costs of these technologies. Conversely smaller technologies such as small hydro, micro-wind turbines and electricity generating gas boilers can generate electricity directly where it used.

- Nuclear power plants are built to last 40 or more years. As they are so large and last so long, the number built is relatively small and the number of companies involved very small. This limits competition, the scope for innovation and the rate at which technology can be improved, especially if series of nearly identical reactors are built. Conversely, because so many wind turbines are built, the scope for competition and the potential for design improvements and rapid innovation are much greater.

These factors make it difficult to properly compare the costs of a new nuclear programme with the costs of alternatives. Nevertheless, a specialist unit in the UK Cabinet Office did review the economics of nuclear power in Britain in 2002 as part of the Government's review of energy policy leading to the White Paper of 2003. This independent analysis suggested that by 2020, nuclear power would be more expensive than on shore and offshore wind, most energy from biomass and virtually all micro combined heat and power plants.[53]

- Nuclear Power: 3.0-4.5 p/kWh
- Onshore-Wind: 1.5-2.4 p/kWh
- Offshore-Wind: 2.0-3.0 p/kWh
- Energy crops: 2.5-4.0 p/kWh
- Micro Combined Heat and Power (household power generators) : 2.5-3.5 p/kWh

More recently, the Department of Trade and Industry published a report which reviewed the current and future costs of low carbon technologies. These estimates, as shown in Table

One, suggest that some renewable energy technologies that are currently expensive will get significantly cheaper while nuclear costs are likely to fall more slowly. As a result, the economic advantages of renewable energy are forecast to get stronger over time.

Table 1 The Average Costs of Renewable Energy and Nuclear power Compared with Fossil Fuels: Today and in Prospect – pence/kWh

	Current cost	**Projected cost beyond 2020**
Biomass energy		
• Electricity	2.7-8.0	2.1-5.3
• Heat	0.5-2.7	0.5-2.7
• Ethanol for vehicle fuels	1.6-4.8	1.1-2.1
• c.f petrol and diesel	0.8-1.2	0.8-1.2
Wind Electricity		
• Onshore	1.6-2.7	1.1-1.6
• Offshore	3.2-5.3	1.1-2.7
Solar Thermal electricity	6.4-9.5	2.1-5.3
Hydro-electricity		
• Large scale	1.1-4.2	1.1-4.2
• Small scale	2.1-5.3	1.6-5.3
Geothermal energy		
• Electricity	1.1-5.3	0.5-4.2
• Heat	0.27-2.7	0.27-2.7
Marine energy		
• Tidal barrage	6.4	6.4
• Tidal stream	4.2-8.0	4.2-8.0
• Wave	4.2-10.6	2.7-3.7
Grid connected photovoltaics		
• 1000 kWh/m^2 per year (e.g. UK)	27-42	~4.2
• 1500 kWh/m^2 per year (eg. southern Europe)	16-27	~ 2.7
• 2500 kWh/m^2 (most developing countries)	10.6-21	~ 2.1
Stand alone systems (including batteries) 2500 kWh/m^2	21-32	~ 5.3
Nuclear power	2.7-3.7	1.6-2.7
Electricity Grid supplies (incl. transmission) from fossil fuels		
• Off peak	1.1-1.6	Capital Costs will come down with technical progress, but many technologies are largely mature and may be offset by rising fuel costs
• Peak	8-13	
• Average	4.2-5.3	
Rural electrification	13-42	

Source: DTI 2005[54]

The rising cost of oil and gas and faith that future reactor designs will be cheaper to build has led the nuclear industry to claim that it is now economic. The World Nuclear Association claims that "nuclear power in the 21st Century will be economically competitive even without attaching economic weight to the global environmental virtues of nuclear power or to national advantages in price stability and security of energy supply"'[55].

However, independent observers are more sceptical. UBS Investment Research say that "endorsing new nuclear is… a potentially courageous 60-year bet on fuel prices, discount rates and promised efficiency gains…"[56]. It concluded that any investment would require "political buy-in" to make the risk worthwhile. HSBC says that new nuclear would be a "difficult pill to swallow for equity investors"[57]. The Sustainable Development Commission warns of the risks of relying on nuclear industry cost estimates as the industry has a vested interest in playing them down. It says "there is very little certainty over the economics of nuclear power"[58].

As the Parliamentary Office of Science and Technology concluded in 2003 "the basic problem in all these comparisons is that the situation is a classic catch-22. Only the construction of a new reactor could verify the cost assumptions made by the nuclear industry"[59]. Given the costs of building one reactor are expected to be higher than if a series of ten are built, even this wouldn't be enough. We'll only know the cost of building ten reactors once they get built. That's a high risk strategy.

Two factors are clear though.

Firstly, nuclear reactors produce waste that requires careful storage long after the power plant has closed down. Any regulatory regime governing the building of new reactors needs to ensure that their operators set aside funds to pay for managing the waste they create. If they don't, investors may pay to build the plants and leave the taxpayer to pick up the bill for the waste – as has happened in the past.

Secondly, no new nuclear programme is likely to start unless it gets financial and political support from the Government. The nuclear industry claims that it is cheap and economic and that it only needs some minor assistance. However, assistance given in the past has turned into huge subsidies and long term government financial commitments.

Nuclear Support Mechanisms

There has been nothing stopping any company applying to the Government to build a nuclear power station it if choose to do so. However, none have done so because they know that it would not be economic without further Government assurances and financial assistance. Consequently, the industry has lobbied the Government to change planning rules (see p. 3-4) and/or provide direct or indirect subsidies to encourage new build. The Government has yet to say exactly what form any subsidy might take. There are a number of options that are likely to be considered including:

- **Capital grants or loan guarantees.** The Government could award capital grants for new construction. In France, the EPR in Flamanville is expected to receive around €500 million in capital grants from the Government. Alternatively, the Government could underwrite (guarantee) commercial loans for new build, enabling the industry to borrow at a lower interest rate.

- **Guarantees on cost overruns.** Utilities may seek Government assurances that they will be compensated for any time or cost over-runs resulting from extended licensing processes. This could involve the Government paying the interest on any loan extensions.
- **Caps on insurance liabilities.** The Nuclear Installations Act of 1965 already limits nuclear operators' liabilities in the event of an accident to £140 million, enabling it to pay less for insurance[60]. The Government could provide a slowly increasing subsidy to the industry simply by keeping this cap at its current level.
- **Climate change levy exemption.** The Government may exempt nuclear generation from its Climate Change Levy – on the basis that nuclear power is a low carbon technology.
- **Nuclear Obligation.** This would require all electricity suppliers to supply a percentage of their electricity from nuclear power – so long as costs didn't rise above a certain price. This would be similar to the existing Renewables Obligation.
- **Tax Breaks.** The Government could exempt the nuclear industry from business rates or allow them to pay less or to defer payment. This could be achieved locally, through adjusted business rates –as has already been done on occasion - or nationally through alteration of their tax status.
- **Caps on nuclear liabilities.** Liability for decommissioning British Nuclear Fuels' plants and storing or disposing its waste has already been transferred to the state-funded Nuclear Decommissioning Authority (NDA), as has liability for the waste created by British Energy before its collapse in 2002. However, British Energy is liable for new waste created in the future and, under existing law, any company that built a new nuclear plant would be liable for its waste and decommissioning costs. Under the Energy Act 2004, the Secretary of State could limit these liabilities to a certain level or even transfer them wholesale to the NDA.

The US Government has announced a massive subsidy programme in an attempt to encourage nuclear new build (no new reactors have been ordered in the US for 30 years). This package includes:

- a tax credit of 1.8 cents/kWh for the first 8 years of generation for the first six units;
- a federal loan guarantee of up to 80% of the cost of innovative technologies;
- a support framework against regulatory or judicial delays, worth up to $500 million for the first two reactors and $250 million for the next four; and further research and development funding worth $850 million;
- assistance with historic decommissioning costs (up to $1.3 billion)[61].

It is thought that the total cost of this nuclear support programme is around $12 billion (£7 billion).

What would be the effect of a new nuclear programme on nuclear waste?

Nuclear power creates energy through nuclear fission. Atoms of heavy metals like uranium and plutonium are split by bombardment with neutrons. This creates intensely radioactive 'fission products' – smaller atoms that decay over time until they reach a stable state. The neutron bombardment also makes the walls of the reactor radioactive.

These radioactive materials cannot be destroyed and need to be kept away from people until their radioactivity falls to safe levels. In the case of the most radioactive materials, this may take hundreds of thousands of years. This is nuclear waste.

Although nuclear power plants have been in operation for over 50 years, the UK has no final facility or even a firm plan for the long term management of the most dangerous of these wastes. This is not unusual. No country in the world has an operating facility for the permanent disposal or storage of its most dangerous nuclear wastes.

This failure is one reason why many people oppose the use of nuclear power. In 1976, the Royal Commission on Environmental Pollution recommended that: Athere should be no commitment to a large programme of nuclear fission power until it has been demonstrated beyond reasonable doubt that a method exists to ensure the safe containment of long-lived, highly radioactive waste for the indefinite future[62].

The uncertainty over what Britain should do with its existing nuclear waste overshadows any decision on whether to create more by building a new generation of nuclear reactors.

Our existing waste problem

Past operations and continued operation of existing reactors to the end of their expected life will leave Britain with millions of cubic metres of nuclear waste. There is no management plan for about 470,000 m^3 of this - enough to fill the Royal Albert Hall five times over – including all of the most dangerous wastes[63]. The cost of decommissioning reactors and managing this waste is conservatively estimated at £56 billion[64] and could be £20 billion higher[65]. The Nuclear Decommissioning Authority which was set up to oversee nuclear waste management, once it became clear that the nuclear industry hadn't the funds to do so, says the cost "could rise significantly in the future". Meanwhile, decommissioning of British Energy's reactors and the management of its waste is expected to cost around £13 billion. These costs are to be met from British Energy's income but any shortfall will be provided by the Government.

Table Two shows the expected volume of radioactive waste once packaged (i.e. excluding discharges from Sellafield and power plants) and includes normal forecasts for operation of nuclear power plants.

For decades the nuclear industry and the Government have been trying to find a permanent site and disposal mechanism for this waste. The greatest volume is of low level waste. By contrast, most of the radioactivity comes from the relatively small volumes of high level waste and spent fuel.

Table 2: The United Kingdom's existing waste problem (by volume and radioactivity)		
Type	**Packaged volume (cubic metres)**	**Radioactivity in 2040 (terabecquerels)**
Waste with no disposal route		
HLW	1,290	39 000 000
ILW	353 000	2 400 000
LLW (not suitable for Drigg)	37 200	<100
Plutonium	3,270	4 000 000
Uranium	74, 950	3 000
Spent Nuclear Fuel	8 150	33 000 000
Total	**477 860**	**78 000 000**
Waste with a proposed disposal route		
LLW (suitable for Drigg or similar dumps)	2,480,000	??
Very LLW (to landfill)	18,000,000	??

Source: CoRWM[66]

Broadly speaking, there are two options. One involves storing the waste while the other involves disposal - dumping it, probably deep underground. In the case of much low level waste, storage would be needed until its radioactivity falls to natural levels. In most cases, this would take about 100 years or more. However, high level waste will stay dangerously radioactive for a very long time - the official institution responsible for final disposal in Switzerland assumes that the safety of a repository for spent fuel and high level radioactive waste has to be guaranteed for at least one million years. No one believes that waste should be stored for this length of time and the justification for storing it now is that the risks of dumping underground are too great. In essence, the hope is that future generations will find a better way of disposing of it than we can.

For many years, environmental groups have favoured storage while the nuclear industry and Government have favoured disposal. In 1982, the Government established Nirex to implement a strategy for the safe disposal of low and intermediate-level waste. As part of this work a confidential short list of potential disposal sites was drawn up. This was released in June 2005 and contained twelve locations (from an original list of more than 500):

- Adjacent to Bradwell nuclear power station in Essex
- Ministry of Defence land on Potton Island, 8 km from Southend on Sea. Essex
- Under the North Sea, accessed from the port at Redcar, Yorkshire
- Under the sea between the Inner Hebrides and Northern Ireland, accessed from the port at Hunterston in North Ayrshire
- Killingholme, South Humberside
- Ministry of Defence training area, Stanford, Norfolk
- Adjacent to Dounreay nuclear plant in Caithness

- Two sites near the Sellafield nuclear plant in Cumbria
- Altnabreac in Caithness 18 km south of Dounreay
- Fuday, small, uninhabited island north of Barra in the Western Isles
- Sandray, small, uninhabited island south of Barra in the Western Isles

Nuclear waste categories

The Government categorises nuclear waste on the basis of its danger, and thus the measures needed to handle and store it. These categories are:

Very low radioactive wastes are put into landfill, or discharged into the sea/air.

Low Level radioactive wastes are wastes with a radioactive content below four GBq/tonne of alpha activity or 12 GBq/tonne of beta/gamma activity. Low-level wastes require containment to protect the operators, but (under current guidance procedures) don't normally require radiation shielding. Since 1959 about 1,000,000 cubic metres of low-level waste has been disposed of, mainly, at Drigg near Sellafield in Cumbria[67]. There is enough space for another 750,000 cubic metres at this site[68] which is expected to be full by 2050. According to the Environment Agency, rising sea levels caused by climate change could destroy the Drigg site in as little as 500 years, resulting in leaks which would increase the risk of local people contracting cancers by at least 100 times[69]. Some low level waste is not suitable for Drigg because of its chemical properties or because it is liquid or flammable. This is currently stored across the UK wherever it was produced, awaiting a policy on long-term management.

Intermediate Level Wastes are wastes whose radioactive content exceeds the upper limits for low level waste but that don't require active cooling. Intermediate level wastes require radiation shielding and/or containment during transport and storage/disposal in order to protect nuclear operators and the public. They are stored across the UK wherever they are produced, awaiting a policy on long-term management.

High Level Wastes are so radioactive that they generate heat and require active cooling. They are mainly fission products from spent (used) nuclear fuel that have been separated out after nuclear reprocessing and are stored at Dounreay and Sellafield. This waste is then solidified in glass prior to storage.

Plutonium, uranium and spent fuel. As fuel rods are bombarded with neutrons in nuclear reactors, the amount of uranium they contain falls and the proportion of fission products increases. As a result, their effectiveness declines well before all the uranium is used up. To make use of the remaining uranium, the nuclear industry sends the spent (used) fuel rods to Sellafield for reprocessing. This involves dissolving them in hot acid to separate the uranium from the fission products. Coincidentally, some uranium in the reactor is turned into plutonium. This is separated out too. The industry would like to make this uranium and plutonium into fuel for new reactors. However, this is not currently cost effective and the uranium and plutonium may become waste. The fuel used at the Sizewell pressurized water reactor is not reprocessed and remains at the reactor. Unless it is reprocessed, it will be waste too.

This approach was abandoned and instead Nirex focused on deep disposal at two possible sites in Dounreay and Sellafield. In the 1990s, it applied for permission to build a test facility beneath Sellafield to determine whether its geology made it suitable for a dump. This proposal was rejected in 1997 by the then Secretary of State for the Environment, John Gummer with the whole exercise reported to have costs around £450 million[70].

The incoming Labour Government set up the Committee Radioactive Waste Management (CoRWM) to start again. After much deliberation, CoRWM published its draft recommendation on 27 April 2006[71]. It "considers geological disposal to be the best available approach for the long-term management" of all the nuclear waste that currently has no disposal route. However, it recognises that "implementation will take several decades" or even "for as long as one or two generations" even if a suitable site can be found and therefore "recommends that a programme of interim storage is required as … an integral part in the long-term management strategy".

CoRWM is due to make a final recommendation at the end of July 2006. Nuclear lobbyists, aware that the absence of a long term plan is an impediment to the creation of more waste, are likely to claim quickly that a solution has been found. The New Scientist magazine says this is "optimism gone mad". "Deciding to put waste down a hole, with no idea what form the repository should take or where it should be, is no more of a plan than has existed for the past 30 years" it concluded[72]. Friends of the Earth has called on the Government to reject the recommendation for deep disposal.

Meanwhile, uncertainty over the form and location of both the proposed interim store or dump makes it impossible to say how much such a strategy might cost. There is no actual experience and thus little firm evidence that current cost estimates will be correct. Some nuclear advocates believe that existing funds will more than adequately cover the necessary work, while others speculate that they will fall well short. One estimate undertaken by the German Oko Institute suggests that the complete costs of construction, operation and closure of a high level waste repository will be in the order of €10 billion[73]. This would add another 10% to the cost of nuclear electricity. Estimates prepared by a group of experts for CoRWM suggest that the the range of option could cost from £3-30 billion[74].

The impact of new reactors

Nirex has calculated how much new waste would be created if different types of new reactor are built (and assuming no reprocessing of spent fuel). Table Three shows that, if a further 10 reactors were built, the overall increase in the volume of waste would be low, but that the volume of highly radioactive spent fuel would increase by an additional 31,900 cubic metres.

Table 3: The impact of new reactors on the UK's radioactive waste problem (packaged volume – m^3)

	Baseline	10 AP1000s	7 EPRs
High level waste	1,290	0	0
Intermediate level waste	353,000	+ 9,000	+ 13,000
Low level waste (Drigg)	2,480,000	+ 80,000	+ 100,000
Low level waste (non-Drigg)	37,200		
Plutonium	3,270	0	0

Uranium	74,950	0	0
Spent Fuel	8,150	+ 31,900	+ 21,000

Source: CoRWM[75]

Table Four shows Nirex data on the impact on the radioactivity of the most radioactive components of the waste problem. To make the comparison more meaningful, Nirex has assessed the impact of new reactors at different time periods (10, 500 and 100 years after the last fuel was removed from the last reactor).

It confirms that a new nuclear programme would significantly increase the overall radioactivity of the UK's waste problem. In 2180, almost 100 years after the last of the fuel rods had been taken from the new reactors, the radioactivity of the new waste would only just have fallen to the level that existing waste will reach in 2090.

Table 4: The impact of new reactors on the UK's radioactive waste problem (radioactivity – petabecquerels - 1000s of terabecquerels)

	Year	Spent fuel	High level waste	Intermediate level waste	Total
Baseline	2090	6,000	14,000	1,100	20,000
10 AP1000s (last fuel removed in 2080)	2090	1,800,000	-	87	180,000
	2130	60,000	-	-	60,000
	2180	18,000	-	-	18,000

Source: Sustainable Development Commission[76]

Nirex estimate that a new programme of ten AP1000 reactors would increase the number of canisters of spent fuel and high level waste that would need to go into a long-term waste store or underground dump by 87 per cent[77].

Will a new nuclear programme be safe?

"The push to bring back nuclear power as an antidote to global warming is a big problem. If you build more nuclear power plants we have toxic waste at least, bomb-making at worse"[78].

Bill Clinton

Nuclear power is inherently dangerous. It requires the handling of highly toxic and radioactive materials that can also be used to make devastating weapons. The basic process involves a chain reaction that can generate huge quantities of heat, potentially causing fires and explosions. Releases of nuclear materials could have serious health consequences for people living around reactors – and further afield. It is not surprising that safety concerns bedevil the industry.

Broadly speaking, concerns fall into three types:

- fears of accidental release of nuclear materials following a fire or explosion at a reactor
- fears that countries will use nuclear power as a means to produce (or a smokescreen to hide the production of) nuclear weapons.
- fears that terrorists will cause radioactive releases by attacking nuclear power plants or by using nuclear materials in a 'dirty bomb'.

Safety

Nuclear power has always been linked in the public's mind with nuclear weapons. The knowledge that both are fuelled by the same heat-generating, nuclear, chain reaction (nuclear fission) has led to concerns that nuclear reactors might get out of control and explode.

This risk is real. Serious nuclear accidents have happened.

- **Windscale.** On 10 October 1957, a fire at a military reactor at Windscale (now Sellafield) caused the release of radioactive materials across west Cumbria. Consumption of milk produced in the surrounding 500 km^2 was banned and the reactor written off[79].
- **Three Mile Island.** On 28 March 1979, a breakdown in the cooling system of a commercial reactor, coupled with the failure of some safety equipment, caused operators to shut down the flow of water that was cooling the reactor. Overheating severely damaged the reactor core and led to a dangerous build up of hydrogen – which had to be released to the atmosphere. The reactor was written off[80].
- **Chernobyl.** On 25 April 1986, operators of the Chernobyl Reactor 4 began a test to see whether the reactor could continue to power its own cooling system as it was shutdown. Safety systems were deliberately switched off during the test. Reduced coolant flow caused water to boil leading to a power surge and a sudden increase in temperature. Steam built up, burst the containment and exposed the reactor core to the atmosphere. Large amounts of radioactivity were released contaminating the surrounding area and eventually spreading across Europe to the UK. Thirty one reactor staff died directly[81].

  Assessments of the wider impacts on health vary. The Chernobyl Forum, comprising UN and Government specialists called together from UN agencies and the Governments of Belarus, Russia and Ukraine, says that as few as 4,000 people will die as a result[82]. However, a Greenpeace study, involving numerous independent experts from the affected region, puts the figure at up to 200,000[83]. Furthermore, the number of people killed would have been far higher if the most heavily contaminated areas hadn't been evacuated.

Nuclear supporters point out that there are over 400 operating reactors in the world. These provide 10,000 "reactor-years" of operational experience and that the "the probability of a major accident with significant contamination outside plant boundaries is very small"[84]. They claim, and the Sustainable Development Commission has concurred that "modern nuclear power stations are built to a high standard with multiple layers of protection to guard against faults and passive safety features which will come into play automatically when a fault condition occurs"[85]. They also point to the safety record of other energy generating technologies and increasingly to the huge number of people expected to be killed as a result of climate change.

However, it is clear that:

- nuclear reactors have the potential to contaminate surrounding areas to an extent that requires their evacuation for a considerable period of time. This risk is unique to nuclear power and can never be entirely eliminated.
- new reactors must be built to modern safety standards. The safety of the reactor designs

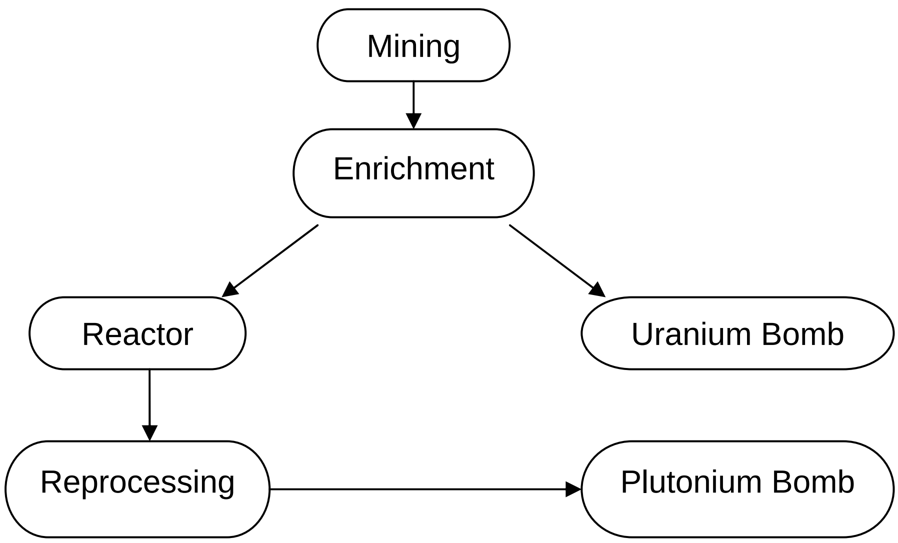
likely to be proposed in the UK has yet to be assessed by Nuclear Installations Inspectorate. Doubts have been raised about whether they are over-reliant on passive safety features and that more back-up safety features are needed[86]. If so, this could have a big effect on cost.

Proliferation

The history of nuclear power is intimately linked with the history of nuclear weapons. The first nuclear power programmes, in the France, Russia, UK and United States, were born directly out of those countries' nuclear weapons programmes. The first British Magnox reactors UK were dual use. They produced electricity and plutonium. It is therefore no surprise that, even today, nuclear power programmes are seen by many, as in the case of Iran, as a means to develop nuclear weapons.

The links between nuclear power and nuclear bomb-making are real. The expertise, the materials and technology used for one can often be used for the other. In fact, the US Department of Defense says "the acquisition of fissile material in sufficient quantity is the most formidable obstacle to the production of nuclear weapons"[87]. The easiest way of producing fissile materials (or of hiding their production behind a smokescreen of legitimate activity) is through a nuclear power programme.

The ways that nuclear power generation connects with bomb making are shown below:



There are four connections where the link with bomb-making is particularly strong.

- **Uranium enrichment.** Nuclear power generates energy through nuclear fission – the splitting of uranium atoms by bombardment with neutrons. However, only certain sorts of uranium atoms (^{235}U) split apart in this way. More than 99 per cent of the uranium in the world is of a different sort (^{238}U). Therefore, before it is made into fuel rods, uranium is spun in centrifuges to separate out the two different kinds. For reactors, the proportion of ^{235}U is increased from its natural 0.7 per cent to between 3-5 per cent. This is enriched uranium. If the concentration is increased to about 90 per cent, super-enriched or weapons-grade uranium is produced. This means the same technology can be used to make super-enriched uranium as to make enriched uranium for nuclear power plants. In fact, much of the energy and time needed goes toward increasing the concentration those first few percentage points.

- **Reprocessing.** The efficiency and integrity of fuel rods in nuclear reactors falls after they have been in the reactor for a few years. The proportion of ^{235}U declines and more and more fission products are created. The fuel rods are therefore taken out – well before all the ^{235}U is used up. In most parts of the world, the fuel rods are then stored as waste. But in Britain, France and a few other countries, they are dissolved in nitric acid and the remaining ^{235}U is recovered for potential re-use. Coincidentally, while in the reactor, the neutron bombardment turns some of the ^{238}U into ^{239}U which then decays to form plutonium. This is also separated out. Plutonium, like the recovered ^{235}U, can be used in new reactors, but it also makes excellent bombs.
- **Specific materials.** Some nuclear weapons make use of radio-active materials like tritium – a super-heavy form of hydrogen. Tritium has a half–life of only twelve years and stocks therefore decline rapidly. Civilian nuclear reactors can be used to make more if stocks become depleted (perhaps, for example, when a country is contemplating replacing its nuclear weapons)[88].
- **Equipment and know-how.** Finally there is a wealth of more general equipment and know-how, such as in the control of the fission reaction, which is common to both nuclear power generation and weapons programmes.

Of course, the United Kingdom already has nuclear weapons and although the Government is considering whether and when to replace them, there is no evidence that any decision to build new reactors is being influenced by weapons considerations. A new power programme might also be designed to use up stockpiles of plutonium whose only other use would be for weapons manufacture.

The proliferation danger, in Britain building new reactors, is the example it sets abroad. Climate change is a global problem. Other countries are expected to cut their emissions just as the UK is. If Britain uses nuclear power to tackle climate change, other countries may follow suit. Transfer of technology is expressly encouraged under the United Nations Framework Convention on Climate Change. Other countries may demand access to nuclear technology and know-how on the pretence of tackling climate change – and refuse to cut their emissions until they are given it. And there is plenty of evidence to suggest some countries will misuse civil nuclear technology to make bombs.

Terrorism

The misuse of civil nuclear technology for bomb making is not the only security threat posed by a widespread return to nuclear power. In recent years there has been an apparent increase in attempted terrorist attacks around the world. In the UK, in addition to the bombing in London in July 2005, "a significant number of terrorist attacks have been thwarted in the UK since 11 September 2001"[89].

Power plants, with their importance to modern society, are obvious targets. MI5 highlights this when it reported that "Bin Laden has also threatened to attack 'economic interests'. These might include energy or major transport facilities, both aviation and maritime, and financial, business or commercial centres"[90]. The civilian nuclear power sector has particular traits that increase its attractiveness to terrorist groups, including:

- The breaching of the containment and subsequent release of radiation could have large and long lasting economic and environmental impacts.
- Nuclear power stations usually make a significant contribution to the electricity sector in which they operate, their closure could disrupt the economy.
- A successful attack on a nuclear power plant in one country would have impacts on nuclear power plants in other countries.

Terrorists have already attacked nuclear facilities. In December 1977, Basque separatists set off bombs damaging the reactor vessel and steam generator and killing two workers at the Lemoniz nuclear power plant, which was under construction in Spain. In 1982, the African National Congress set off four bombs inside the Koeberg plant, which was under construction in South Africa[91].

More recent press reports have suggested that nuclear facilities are still being targeted.

- **Australia.** The Lucas Heights nuclear reactor in Sydney may have been a target of suspected terrorists. Three of eight Sydney men currently facing terrorism charges were stopped by police near the nuclear facility in December 2005[92]
- **Chechnya.** A foiled Chechen rebel assault on the Russian city of Nalchik in October was reported to have involved an attempt to hijack five planes that could be flown into various targets, including a nuclear power station[93]
- **United States.** In his January 2002 State of the Union speech, President Bush said that U.S. forces "found diagrams of American nuclear power plants" in al-Qaeda materials in Afghanistan. An al-Qaeda training manual lists nuclear plants as among the best targets for spreading fear in the United States[94].

Prior to the attacks in the US in September 2001, the idea that someone might fly a commercial airline into a nuclear power plant was not considered credible. The containment systems around older reactors were therefore only required to withstand the impact of a jet fighter or smaller aircraft. Yet, in a worst case scenario, the impact of large aircraft on certain facilities could cause a significant release of radioactive material with effects over a wide area[95].

Following the attack on the World Trade Centre, David Kyd of the International Atomic Energy Agency (IAEA) told the Times that "reactors .... are built to withstand impacts but not that of a wide-bodied passenger jet full of fuel. A deliberate hit of that sort is something that was never in any scenario at the design stage. These are vulnerable targets and the consequences of a direct hit could be catastrophic"[96].

Moreover, it is not just nuclear power plants that might be a potential target. Reprocessing creates highly radioactive liquid wastes that could be released as a result of a terrorist strike. A report commissioned by the European Parliament concluded that a plane crashing into the waste stores at Sellafield could lead to radioactive releases forty times more dangerous than those from Chernobyl[97]. Sellafield also contains the world's largest stockpile of plutonium – about 90 tonnes. Frank Barnaby, of the Oxford Research Group says that "if evenly distributed, a kilogram of plutonium in the Sellafield store will, on average, contaminate more than 300 square kilometres to the level at which the NRPB (National Radiation Protection Board) recommends evacuation. A terrorist attack on a plutonium store at Sellafield could contaminate a huge area of land"[98].

Finally, there is also the possibility that nuclear materials could be stolen by terrorists to make a nuclear weapon or, more likely, a 'dirty bomb' using nuclear materials in a conventional bomb to contaminate an area. This is not expected as a result of the theft of nuclear materials from a British civil nuclear programme, but again, it is more likely if a British nuclear programme then encourages other countries to follow suit.

Conclusion

Nuclear power is particularly dangerous technology. Many of the materials and the technologies and know-how needed for nuclear power can be misused to make nuclear weapons. A British decision to build new reactors could encourage other countries to follow suit, perhaps in some cases as a smokescreen for bomb making.

Nuclear facilities have been attacked by terrorists and could be attacked again. The impacts of a successful attack against a nuclear facility could be extremely severe. An international return to nuclear power, following a British decision to build new reactors, would increase the risk that nuclear materials would fall into the hands of terrorists.

What are the alternatives?

Nuclear power could be an expensive, dirty and dangerous bit player in the development of a low carbon energy policy in the UK – and no new reactors are likely to be built for at least ten to fifteen years. However, something must be done as Britain's carbon dioxide emissions are growing when they should be falling.

In fact, there are many alternatives to nuclear power that can help meet Britain's energy needs in ways that don't cause climate change. Broadly speaking, they fall into two categories:

- Renewable energy
- Energy efficiency and energy conservation

Together they form a clean, secure and sustainable way of meeting our needs for electricity, heat and transport fuel.

Renewable energy

The world as a whole and the United Kingdom in particular is blessed with varied and abundant sources of clean renewable energy. We simply have to deploy the technologies to harness it.

To some extent we already are. Globally, renewable sources provide 13.3 per cent of all energy used – double the contribution of nuclear power[99]. Renewable energy even provides more electricity than nuclear power. Renewable sources meets 45 per cent of all Norway's energy needs, about 20 per cent of Austria and Finland's needs and about 15 per cent of those of Portugal and Switzerland[100]. However most of the energy used from renewable sources comes from the burning of wood, straw, dung and other forms of biomass – much in developing countries. Most of the remainder, and most of the electricity generated, comes from hydro-electricity. Many other sources of renewable power are scarcely tapped.

The United Kingdom hardly makes use of renewable energy at all. Only 1.3 per cent of our energy comes from all renewable sources. Yet, Britain has an enormous renewable resource. Some estimates of the potential are shown in Table Five. The UK's annual electricity consumption, by way of comparison, is about 400 TWh/year, while a 1000 MW nuclear power plant would produce about eight TWh/year.

It is clear that the theoretical potential – the amount of energy that could be obtained – is enormous. As the Performance and Innovation concluded "taken together they exceed UK primary energy consumption several times over"[101]. Potentials are large even when constraints such as competition with other land and sea uses, grid connections and landscape are taken into account.

<table>
<tr><th colspan="7">Table 5 The potential of renewable energy in the UK (TWh/year)</th></tr>
<tr><th></th><th>PIU[102] in theory[i]</th><th>PIU[103] (2025)[ii]</th><th>Tyndall[104] in practice[ii]</th><th>IEE[105] in practice[ii]</th><th>IAG[106] (2025)[iii]</th><th>Carbon Trust[107][ii]</th></tr>
<tr><td>Onshore wind</td><td>317</td><td>8</td><td>58</td><td>45</td><td>45</td><td>-</td></tr>
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<tr><td>Barrages/lagoons</td><td>-</td><td>-</td><td>50</td><td>-</td></tr>
<tr><td>Biomass</td><td>'large'</td><td>'large'</td><td>31</td><td>80</td><td>8</td><td>-</td></tr>
<tr><td>Solar</td><td>266</td><td>37</td><td>7.2</td><td>-</td><td>0</td><td>-</td></tr>
<tr><td colspan="7">i. These are figures for the technical potential which "refers to the amount of energy that might be extracted from the available resource, using known technologies"[108].
ii. These are figures for what is variously described as the 'practicable potential' or 'practicable resource'. The Performance and Innovation Unit (PIU) defines this as "the amount of the technical potential that might reasonably be accessed, taking into account various technical and physical limiting factors such as competing land (and ocean) use and often includes further limitations, such as electricity grid and system constraints"[109].
iii. These are cost constrained estimates of the resource that might be available at a given price (in this case 3p/kWh).</td></tr>
</table>

There are also other renewable sources of power that aren't considered here – including many micro-renewable technologies that could be fitted to people's homes. These include micro-turbines, small scale hydro-power schemes, solar heating and small biomass or combined heat and power boilers. Taken together, they could generate about 220 TWh of heat and electricity by 2030 and 315 TWh by 2050[110] although some of this will be included in the totals for solar and biomass above.

The Sustainable Development Commission has considered this evidence and concluded that "the UK's practical renewable energy resource could supply 68-87 per cent of our electricity if fully exploited"[111]. Almost all these major renewable technologies have shorter timescales for implementation than nuclear power. Wind projects often take from one to three years from conception to installation. Small scale measures, like micro-CHP, can be installed in weeks[112].

Government help will be needed to realise these potentials.

Government funding for research and development, for the early use of emerging technologies and on public information can speed up innovation and learning and bring down costs. This is particularly true of technologies like solar power that are sold directly to consumers.

But it is not just a question of money. Sympathetic regulation is also necessary. Clear legal frameworks, outlining their powers and responsibilities, are needed if companies are to invest in off-shore energy technologies such as wind and wave power or tidal lagoons. Transparent planning policies and easy to use procedures will be required to help people fit solar panels on roofs. Fair prices for grid connections and electricity sold back to the national grid are expected to have a massive effect on the uptake of technologies like micro wind power.

Over the last thirty years, Britain and other industrialised countries have spent huge sums on the research and development of nuclear power (see 'Balancing Priorities'). That's money that could have been spent on renewable energy. For the first time, in the last few years, Government funding has started to flow toward renewable power – as has parliamentary and regulatory time. It is clear that substantial further subsidies and regulatory changes will be needed if a new generation of reactors are to be built. But any diversion of Government funds and regulatory time from renewables to nuclear could jeopardise the progress made on renewable energy.

Balancing Priorities

Government Research and Development funds are a vital mechanism to speed up the introduction of new technologies. It is widely recognised that more research and development funding should be allocated to renewable energy technology. Yet between 1974-2002, nuclear (fission and fusion) received $169 billion in Government research grants from developed countries compared to just $24 billion for renewables[113].

In their first 15 years of commercial operation, nuclear and wind technology produced a comparable amount of electricity in the United States, but the subsidy to nuclear was 40 times greater than that given to wind ($39.4 billion to $900 billion)[114].

Since 1974 the UK government has spent £6.8 billion in research and development funding for nuclear fission (compared to £540 million for renewables) according to information from the International Energy Agency[115].

In some cases, the investments and regulatory changes needed to support a new generation of reactors are directly incompatible with those needed to promote renewable energy. An example is investment in the national grid. Studies show that the grid investment needed by nuclear reactors is markedly different from that needed for renewable forms of power[116].

Energy efficiency and energy conservation

Renewable energy cannot yet meet all our energy needs. However the potential for saving energy and for using it more efficiently is vast. In 2001, a Government review found that we can save 30 per cent of the energy we use through cost-effective energy saving measures alone. They calculated this would save us £12 billion every year[117]. Since then, energy prices have risen dramatically, so the cost-effective savings are likely to be even greater.

Comparisons of different technologies show the potential:

- A programme to replace inefficient light bulbs with new super-efficient LED or compact fluorescent light bulbs could save seven TeraWatthours (TWh) or 1.75 per cent of our current electricity use by 2020. This is almost the equivalent of one nuclear power station[118].
- Introducing new standards to ensure appliances waste less electricity on stand-by could save eight TWh or two per cent of our current electricity use by 2020. This is the equivalent of one nuclear power station[119].
- Promoting more efficient electric motors in industry could save 24 TWh or six per cent of our current electricity use by 2020. This is equivalent to three nuclear power stations[120].
- Further developing the potential to use the waste heat given off by industrial plants, boilers in offices and other heat sources could generate up to 125 TWh or over 30 per cent of our electricity needs by 2020. This is equivalent to about 15 nuclear power plants[121].

Numerous other examples could be listed and similar savings could be made in our use of fuel for heating and transport through programmes to promote better insulation and the purchase of more fuel efficient cars. More examples (for 2030) are listed in Table Six below.

Table 6: Alternatives to nuclear power and their approximate potential contribution by 2030 (in numbers of 1000 MW nuclear power plants avoided)

	Nuclear plants avoided		Nuclear plants avoided
More efficient standby	1	Wind (onshore)	3.4
More efficient industrial motors	4	Wind (offshore)	12.5
Clever appliances	>0.5	Wave and tidal stream	8.5
Changing how we travel	>9.5	Tidal lagoons	2.5
Light bulbs	1.5	Biomass	>14
More fuel efficient cars	11.5	Solar	>1
More efficient generation using coal and gas			>2.5

Source: Friends of the Earth calculations

Again, however, Government financial and regulatory support will be needed. This will involve everything from funds for public information campaigns through grants to help home owners fit insulation, tax changes to encourage motorists to buy more fuel efficient cars to regulatory changes such as tougher building and product standards.

The Government is already failing to give energy efficiency and conservation the support it needs. Any dilution of the existing meagre attention that energy efficiency and conservation get in favour of nuclear power would jeopardise its potential.

Bringing it all together

The examples above show that many technologies exist to harness renewable sources of energy and to make sure we use energy as efficiently as possible. If implemented, these would boost our energy security and cut the emissions causing climate change. However, the benefits of these technologies can always be eroded if energy consumption increases in other areas – say because more people fly or use patio heaters. The same is true of nuclear power.

It is vital therefore to consider how individual measures work together as part of an overall strategy to maximise their benefits. This strategy might also include regulations and tax changes, for example, to discourage wasteful energy use.

Friends of the Earth has therefore modelled future electricity demand and assessed how these measures could work in combination[122]. Our conclusion, using conservative assumptions, is that it is possible to meet future electricity needs, in a variety of ways, and still cut carbon dioxide emissions from 1990 levels by 48-71 per cent by 2020 and 53-77 by 2030.

Similar assessments have been made of the transport sector. A study for the Department for Transport showed that emissions from the transport sector (excluding international aviation and shipping) could be cut by 60 per cent from 1990 levels by 2030 through a combination of fuel efficiency improvements and changes in travel behaviour[123]. Car use would only be 10 per cent lower than it was in 2000. Yet more studies have been done looking at emissions as a whole.

It is perfectly possible for the UK to meet its energy needs and cut the emissions causing global warming without recourse to nuclear power. Many of the measures proposed, especially to improve energy efficiency, are far cheaper than investment in nuclear power. However, Government support will be needed if the take up of energy efficiency and renewable technologies is to rise. In many cases, the measures needed are incompatible with those needed to promote nuclear power[124].

What about other countries?

2.4 billion people currently lack access to the energy services that we in the western world take for granted[125]. The International Energy Agency (IEA) says this number will increase to 2.63 billion by 2030[126]. Billions rely on solid fuels on open fires for cooking and heating. This results in high levels of indoor pollution, which is believed to cause 1.6 million deaths per year, mostly among the under-fives[127].

The United Nations has approved the Millennium Development Goals to improve the quality of life of billions of the world's poorest people[128]. Any strategy to achieve these goals must ensure people can cook and heat and light their homes safely. It must enable them to travel and to develop industries to boost their livelihoods. All this implies access to and growing use of energy. Yet, at the same time, global emissions of carbon dioxide must peak in the next ten years and halve by 2050[129].

British energy policy must not only provide for our own needs in ways that cut our emissions. It must also be exportable so that poorer countries can meet their needs.

The global role of nuclear power

There are currently 441 reactors generating electricity in 32 countries around the world[130]. In 2004, nuclear power provided 16 per cent of the world's electricity and 6.5 per cent of its energy. However, the construction of new reactors has slowed significantly since the late 1980s and almost as many have been shutdown as built since then[131]. The average reactor is now twenty one years old[132] and as only 27 reactors are under construction anywhere in the world[133], the number of operational reactors is as likely to fall as rise in the next decade[134].

Seven southern countries currently use nuclear power. However, it only plays a minor role in their electricity production: Argentina (8.2%); South Africa (6.6%); Mexico (5.2%); Brazil (3%); India (2.8%); Pakistan (2.4%); and China (2.2%). This means that nuclear power contributes less than 1% of the commercial energy consumed in the regions concerned, compared to global average of 6.5%[135].

Nuclear power is unlikely to play a major role in meeting the developing world's energy needs. Firstly, it cannot be deployed quickly enough. As we have seen, nuclear power plants take years to build and, if they are to be operated safely, need to be monitored by expert regulators. Many countries do not have the resources for this. Secondly, it won't reach the people that most need it. Nuclear power plants depend on electricity grids to move the power to where it's needed. Yet grids in many poor countries are scarcely developed and often do not reach rural communities.

Thirdly, there are real concerns over the global supply of uranium. Although uranium is a common metal, much of it is dispersed in rocks at very low concentrations. Storm van Leuven and Smith have calculated that the energy needed to extract this uranium is too great to justify its extraction[136]. Fourthly, of course, there is the problem of proliferation. As we have seen, much of the technology needed for nuclear power can be used to make nuclear weapons. It is unclear whether rich industrialised countries will be happy to supply this technology to any country that wants it.

Renewable energy on the other hand is being actively developed all over the world and is now the world's fastest growing energy sector. In 2004 about $30 billion was invested in renewable energy capacity and installations[137]. Furthermore, their versatility means that renewable technologies can be rapidly introduced at a size that is suitable for every application. They can also be used off-grid for small scale applications in remote areas which cannot be reached by pylons. Developing countries could leapfrog straight to a decentralised electricity supply without ever needing a national grid. A similar development path is already underway in telecommunications as 70% of all telephone lines in Africa are now mobile[138].

Conclusion

Research has shown that a combination of affordable, innovative renewable energy solutions together with sensible measures to improve energy efficiency and the efficiency of coal and gas-fired power plants can ensure we meet climate change targets and maintain energy supply.

Nuclear power is not needed in the fight against climate change. It is likely to be counter-productive because subsidies given to nuclear power could achieve greater emissions reductions if spent elsewhere.

Meanwhile, the risks of nuclear power continue to far outweigh its benefits:

- Nuclear power produces waste that stays dangerous for tens of thousands of years. The Government still doesn't know what to do with this waste.
- Nuclear reactors have and may again be threatened by terrorists. Attacks, for example by hijacked airliners, could pollute large areas with radioactive materials
- Many processes used as part of nuclear power generation can also be used for covert weapons programmes. If the UK chooses to use nuclear power to cut its greenhouse gas emissions, it will provide an excuse that other countries may use to justify what are really weapons programmes.

Friends of the Earth therefore opposes the construction of a new generation of nuclear reactors. The Government should therefore maintain the strategy laid out in its previous Energy White Paper[139] and pursue with renewed vigour a range of safer, greener and cleaner alternatives.

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