

# TOO HOT TO HANDLE?

## THE FUTURE OF CIVIL NUCLEAR POWER

Frank Barnaby and James Kemp

With a Foreword by David Howarth MP  
Liberal Democrat Shadow Energy Spokesperson



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Caption: Grundremmingen nuclear power plant. (Grundremmingen, Germany). Credits: Petr Pavlicek / IAEA

The security of nuclear facilities around the world has risen to high priority for the IAEA and its Member States since the terrorist attacks on New York and Washington, D.C. in Sept 2001 .Copyright © IAEA

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## Summary

Currently, the world's nuclear-reactor produce a total of 0.9 Tw (out of a total world power production 15 Tw), giving a total electricity generation of 0.37 Tw from nuclear power. This amounts to 56 watts per capita. For comparison, for the non-nuclear types of fuel the world power production is: 5.6 Tw for oil; 3.5 Tw for gas; 3.8 Tw for coal; 0.9 Tw for hydroelectric; and 0.13 Tw for geothermal, wind, solar, and wood. The world per capita energy production is 2,300 watts per capita (6.6 billion people).

Taking just the OECD countries, the countries with nuclear power produce a total of 300,541 MWe of nuclear electricity, or 335 watts per capita. The non-OECD countries (with nuclear power) produce 63,134 Mwe, or 0.018 watts capita. For all OECD countries the production of nuclear energy is 266 watts per capita.

It is probable that by 2075 the world population will reach about 10 billion people. Assuming that countries generate one kilowatt of electricity per capita (probably an underestimation), and that they generate a third of their electricity by nuclear power (twice today's world share) to mitigate CO<sub>2</sub> emissions, the world would need to generate 3 Tw of electricity by nuclear power-reactors, or 3000 reactors (assuming average capacity of 1Gw) – that's over four new builds a month from now on,\* compared to 3.4 per year which is the highest historic rate (France, 1977 to 1993).

Supporters of nuclear power quite rightly point to the fact there are only eight (excluding DPRK) nuclear weapons states, so the Nuclear Non-proliferation Treaty (NPT) and IAEA have successfully managed to control the proliferation risks of civil nuclear power to a reasonable degree. That the international nuclear control regime has prevented widespread weapons proliferation is a little reassuring (if India, Pakistan, Iraq, Israel and DPRK are discounted), but does not mean that it will continue to do so over the next twenty to fifty years or that it can deal with the consequences of a nuclear renaissance, despite recent non-proliferation initiatives.

The question is whether, in the 21<sup>st</sup> century, the security risks associated with civil nuclear power can be managed or not?

Tw=10<sup>12</sup>watts; Gw=10<sup>9</sup>watts; Mw=10<sup>6</sup>

\* Assuming a ten-year construction time and excluding replacing decommissioned plants.

## Foreword

*“What possible standing can we have to ask other countries to restrain themselves if we ourselves refuse to do so?”*

In the 1970s we used to say that if nuclear power was the answer, it must have been a very silly question. But as Britain's former Prime Minister Tony Blair insisted on saying at every opportunity he had, nuclear power is back on the agenda 'with a vengeance'. It is not that nuclear power has changed much in its basic characteristics – it is still the same inherently dangerous, though immensely powerful, process that it always was. It is just that it has found a new question, that of climate change, to which it can pose as the answer. In the words of the great organisational theorists Cohen, March and Olsen nuclear power is 'an answer actively looking for a question'.

If one were to set out to design from scratch a solution for the problem of climate change in a world without nuclear power, there is little chance that anyone would come up with nuclear power as that solution, or, if they did, that anyone would think that nuclear power was anywhere near acceptable. It would look simply too risky to try, especially in comparison with all the other options, from energy saving to renewable energy and carbon capture and storage. Technological progress will undoubtedly form part of the world's response to climate change, but not all novelties constitute progress.

And yet acceptance of nuclear power is growing. That is partly because some people believe the myth that without nuclear power, the lights will go out or that we will have to return to medieval levels of energy usage – a claim particularly absurd in a country such as Britain in which the potential for renewable power vastly exceeds current electricity consumption. But it is also partly because many people seem to have forgotten about nuclear power's inherent problems. That is why Frank Barnaby and James Kemp's work is so much to be welcomed. They remind us about what makes nuclear power more of a problem than a solution.

They make important new points, such as the infeasible rate of building new nuclear power stations that would be needed for a nuclear renaissance to make much of a global difference, alongside restating older points, such as the problem of the declining quality of uranium ore that undermines some of the more extravagant claims about nuclear power's low carbon footprint. But above all, they analyse in convincing and sometimes alarming detail the problems of international and domestic security that a worldwide revival in nuclear power would pose. An international nuclear renaissance, especially if it moves in the direction that nuclear enthusiasts want of using MOX fuel and of developing fast-breeder reactors, will lead to very great dangers indeed in terms of nuclear weapons proliferation and the threat of terrorist action.

Apologists for nuclear power sometimes say that they doubt whether a pro-nuclear decision in Britain will make much difference to whether the rest of the world goes nuclear. That is a dangerous argument. It is the same as that used by those who say that since Britain is the source of only 2% of world greenhouse gas emissions, we should do nothing about climate change. Its use by the nuclear lobby makes one doubt the sincerity of their claim to be concerned about climate change in the first place. It is also wrong. What possible standing can we have to ask other countries to restrain themselves if we ourselves refuse to do so? Britain is admittedly no longer a great power. It can no longer require anyone to do anything. But it can try to regain at least some semblance of moral leadership.

Nuclear power is unique. It is the only form of electricity production that in itself poses a threat to international peace and domestic security. It is also, as a consequence of its dangers and of the secrecy that inevitably surrounds it because of its connections with nuclear weapons, the only form of electricity production that in itself poses a threat to individual liberties. Those who advocate it might not care about peace or freedom, but for those of us who do, we cannot say that we were not warned.

David Howarth MP  
Liberal Democrat Shadow Energy Spokesperson, June 2007

## Introduction

Many countries, the UK among them, are reviewing their nuclear-energy policies because they are concerned about:

- the security of their energy (electricity) supplies; and
- the consequences of global warming.

### Energy security

Assuming a business as usual scenario, global energy demand is projected to be 50% higher in 2030 than today.<sup>1</sup> Regardless of the scenario, most of the demand growth will occur in China, India and East Asia, although demand in Middle Eastern and North African states is expected to grow significantly too.<sup>2</sup> Unless major changes to national and regional energy policies are implemented, over 60% of this demand increase is anticipated to be met by coal, oil and natural gas, with serious consequences for global CO<sub>2</sub> emissions. China, for example, is currently commissioning a new one gigawatt (GW) coal powered electricity station every five days, using standard technology which releases all the carbon dioxide in the coal into the atmosphere.<sup>3</sup>

The combination of intensifying competition for fossil fuels and a concentration on a small number of producing states leads to considerable medium-term insecurity over supplies. In this context, nuclear power is presented as an effective way to reduce dependency on imported fossil fuels and increase baseload electricity security.

### Global warming

42 Gigatonnes (gT) of CO<sub>2</sub> equivalent are emitted annually.<sup>4</sup> If emissions were capped at this level then atmospheric Greenhouse Gas (GHG) concentrations would reach 550 parts per million (ppm) by 2050 (today they are between 311-435 ppm compared to 280 ppm before the industrial revolution).<sup>5</sup> At between 480 and 550 ppm the global average temperature would rise by 2 °C above pre-industrial levels.

According to the scientific consensus, to keep climate change within manageable limits it is essential that global average temperature increase is less than 2 °C. At 3 °C and above, the changes to various climate systems would threaten to lead to runaway changes to the climate.<sup>6</sup> But the annual flow of emissions is not static, it is increasing, meaning that 550 ppm could be reached if not exceeded by 2035 unless urgent action is taken.<sup>7</sup>

What is required to reduce the risk of the global temperature rising above 2 °C is at least a 60% reduction of CO<sub>2</sub> emissions by 2050 against 2000 levels. Given that 24% (and growing) of global CO<sub>2</sub> emissions are produced by the power sector (and 65% in the energy sector), this sector has the potential for making significant contributions to reductions in CO<sub>2</sub> emissions. Below is an outline of the potential civil nuclear power contains for mitigating CO<sub>2</sub> emissions, based on:

- 1 current nuclear capacity;
- 2 new reactors under construction;
- 3 planned and proposed reactors; and
- 4 future demand for electricity.

## World nuclear-power reactors (May 2007)

Table 1	Country	No. of operating nuclear reactors	% of electricity generated by nuclear power	Populations <sup>a</sup>
	Argentina	2	6.9	40,301,927
	Armenia	1	42	2,971,640
	Belgium	7	54	10,392,226
	Brazil	2	3.3	190,010,647
	Bulgaria	2	44	7,322,858
	Canada	18	16	33,390,141
	China	11	1.9	1,321,851,888
	Czech Republic	6	31	10,228,744
	Finland	4	28	5,238,460
	France	59	78	63,713,929
	Germany	17	32	82,400,996
	Hungary	4	38	9,956,108
	India	17	2.6	1,129,866,254
	Italy	0	>10 <sup>o</sup>	58,147,733
	Japan	55	30	127,433,494
	South Korea	20	39	49,044,790
	Lithuania	1	72	3,575,439
	Mexico	2	3.5	108,700,891
	Netherlands	1	3.5	16,570,613
	Pakistan	2	2.7	164,741,924
	Romania	1	10	22,276,056
	Russia	31	16	141,377,752
	Slovakia	5	57	5,447,502
	Slovenia	1	40	2,009,245
	South Africa	2	4.4	43,947,828
	Sweden	10	48	9,031,088
	Switzerland	5	37	7,554,661
	Taiwan	6	20	22,858,872
World Total:	Ukraine	15	48	46,299,862
429 reactors	UK	19	19	60,776,238
generating	USA	103	19	301,136,947
370,163 MWe				

### Nuclear-power reactors under construction

The 25 new reactors will, on average, each generate somewhat less electricity than those already operating – about 770 MWe compared to about 850 MWe.

Table 2

Country	Number of reactors under construction
Iran	1
Argentina	1
Finland	1
Romania	1
South Korea	1
USA	1
Canada	2
China	4
India	6
Japan	2
Russia	5

### Plans and proposals to construct new nuclear-power reactors

Some countries have announced plans to build new reactors. In addition, some countries have announced that they propose to build new nuclear-power reactors. These are, of course, in many cases much less certain to be built than those planned.

Table 3

Country	Planned	Proposed
Argentina	0	1
Armenia	0	1
Brazil	1	4
Bulgaria	2	0
Canada	4	0
China	23	54
Czech Republic	0	2
Egypt	0	1
France	1	1
India	4	15
Indonesia	0	4
Iran	2	3
Israel	0	1
Japan	11	1
North Korea	1	0
South Korea	7	0
Kazakhstan	0	1
Lithuania	0	1
Mexico	0	1
Pakistan	2	2
Romania	0	3
Russia	8	18
Slovakia	2	0
Slovenia	0	1
South Africa	1	24
Turkey	3	0
Ukraine	2	0
USA	2	21
Vietnam	0	2

The amount of electricity generated by these 76 planned reactors will, on average, be greater than that generated by those under construction – about 1,100 MWe compared with 770 MWe. The amount of electricity generated by these 162 proposed reactors will, on average, be about 800 MWe.

If all the proposed reactors are built the number of countries operating nuclear-power reactors will increase from today's number of 31 to 38. Some future reactors will generate more electricity than those used today. The new reactor under construction in Finland, for example, will have a generating capacity of 1,600 MWe. However, smaller nuclear-power reactors are better suited to supplying the electricity needs of some countries. The reactors that South Africa proposes to construct have an average generating capacity of less than 200 MWe. But reactors of 1,000 MWe and more will become commonplace.

A number of other governments have indicated that they may, at some future date, construct new nuclear reactors. The UK, for example, may build eight new reactors, two at each of four sites on which an existing nuclear-power reactor is operating. Middle Eastern countries newly interested in nuclear power include Bahrain, Jordan, Kuwait, Oman, Qatar, Saudi Arabia, Syria, the United Arab Emirates, and Yemen.<sup>11</sup>

### Future demands for electricity

Future demands for energy will depend on population size and consumption patterns. It is probable that by 2075, for example, the population of China will reach about 1,600 million, that of India will be about 1,800 million, and that of Indonesia will be about 375 million. Assuming that these countries generate one kilowatt of electricity per capita (probably an underestimation), and that they generate a third of their electricity by nuclear power (twice today's world share but only around one-sixth of total energy consumption), China would require about 530 GWe of nuclear power, India would require about 600 GWe, and Indonesia would require about 125 GWe.

For comparison, the population of the USA is likely to be about 445 million by 2075, requiring about 146 GWe, assuming one kilowatt of electricity per capita and a third of the electricity generated by nuclear power. Bangladesh, Brazil, Congo, Ethiopia, Nigeria and Pakistan would each need more than 65 GWe. Bangladesh, Congo, Ethiopia, Indonesia and Nigeria now have no nuclear-power reactors. But if nuclear power were to play more than a marginal role in combating global warming then some nuclear-power reactors would have to be operated in these countries.<sup>12</sup>

### The future of nuclear power: how many would we need to help?

Taking an average reactor size of 1,000 MWe (many will be breeder reactors), between 2,000 and 2,500 power reactors will be needed worldwide.<sup>13</sup> If we take 2,250 new reactors, then between now and 2075 nearly three new reactors a month would need to start delivering electricity to their respective grids. Moreover, because of the limited lifespans of nuclear-power reactors old reactors will have to be replaced.<sup>14</sup> Lets say it will be fifteen years until a new reactor is delivering electricity (2022), but that an additional 250 reactors would be required to replace the aging fleet. This means that nearly four new reactors would have to begin construction each month from now until 2075.

A civil nuclear construction and supply programme on this scale is a pipedream. In the UK it is expected to take at least 17 years from licensing to generating electricity.<sup>15</sup> No previous civil nuclear power programme has got anywhere near the kind of new build rate discussed above. France operates the largest number of nuclear-power reactors, with 59 operating nuclear-power reactors, generating 76% of its own electricity and having some surplus electricity to export to other European countries. In addition, France has permanently shut down 11 reactors, many of them associated with the French nuclear-weapon programme. Between 1977 and 1993, 58 nuclear power reactors came into operation – an average of 3.4 reactors per year.

*“A worldwide nuclear ‘renaissance’ is beyond the capacity of the nuclear industry to deliver, and would stretch to breaking point the capacity of the IAEA to monitor and safeguard civil nuclear power.”*

***“official confidence in nuclear power’s low carbon credentials should be reviewed.”***

## What impact could nuclear power have on global CO<sub>2</sub> emissions?

Policies intended to mitigate CO<sub>2</sub> emissions will fail unless they take into account the global context. A UK GHG emission reduction of 50% by 2025, for example, would be insignificant, constituting as it would less than 1% of global emissions. Therefore, when choosing which technologies to invest in UK policy-makers need to consider the impact that decision will have on:

- that technology’s market credibility (investor risk);
- market viability of renewable technologies in the UK and abroad;<sup>16</sup>
- research and development in other energy sources; and
- UK national security and international security.

The global context is also essential to delivering energy security goals. Instability, competition and conflict caused by energy insecurity is a global problem. Policies to secure UK energy supplies and reduce dependence on Russian gas and middle eastern oil, for instance, would improve the UK’s security only marginally unless such security was achieved across the world. As we have shown, nuclear power cannot deliver such security.

According to the IPCC (2007), nuclear power supplied 16% of global electricity in 2005, from 442 nuclear-power reactors operating in 31 countries, generating 375 GW of electricity.<sup>17</sup> Literature cited by the IPCC shows that nuclear power currently saves 2.2 to 2.6 GtCO<sub>2</sub>/yr if that power was instead produced by coal. Or 1.5 GtCO<sub>2</sub>/yr if using the world average CO<sub>2</sub> emissions (540 gCO<sub>2</sub>/kWh) from electricity production in 2000.<sup>18</sup> Accordingly, nuclear power is considered an “effective GHG mitigation mechanism”. However, the IPCC authors also point out that evidence presented by J. W. S van Leeuwen and P. Smith (2005) indicate that emissions from ore processing, construction and decommissioning are significantly higher than other official sources.<sup>19, 20, 21</sup> Given the fact that all the evidence cited by IPCC is subject to rigorous scrutiny, the inclusion of this evidence is important as it indicates that official confidence in nuclear power’s low carbon credentials should be reviewed.

### Annual CO<sub>2</sub> emissions from nuclear power

If nuclear power is to mitigate global CO<sub>2</sub> emissions, then decision-makers need to calculate reliably how much CO<sub>2</sub> would be displaced, i.e. how much more CO<sub>2</sub> would be generated if gas-fired plants were used instead of nuclear power. The range of emissions shown in table 4 supports the following recommendation made by the House of Commons Environmental Audit Select Committee in 2006:

*“the Government should consider asking the Royal Commission on Environmental Pollution to report on carbon emissions associated with all generating technologies.”<sup>22</sup>*

The remit of such an enquiry would need to look at CO<sub>2</sub> emissions over time, because for technologies such as nuclear power that depend upon naturally occurring resources, the quality of available ores makes a significant difference to the amount of work required to produce fuel, and consequently CO<sub>2</sub> emissions will change over time too.<sup>23</sup>

Table 4: CO<sub>2</sub> emissions for energy sources per kilowatt hour (gCO<sub>2</sub>-e/kWh)

Natural gas	386	Nuclear (OECD)	11 - 22
World Av.	540	Nuclear (Storm & Smith)	84 - 122 <sup>24</sup>
Coal	755	Nuclear (ISA, Uni. of Sydney)	10 - 130 <sup>25</sup>
Nuclear (Oko Institute)	31 <sup>26</sup>		

Unless it can be demonstrated with certainty that nuclear power can make a major contribution to global CO<sub>2</sub> mitigation, nuclear power should be taken out of the mix. One of the main reasons for treating nuclear power differently to other energy technologies is that nuclear power, unlike other energy sources, is pregnant with one of the most challenging and inhumane threats to international peace and stability – nuclear weapons.<sup>27</sup> Even a small expansion in the use of nuclear power for electricity generation would have serious consequences for the spread of nuclear weapons to countries that do not now have them and for nuclear terrorism. A decision by the UK to license and support a new round of nuclear power stations would strengthen political and market support for civil nuclear power, both of which are essential for its future.

### Security aspects of an increased use of nuclear power

Supporters of nuclear power quite rightly point to the fact there are only eight (excluding DPRK) nuclear weapons states, so the Nuclear Non-proliferation Treaty (NPT) and IAEA have successfully managed to control the proliferation risks of civil nuclear power to a reasonable degree.<sup>28</sup> That the international nuclear control regime has prevented widespread weapons proliferation is a little reassuring (if India, Pakistan, Iraq, Israel and DPRK are discounted), but does not mean that it will continue to do so over the next twenty to fifty years, or that it can deal with the consequences of a nuclear renaissance.

## *The question is whether in the 21<sup>st</sup> century the security risks associated with civil nuclear power can be managed or not?*

### The Nuclear Fuel Bank and the Global Nuclear Energy Partnership

Two major proposals have been put forward to supply the nuclear fuel for nuclear-power reactors operated by non-nuclear-weapon countries in a way that would reduce the risk that fissile material from civil nuclear programmes would be diverted to the production of nuclear weapons. The aim is to try to prevent nuclear weapons spreading to countries that do not now have them and to nuclear terrorists. The proposals aim to guarantee countries' supplies of nuclear fuel, the essential material for the generation of electricity by nuclear-power reactors.

#### *A nuclear fuel bank under international safeguards*

One of the proposals is to set up a nuclear "fuel bank" or nuclear fuel reserve, administered by the IAEA. The fuel bank would assure a back-up supply of fuel for power reactors on a non-discriminatory, non-political basis, thereby reducing the need for countries to develop their own uranium enrichment and plutonium reprocessing technologies that could, if the political decision were taken to do so, be used to produce highly enriched uranium or plutonium for use in nuclear weapons.

The fuel bank would, it is proposed, be set up in a way that would not disrupt the existing commercial market in nuclear fuels. IAEA Director General Mohamed El Baradei explains: "I want to make sure that every country that is a bona fide user of nuclear energy, and that is fulfilling its non-proliferation obligations, is getting fuel. It is not asking any State to give up its rights under the NPT. The importance of this step is that, by providing reliable access to fuel at competitive market prices, we remove the need for countries to develop indigenous fuel cycle capabilities. In so doing, we could go a long way towards addressing current concerns about the dissemination of sensitive fuel cycle technologies."<sup>29</sup>

Both America and Russia have stated that they are willing to make nuclear material available for a fuel bank administered by the IAEA. Russia has proposed the establishment of international centres under a Global Nuclear Power Infrastructure (GNPI)<sup>30</sup> to provide nuclear fuel cycle services, including the enrichment of uranium, in a non-discriminatory way, supervised by the IAEA. And, under the Global Nuclear Energy Partnership (GNEP),<sup>31</sup> proposed by the Bush Administration, the USA, in partnership with other countries, would develop a nuclear fuel services programme to supply developing nations with “reliable access to nuclear fuel in exchange for a commitment to forego the development of uranium enrichment and plutonium reprocessing technologies”.

In the words of Tariq Rauf, Head of the Verification and Security Policy Coordination Section, Office of External Relations and Policy Coordination, IAEA, the setting up of a nuclear fuel bank, under international safeguards: “is an either/or situation, if we don’t make it work, then we must prepare to live in a world where dozens of countries have the capability and key ingredients to make nuclear weapons.”<sup>32</sup>

*“If GNEP goes ahead and the Americans reprocess spent reactor fuel elements, it will reverse 30 years of American government policy.”*

#### *The Global Nuclear Energy Partnership*

GNEP is the plan put forward by the Bush Administration to encourage an increase in the use of nuclear power for the generation of electricity in the USA and other countries (sometimes called the nuclear renaissance). The ostensible aims of GNEP are to reduce dependence on foreign oil, reduce the emissions of CO<sub>2</sub> into the atmosphere to slow the pace of global warming, and reduce the risk of nuclear proliferation. To achieve this GNEP would:

- construct a new generation of nuclear-power reactors in the USA;
- reprocess spent reactor fuel elements; and
- develop a fast reactor that would use the reprocessed waste as nuclear fuel.

When GNEP is operating, the nuclear-weapon powers will sell nuclear-power reactors and the nuclear fuel for them, to non-nuclear-weapon powers. They would then arrange to take back the spent fuel elements from the reactors, reprocess them and eventually permanently dispose of the radioactive waste.

A number of nuclear experts have criticised GNEP. A greater use of nuclear power for electricity generation, it is pointed out, will have little or no impact on America’s use of foreign oil because no more than 3% of America’s electricity is generated by oil fired power stations. This percentage is likely to almost halve by 2025.

If GNEP goes ahead and the Americans reprocess spent reactor fuel elements, it will reverse 30 years of American government policy. In 1977, President Jimmy Carter (who was a nuclear engineer) banned reprocessing in the US because of concerns that the plutonium separated from the civil reactor fuel elements would be used to fabricate nuclear weapons.

Matthew Bunn of Harvard University stated: “A near-term decision to reprocess U.S. commercial spent nuclear fuel would be a serious mistake, with costs and risks far outweighing its potential benefits.” He also stated that reprocessing would undermine current U.S. efforts to prevent nuclear proliferation.

Richard L. Garwin, IBM Fellow Emeritus and an expert in nuclear-weapon technology, argues that the new reprocessing scheme proposed in GNEP would make it easier for terrorists to acquire fissile material needed to fabricate nuclear weapons. Reprocessing was abandoned not only because of the increased risk of nuclear proliferation but also because it was too expensive to make commercial sense.

Garwin argues that, far from being proliferation resistant, GNEP makes it easier for terrorists to acquire nuclear material suitable for fabricating nuclear weapons. He points out that: "To obtain 10 kg of plutonium from ordinary Pressurised Water Reactor spent fuel containing 1% plutonium, a terrorist would need to acquire and reprocess 1000 kg of highly radioactive material."

*“reprocessing would not remove the need for a permanent repository for the disposal of high-level radioactive waste”.*

Under GNEP: “the plutonium will be contaminated only with a modest amount of transuranics (TRU) so that the terrorist would need to reprocess a mere 11 kg of material, and according to recent Department of Energy (DOE) studies, this would have only about 1/2000 of the penetrating radiation that would count as ‘self protecting’.” Spent nuclear-power reactor fuel, however, is so radioactive that it is self-protecting and cannot be handled without remote-handling equipment.

It is argued that reprocessing makes easier the management of radioactive waste produced by nuclear-power reactors. Steve Fetter, of the University of Maryland, points out that reprocessing would not remove the need for a permanent repository for the disposal of high-level radioactive waste (an argument often used in favour of reprocessing) and would, in fact, be very much more expensive. In short, reprocessing spent reactor fuel elements is both an economic and an environmental disaster. As shown earlier, reprocessing considerably increases the risk of the theft of nuclear material that can be used to fabricate nuclear weapons and, therefore, increases the risk of nuclear terrorism.

Under GNEP, after the radioactive wastes are reprocessed they would be used to make nuclear fuel for use in Advancer Burner Reactors (ABR). These reactors do not now exist. But they are similar in design to fast breeder reactors (FBRs) but they do not have a uranium blanket in which plutonium is produced ('bred'). Experience shows that FBRs are expensive and unsafe, to say the least.

The French FBR programme, for example, proved incapable of making the technology work safely and economically. France's Superphenix FBR was permanently shut down in 1987 after leaking 20 tons of liquid sodium coolant. The Japanese Monju FBR was shutdown in 1995 after three tons of sodium leaked causing the reactor to over heat. And FBR programmes in the UK, Germany, and the USA were terminated. GNEP should learn from these ill-fated programmes.

President Bush has warned that: “The gravest danger in the war on terror, the gravest danger facing America and the world, is outlaw regimes that seek and possess nuclear, chemical, and biological weapons.” Both President Bush and Prime Minister Blair have warned about the dangers of nuclear terrorism. President Bush's ill-conceived GNEP will only increase the potential that fissile material for and knowledge about nuclear weapons will fall into the wrong hands.

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## Nuclear weapons proliferation and nuclear reactors

A major security concern is that the fuel used in many new nuclear-power reactors will contain plutonium that could be used to manufacture nuclear weapons. Some countries have stocks of plutonium, which has been separated from spent nuclear-power reactor fuel elements, in store and would like to reduce these stocks by using the plutonium as nuclear fuel.

The world's current stock of separated civil plutonium is very large, and it is increasing considerably. Civilian stocks of weapons-usable plutonium have now reached 215 tonnes, about the same as the 250 tonnes of military plutonium. In France, Japan, Russia, and the UK, stocks of plutonium will increase by as much as 125 tons by 2015, equal to half the plutonium produced by the nuclear weapon states during the Cold War.

Generation I reactors were the early prototype reactors, of 1950s and early 1960s vintage (e.g., the Magnox reactors); generation II reactors are the commercial power reactors of the 1970s and 1980s (e.g., advanced gas cooled and light water reactors and Canadian CANDU reactors); generation III reactors are advanced light water reactors, such as the European Pressurised Reactors and Advanced CANDU reactors, that will soon mature; and generation IV reactors will, the nuclear industry hopes, eventually be the core of the nuclear renaissance, and include such advanced reactor types as fast breeder reactors.

Generation II and III reactors can use a mixed-oxide (MOX) nuclear fuel, which is a mixture of uranium and plutonium dioxides. MOX fuel has serious implications for nuclear-weapon proliferation because the plutonium dioxide can easily be separated from the uranium dioxide, using straightforward chemical methods, and used to fabricate nuclear weapons. Generation IV reactors will be fuelled with plutonium. The plutonium will be of a type suitable for use in the most efficient nuclear weapons. The consequence of the widespread use of generation IV reactors for nuclear-weapon proliferation and nuclear terrorism is very serious indeed.

Why are breeder nuclear reactors sought?

*“Any country operating new nuclear power reactors, particularly breeder reactors, will have relatively easy access to plutonium usable in effective nuclear weapons.”*

A significant increase in the use of nuclear power for electricity generation will, in the medium- and long-term, lead to the operation of so-called generation IV reactors. A number of countries are experimenting with breeder reactors. Using a cunning design, they produce more nuclear fuel than they use. Therefore, a significant use of breeder reactors would decrease demand for uranium fuel and extend uranium supply. Future breeder reactors will be fuelled with plutonium and only a small input of uranium. The plutonium will be of a type suitable for use in the most efficient nuclear weapons. Thus, the normal operation of these reactors will, as a matter of course, multiply the amount of weapons useable plutonium available across the world. Why invest in breeder technology?

The DTI cites OECD/NEA 'Red Book' figures to claim that based on 2004 generation levels, known reserves (at \$130/kg) will last for around 85 years.<sup>33</sup> This headline figure conceals important details which affect the security of uranium supply into the future. Due to restrictions on the availability of sufficiently high-grade uranium ore, the nuclear industry will need to develop generation IV reactors to be used commercially after about 2030. Otherwise, it is anticipated that uranium reserves will not be able to supply demand. Insecurity of uranium supplies is a significant driver for commercial breeder technology.

Nuclear weapons proliferation

A significant use of generation III and IV reactors will carry with it the real risk that nuclear terrorist groups will eventually acquire plutonium, fabricate primitive nuclear weapons and use them in terrorist attacks.

Any country operating new nuclear-power reactors, particularly breeder reactors, will have relatively easy access to plutonium usable in effective nuclear weapons and will have competent nuclear physicists and engineers who could design and fabricate them. Because they could produce a nuclear force in a short time – months rather than years – these countries will be latent nuclear-weapon powers. Within 30-40 years, according to the IAEA, about 30 countries are likely to have access to fissile materials from their civil nuclear power programmes that can be used for nuclear weapons and competent nuclear physicists and engineers who could design and fabricate them.

*“If a state of concern or potential concern decided to develop a civil nuclear power programme, defence strategists would certainly take that information into account”.*

The crux of the issue is whether any of these countries will take the political decision to become nuclear-weapon powers, i.e. can the international community manage the proliferation risks associated with current trends in civil nuclear power, let alone a nuclear ‘renaissance’? What drives the political decision-making?

This risk boils down to perceptions of capability and intent. In the case of Iran, for example, there is considerable distrust over the sections of the ruling elite’s intentions. This is why the USA, Britain and many other states are so anxious to prevent Iran acquiring a nuclear weapons capability. If Iran did become a nuclear weapons state, its capability would change, affecting the balance of power in the Middle East and elsewhere.

It takes many years to develop a strategic nuclear weapons programme. Decision-makers assessing national vulnerabilities, looking perhaps to begin lengthy and binding defence projects, would first of all make medium-term assessments of the intentions and capabilities of a range of state and non-state actors that impact upon defence policy.<sup>34</sup> If a state of concern or potential concern decided to develop a civil nuclear power programme, defence strategists would certainly take that information into account – it signals to defence planners the potential to develop the resources and expertise required for a nuclear weapons programme some time in the future. In short, a civil nuclear power programme changes assessments of capability.

This process of weighing up and anticipating intentions and capabilities to assess vulnerabilities and recommend defence policies, including latent nuclear weapons programme, may be part-fueling the nuclear renaissance. We must remember that such a process is not scientific or rational: the fears and hopes of individual decision-makers involved in this type of decision are important. This fact is significant and very hard to account for in official decision-making.

Where trust in existing mechanisms for controlling the spread of nuclear weapons technology and materials is weak, as they are today, decision-makers and planners might ‘hedge their bets’ to protect vulnerabilities. Mutual suspicion is signalled by one person’s prudence, which is to another is a provocative act. These are the raw ingredients of a slow burning arms race.

### Nuclear terrorism

The world of the nuclear ‘renaissance’ will be one containing a huge amount of separated plutonium, some of which is bound to fall into the wrong hands including those of terrorists. Surprisingly, the potential spread of nuclear weapons to terrorists is receiving very little attention.

By 2075, the nuclear industry predicts that most nuclear electricity will be generated by fast breeder reactors. If this is correct, more than 4,000 tonnes of plutonium will have to be fabricated into fresh reactor fuel each year – twenty times the current military stockpile. Society has to decide whether or not the risks of nuclear-weapon proliferation and nuclear terrorism in a world with many nuclear-power reactors are acceptable.

The key activity to be considered is the reprocessing of the spent reactor fuel elements to separate chemically unused uranium from the plutonium and the fission products in the elements. When removed from the reactor the fuel elements are so radioactive that they are self-protecting. No one can get near them and survive – they have to be handled remotely using very heavy remote-handling equipment. After reprocessing, however, the plutonium can be handled relatively easily.

A nuclear terrorist attack may be one of several types. A terrorist group may attack, sabotage or hijack a transporter of nuclear material, such as radioactive waste. They may blow up containers of radioactive waste to spread the radioactivity. The more nuclear-power stations there are the greater will be the number of nuclear transports.

Terrorists may attack a plutonium store at a reprocessing plant, like Sellafield, to spread the plutonium in it. Plutonium is a very toxic substance, particularly when inhaled. The human environment must, therefore, be kept completely free of it. Even small amounts of plutonium contamination must be removed.

### A crude terrorist nuclear explosive

Terrorists may acquire plutonium to make and detonate a crude nuclear weapon. They would do so using the implosion technique. This would involve surrounding a sphere of plutonium, having a mass less than the critical mass, or surrounding a spherical volume of plutonium dioxide, of less than critical mass, by conventional high explosives.

A terrorist group containing people with appropriate skills could design and fabricate such a crude nuclear explosive. The size of the nuclear explosion from such a crude device is impossible to predict. But even if it were only equivalent to the explosion of a few tens of tonnes of TNT it would completely devastate the centre of a large city. Such a device would, however, have a strong chance of exploding with an explosive power of at least a hundred tonnes of TNT. Even one thousand tonnes or more equivalent is possible, but unlikely.

Terrorists would be satisfied with a nuclear explosive device that is far less sophisticated than the types of nuclear weapons demanded by the military. Whereas the military demand nuclear weapons with predictable explosive yields and very high reliability, most terrorists would be satisfied with a relatively primitive nuclear explosive.

### Terrorist use of a radiological weapon

The simplest and most primitive terrorist nuclear device is a radiological weapon or radiological dispersal device, commonly called a dirty bomb. A dirty bomb would consist of a conventional high explosive (for example, semtex, dynamite or TNT), some incendiary material (like thermite) surrounding the conventional explosive, and a quantity of a radioisotope, probably placed at the centre of the explosive.

When the conventional high explosive is detonated the radioactive material would be vaporised. The fire ignited by the incendiary material would carry the radioactivity up into the atmosphere. It would then be blown downwind, spreading radioactivity. A dirty bomb is not the same as a nuclear weapon in the normal sense of the phrase – it does not involve a nuclear explosion.

The use of plutonium in a dirty bomb would cause the greatest threat to human health, because of its very high inhalation toxicity, and the most extensive contamination. Radioactive waste could also be used.

Many other types of radioisotopes (radioactive isotopes) would be suitable for use in a dirty bomb. But the most likely one to be used is one that is relatively easily available, has a relatively long half-life, and emits energetic radiation. Suitable ones include caesium-137, cobalt-60, and iridium-192; these emit mainly gamma rays (electromagnetic radiation). Strontium-90, which emits beta particles (electrons) and is concentrated in bone, is also a possible candidate.

***“The main potential impact of a dirty bomb is psychological – it would cause considerable fear, panic and social disruption, exactly the effects terrorists wish to achieve.”***

The detonation of a dirty bomb is likely to result in some deaths but would not result in the hundreds of thousands of fatalities that could be caused by the explosion in a city of a crude nuclear weapon. Generally, the explosion of the conventional explosive would be the most likely cause of any immediate deaths or serious injuries.

The radioactive material in the bomb would be dispersed into the air but would be soon diluted to relatively low concentrations. If the bomb is exploded in a city, as it almost certainly would be, some people are likely to be exposed to a dose of radiation. But the dose is in most cases likely to be relatively small. A low-level exposure to radiation would slightly increase the long-term risk of cancer.

The main potential impact of a dirty bomb is psychological – it would cause considerable fear, panic and social disruption, exactly the effects terrorists wish to achieve. The public fear of radiation is very great indeed, some say irrationally so.

The explosion of a dirty bomb could result in the contamination of an area of a city and the surrounding areas with radioactivity. Areas as large as tens of square kilometres could be contaminated with radioactivity to levels above those recommended by the National Radiological Protection Board for the exposure of civilians to radioactivity. The area would have to be evacuated and decontaminated.

The degree of contamination would depend on the amount of high explosive used, the amount and type of radioisotope released during the explosion of the bomb, the nature of the device used to spread the radioactivity, whether it was exploded inside a building or outside, and speed and direction of the wind, the general weather conditions, and the size and position of buildings near the detonation site. The size of the radioactive particles released by the device will determine how far they are carried by the wind and how easily people inhale them. Radioactivity will be carried away on people’s clothes and spread by vehicles passing through the contaminated areas. People may also ingest radioactivity by eating contaminated food and drinking contaminated water.

In the longer term, any exposure to ionising radiation can cause fatal cancers. The number of fatalities in a group of people will be proportional to the total radiation dose received by the group.

The effects on the health of people exposed to the radioactivity released by a dirty bomb will depend on how long they remain in the contaminated area, the size of the particles released by the explosion and the type of radioactivity emitted by the radioisotopes in the bomb. Decontamination is likely to be very costly (costing millions of pounds) and take weeks or, most likely, many months to complete.

There are no ways to decontaminate effectively buildings contaminated with significant amounts of radioactivity; the buildings may, in practice, have to be demolished. If a dirty bomb were detonated in, for example, London’s Oxford Street or in the City of London, the cost would be huge, potentially many hundreds of millions of pounds.

Such is the public fear of ionising radiation that even relatively small levels of radioactive contamination on or in buildings, on roads or footpaths, or on public areas would be publicly unacceptable. Decontamination would have to be virtually complete. Roads and walkways in contaminated areas, for example, would have to be re-surfaced. Radioactive contamination is by far the most threatening aspect of a dirty bomb.

***“Society should consider whether or not the risk that terrorists will acquire plutonium and make and detonate a nuclear weapon is unacceptably high”.***

### Terrorist attack on a nuclear-power station <sup>35</sup>

Instead of exploding a nuclear weapon, a terrorist group may decide to attack a nuclear facility. It is generally recognised that a terrorist group with significant resources could attack and damage a nuclear-power plant. There is argument, however, about how much damage and how many people would be harmed by such an attack. It is probably true that attacks on nuclear-power plants that could do a great deal of damage and cause many fatalities do not have a large chance of success. But many believe that the damage caused by and the number of people killed by a successful terrorist attack on a nuclear-power plant could be so catastrophic that even a small risk of such an attack is not acceptable.

There are two potential targets in a nuclear-power station for a terrorist attack: the reactor itself and the ponds storing the spent fuel removed from the reactor. An attack on the reactor could cause the core to go super-critical (as happened during the 1986 accident at the Chernobyl reactor) or cause a loss of the coolant that removes heat from the core of the reactor (as happened during the reactor accident at Three Mile Island).

Spent fuel elements are normally kept in storage ponds for five or ten years under three or so metres of water before they are either finally disposed of in a geological repository or sent to a reprocessing plant where the plutonium inevitably produced in the fuel elements is chemically separated from unused uranium and fission products in the fuel elements. The ponds are normally built close to the reactor building. The buildings containing the spent fuel ponds are less well protected than the reactor and are, therefore, more attractive targets than the reactor building.

Terrorists could target a reactor or spent fuel pond by: using a truck carrying high explosives and exploding it near a critical part of the target; exploding high explosives carried in a light aircraft near a critical part of the target; crashing a high-jacked commercial airliner into the reactor building or spent-fuel pond; attacking the power station with small arms, artillery or missiles and occupying it; or by attacking the power lines carrying electricity into the plant.

Alternatively, a terrorist group may infiltrate some of its members, or sympathisers, into the plant to sabotage it from inside. A saboteur may attack, for example, the systems cooling the reactor core or drain water from the cooling pond. This could cause the temperature of the reactor core to rise, resulting in a release of radioactivity from the core, or cause the temperature of the spent fuel rods to rise, again resulting in a release of radioactivity.

### Measures to counter nuclear terrorism

To effectively counter nuclear terrorism it is important to prevent terrorists from acquiring plutonium and from acquiring significant quantities of radioactive materials to build a dirty bomb. The protection of these nuclear materials is clearly of the utmost importance.

It seems that UK government policy is to stop operating the THORP reprocessing plant at Sellafield in 2010 but presumably the Sellafield MOX Plant (SMP) will continue operating using plutonium from stock. The future risk of a terrorist group acquiring plutonium from MOX will, therefore, remain.

Society should consider whether or not the risk that terrorists will acquire plutonium and make and detonate a nuclear weapon is unacceptably high. If it is too high, a decision should be taken to shut down SMP.

Making existing nuclear-power reactors less vulnerable to terrorist attack is not very feasible although storage ponds for spent fuel elements could be more hardened. And greater care could be taken to vet staff to make it more difficult for a terrorist group to infiltrate people into

*“how would the market and public respond to a foiled terrorist attack?”*

a nuclear-power station. Also, staff in all sensitive nuclear facilities, such as reprocessing plants and MOX fabrication plants, should be thoroughly vetted.

The protection of a nuclear facility with, for example, fighter aircraft or surface-to-air missiles is, to say the least, not an easy task. If a terrorist group hijacks a commercial aircraft on a regular flight path that takes it close to, for example, the Sellafield establishment and dives it on to a target in the nuclear facility, the time available to make sure that the aircraft really is attacking the facility and then to scramble fighter aircraft or fire surface-to-air missiles is probably too short to make a successful interception.

The capacity of intelligence and security services to prevent nuclear terrorism in a world of many more potential targets also needs very careful consideration. In the UK new nuclear plants will be required to build-in physical protection measures based on “Design Basis Threats” (DBTs) to reduce vulnerability to a range of terrorist attack scenarios. The details of these are confidential, so it is impossible to independently verify their adequacy.

The combination of DBTs with various other physical and human security measures including counter-terrorism exercises, staff vetting, and, of course, on-going security and intelligence work, are sufficient for the Office of Civil Nuclear Security (OCNS) and Department for Trade and Industry (DTI) to assert that: “the risks associated with building new nuclear power stations can be appropriately managed.”<sup>36</sup> This may be the case today, but will it be true in ten, twenty or thirty years time? And if the threat assessment changes significantly, how will a completed new nuclear station respond? How would the market and public respond to a foiled terrorist attack against a nuclear plant, let-alone a successful one?

Even a failed terrorist attack on one of the first new builds would most probably cause subsequent new build to halt in many countries. If this happened, Governments would need to re-review energy policy minus civil nuclear power. In other words, progress to a sustainable and secure energy policy would be seriously delayed, possibly causing the UK and other affected countries to miss the window of opportunity to seriously mitigate CO<sub>2</sub> emissions.

## Conclusions

Many of the risks associated with civil nuclear power are well known and have to some extent been managed... just: recall Chernobyl, Three Mile Island, Hiroshima, the Cuban Missile Crisis, Iraq, Dr. A Q Khan and reports of al Qaida's plans.<sup>37</sup> For the nuclear weapons proliferation and nuclear terrorism risks to be worth taking, nuclear must be able to achieve energy security and a reduction in global CO<sub>2</sub> emissions more effectively, efficiently, economically and quickly than any other energy source. There is little evidence to support the claim that it can, whereas the evidence for doubting nuclear power's efficacy is clear.

The two current proposals to reduce the risk that a global expansion of nuclear power poses for nuclear weapon proliferation and nuclear terrorism, the Global Nuclear Energy Partnership and the Nuclear Fuel Bank both have serious shortcomings. GNEP requires spent-fuel reprocessing and the use of fast breeder reactors. Both have been shown to be commercial disasters. In addition, FBRs have proved to be very unreliable, uneconomical, and unsafe.

Furthermore, current national and international safeguards systems cannot monitor the movement of nuclear materials through reprocessing and enrichment plants sufficiently adequately to ensure that the diversion of nuclear materials from civil to military use will not occur. In short, the plutonium economy will inevitably increase the risk that the capability to fabricate nuclear weapons will spread and that fissile materials will be used by terrorists to make nuclear explosives.

The idea of a nuclear fuel bank operated by the IAEA is seen by many countries to be discriminatory. Countries want to be able to enrich uranium using their own technology in their own plants. Allowing just a few advanced countries to have the monopoly of the technology is unacceptable to many.

The NPT gives the non-nuclear-weapon parties to the Treaty powers inalienable right to enrich uranium and requires that the nuclear-weapon parties assist them to do so. To divide the world into countries that can enrich uranium and those that cannot is no-longer acceptable.

The twin challenges of CO<sub>2</sub> mitigation and energy security can be addressed effectively so long as policy-makers properly review the evidence submitted to the current energy consultation. If a decision to go with nuclear power is taken then the UK will implement a flawed and dangerously counter-productive energy policy – one from which the blowback may be a lot worse than higher heating bills.

## Endnotes

1. International Energy Agency: [www.iea.org/textbase/nppdf/free/2005/weo2005.pdf](http://www.iea.org/textbase/nppdf/free/2005/weo2005.pdf)
2. Which may reduce the capacity of producing states to export oil. This fact is sometimes presented as the reason why states such as Iran and Saudi Arabia, which have plentiful fossil fuel supplies, would want to invest in civil nuclear power: it is so they can meet growing domestic demand without reducing income from exports. Another reasons relates to powering energy-intensive desalination plants.
3. For a valuable discussion of energy and climate security / EU - China relations, see: "Europe in the World" pamphlet by Tom Burke and Nick Mabey of E3G: [www.e3g.org/index.php/programmes/europe-in-the-world-pamphlet/](http://www.e3g.org/index.php/programmes/europe-in-the-world-pamphlet/)
4. [www.hm-treasury.gov.uk/media/4/3/Executive\\_Summary.pdf](http://www.hm-treasury.gov.uk/media/4/3/Executive_Summary.pdf) (Figure 1)
5. See IPCC Fourth Assessment: [www.mnp.nl/ipcc/pages\\_media/FAR4docs/chapters/CH1\\_Introduction.pdf](http://www.mnp.nl/ipcc/pages_media/FAR4docs/chapters/CH1_Introduction.pdf)
6. This World Wildlife Fund (UK) briefing outlines the environmental affects of a global average temperature increase of 20°C: [www.stopclimatechaos.org/documents/wwf\\_below\\_2\\_degrees\\_c.pdf](http://www.stopclimatechaos.org/documents/wwf_below_2_degrees_c.pdf)
7. For a summary of these projections see the "Stern Review: The Economics of Climate Change", Executive Summary: [www.hm-treasury.gov.uk/media/4/3/Executive\\_Summary.pdf](http://www.hm-treasury.gov.uk/media/4/3/Executive_Summary.pdf)
8. See: [www.cia.gov/library/publications/the-world-factbook/geos/bu.html](http://www.cia.gov/library/publications/the-world-factbook/geos/bu.html)
9. Italy imports nuclear generated electricity.
10. For a discussion of the economics of nuclear power, including the new Finish reactor under construction, see: [www.greenpeace.org.uk/media/reports/the-economics-of-nuclear-power](http://www.greenpeace.org.uk/media/reports/the-economics-of-nuclear-power)
11. For a good article on this development see: [www.nytimes.com/2007/04/15/world/middleeast/15sunnis.html?ei=5088&en=5d616358682635ee&ex=1334289600&partner=r&pagewanted=print](http://www.nytimes.com/2007/04/15/world/middleeast/15sunnis.html?ei=5088&en=5d616358682635ee&ex=1334289600&partner=r&pagewanted=print)
12. Electricity will probably account for only a third of the total energy consumed. These amounts of nuclear power, although huge, will not have a significant effect, to say the least, on the impact of global warming. Moreover, there will almost certainly be insufficient technical know-how and trained personnel or capital available to construct, operate and maintain nuclear power on anything like this scale. A massive growth in the global use of nuclear electricity is, therefore, not feasible.
13. Other projections include 3000 GW by 2075 (H. A. Feiveson, American Physical Society, 2003); 1000 GW by 2050 (MIT, 2003); 1,900-3,300 GW by 2050 to hold emissions constant at 2000 levels (B. Smith, Institute for Energy and Environmental Research, 2006).
14. For a good analysis of the future of civil nuclear power, see the Council on Foreign Relations Special Report by Charles Ferguson, "Nuclear Energy: Balancing Benefits and Risks": [www.cfr.org/content/publications/attachments/NuclearEnergyCSR28.pdf](http://www.cfr.org/content/publications/attachments/NuclearEnergyCSR28.pdf)
15. For further analysis of civil nuclear power's contribution to reducing global carbon emissions, see the Institute for Energy and Environmental Research report by Brice Smith (2006): [www.ieer.org/reports/insurmountablerisks/summary.pdf](http://www.ieer.org/reports/insurmountablerisks/summary.pdf)
16. See Green Alliance briefing on consequences for renewables in the UK from a nuclear energy policy: [www.green-alliance.org.uk/uploadedFiles/Publications/NewNuclearPower.pdf](http://www.green-alliance.org.uk/uploadedFiles/Publications/NewNuclearPower.pdf)
17. Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report, Working Group III, Chapter Four: [www.mnp.nl/ipcc/pages\\_media/FAR4docs/chapters/Ch4\\_Energy.pdf](http://www.mnp.nl/ipcc/pages_media/FAR4docs/chapters/Ch4_Energy.pdf)
18. Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report, Working Group III, Chapter Four: [www.mnp.nl/ipcc/pages\\_media/FAR4docs/chapters/Ch4\\_Energy.pdf](http://www.mnp.nl/ipcc/pages_media/FAR4docs/chapters/Ch4_Energy.pdf)
19. Ibid. para. 45.

20. To read J. W. S. van Leeuwen and Philip Smith research, see: [www.stormsmith.nl](http://www.stormsmith.nl)
21. See Oxford Research Group's "Secure Energy" (2007) report for an outline of this research: [www.oxfordresearchgroup.org.uk/publications/briefing\\_papers/secureenergy.php](http://www.oxfordresearchgroup.org.uk/publications/briefing_papers/secureenergy.php)
22. See "Keeping the lights on: Nuclear, Renewables, and Climate Change" (HC 584-1, April 2006): [www.publications.parliament.uk/pa/cm200506/cmselect/cmenvaud/584/58402.htm](http://www.publications.parliament.uk/pa/cm200506/cmselect/cmenvaud/584/58402.htm)
23. See Oxford Research Group's "Secure Energy" (2007) report, chapter 3, for an outline of this research: [www.oxfordresearchgroup.org.uk/publications/briefing\\_papers/secureenergy.php](http://www.oxfordresearchgroup.org.uk/publications/briefing_papers/secureenergy.php)
24. Based on an average ore grade of 0.15%.
25. The ISA results were 60gCO<sub>2</sub>/kWh. See: [www.pmc.gov.au/umpner/docs/commissioned/ISA\\_report.pdf](http://www.pmc.gov.au/umpner/docs/commissioned/ISA_report.pdf)
26. See: [www.oeko.de/forschungsergebnisse/dok/230content.php?setlan=1&vers=&id=315](http://www.oeko.de/forschungsergebnisse/dok/230content.php?setlan=1&vers=&id=315)
27. Nuclear weapons proliferation and nuclear terrorism is certainly not the only reasons to caution against nuclear new build. Another reason relate to the impact licensing a new build would have on the commercial viability of renewable energy technologies (See Green Alliance briefing on consequences for renewables in the UK from a nuclear energy policy: [www.greenalliance.org.uk/uploadedFiles/Publications/NewNuclearPower.pdf](http://www.greenalliance.org.uk/uploadedFiles/Publications/NewNuclearPower.pdf)). One other reason concerns the economics of nuclear power and the probability that a new build in the UK would require significant support from the public purse (See Greenpeace analysis (2007) of the economics of nuclear power: [www.greenpeace.org.uk/files/pdfs/nuclear/nuclear\\_economics\\_report.pdf](http://www.greenpeace.org.uk/files/pdfs/nuclear/nuclear_economics_report.pdf)).
28. Iraq is an example of the NPT's failure because military action by Israel postponed and subsequent US-led military action actually stopped Iraq from developing a nuclear arsenal.
29. See: International Atomic Energy Agency, IAEA Seeks Guarantees of Nuclear Fuel, IAEA Press Release 2006/15, 15 September 2006, IAEA Vienna.
30. [www.iaea.org/Publications/Magazines/Bulletin/Bull481/htmls/nuclear\\_fuel\\_cycle.html](http://www.iaea.org/Publications/Magazines/Bulletin/Bull481/htmls/nuclear_fuel_cycle.html)
31. See: [www.gnep.energy.gov](http://www.gnep.energy.gov)
32. See: [www.iaea.org/NewsCenter/PressReleases/2006/prn200615.html](http://www.iaea.org/NewsCenter/PressReleases/2006/prn200615.html)
33. Cited in "The Future of Nuclear Power" (DTI/Pub 8519/4k/05/07.NP): p. 156: [www.dti.gov.uk/files/file39197.pdf](http://www.dti.gov.uk/files/file39197.pdf)
34. This is precisely what MoD and FCO in the UK have done in "The Future of the United Kingdom's Nuclear Deterrent" (FCO, Cm6994, Dec. 2006) and "Delivering security in a changing world" (MoD) (Cm6269, July 2004).
35. For a dynamic online map of UK nuclear sites and possible contamination zones resulting from an accident or terrorist attack, see: [www.no2nuclearpower.org.uk/Chernobyl-UK.php](http://www.no2nuclearpower.org.uk/Chernobyl-UK.php)
36. "The Future of Nuclear Power": [www.dti.gov.uk/files/file39197.pdf](http://www.dti.gov.uk/files/file39197.pdf) p.111, para. 6.47.
37. See: <http://politics.guardian.co.uk/terrorism/story/0,,1947295,00.html>



## OxfordResearchGroup

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ORG is a registered charity and uses a combination of innovative publications, expert roundtables, residential consultations, and engagement with opinion-formers and government, to develop and promote sustainable global security strategies. In 2003, Oxford Research Group was awarded the Niwano Peace Prize, and in 2005 The Independent newspaper named ORG as one of the top twenty think tanks in the UK.

## Too hot to handle? The future of civil nuclear power

In the 1970s we used to say that if nuclear power was the answer, it must have been a very silly question. And yet acceptance of nuclear power is growing. That is partly because some people believe the myth that without nuclear power, the lights will go out or that we will have to return to medieval levels of energy usage – a claim particularly absurd in a country such as Britain in which the potential for renewable power vastly exceeds current electricity consumption. But it is also partly because many people seem to have forgotten about nuclear power's inherent problems. That is why Frank Barnaby and James Kemp's work is so much to be welcomed. They remind us about what makes nuclear power more of a problem than a solution.

They make important new points, such as the infeasible rate of building new nuclear power stations that would be needed for a nuclear renaissance to make much of a global difference, alongside restating older points, such as the problem of the declining quality of uranium ore that undermines some of the more extravagant claims about nuclear power's low carbon footprint. But above all, they analyse in convincing and sometimes alarming detail the problems of international and domestic security that a worldwide revival in nuclear power would pose. An international nuclear renaissance, especially if it moves in the direction that nuclear enthusiasts want of using MOX fuel and of developing fast-breeder reactors, will lead to very great dangers indeed in terms of nuclear weapons proliferation and the threat of terrorist action.

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