Factsheet 1

Secure energy: options for a safer world

SECURITY AND NUCLEAR POWER

INTRODUCTION

A major reason for opposing a nuclear renaissance is that it may considerably increase the risk of nuclear proliferation and, perhaps more importantly these days, nuclear terrorism. There are number of nuclear terrorist activities that a terrorist group may become involved in.

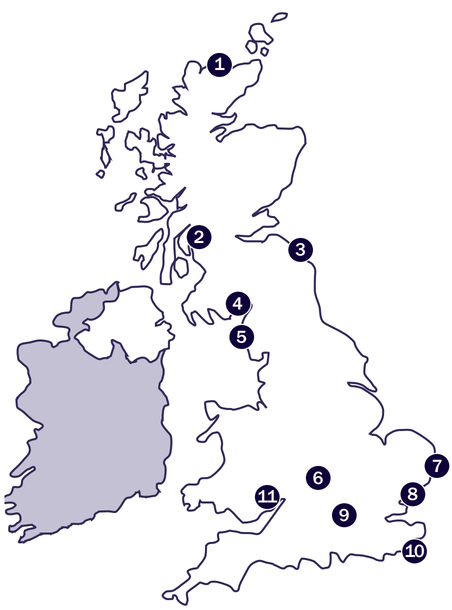
Potential acts of nuclear terrorism

- Stealing or otherwise acquiring fissile material and fabricating a primitive nuclear explosive.
- Attacking a nuclear power reactor or waste-fuel cooling pond.
- Attacking tanks at Sellafield holding high-level radioactive liquid waste.
- Attacking a plutonium store at Sellafield or other locations in the UK.
- Attacking nuclear fuel (particularly MOX fuel) or waste containers in transit.
- Making and detonating a radiological weapon, commonly called a dirty bomb, to spread radioactive material.

All of these types of nuclear terrorism have the potential to cause large, or quite large, numbers of deaths. And the risk of all of them will increase if more nuclear power stations are built. Of particular concern is the danger that terrorists will illegally acquire plutonium and use it to fabricate a primitive nuclear weapon or a dirty bomb.

It must be emphasised that 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 – one that is much easier to fabricate.

Map of breaches of no-fly zones around UK nuclear sites that have been or remain under investigation.



1. **Dounreay:** 6 MoD investigations (2000 - 2003)
2. **Faslane:** 1 MoD investigation (2000 - 2003)
3. **Torness:** 15 MoD investigations (2000 - 2003)
4. **Chapelcross:** 3 MoD investigations (2000 - 2003) and 10 Civil Aviation Authority (CAA) investigations
5. **Sellafield:** 2 MoD investigations (2000 - 2003)
6. **Harwell:** 2 MoD investigations (2000 - 2003)
7. **Sizewell:** 5 MoD investigations (2000 - 2003) and 6 CAA investigations (1999 - 2004)
8. **Bradwell:** 1 MoD investigation (2000 - 2003) and 4 CAA investigations (1999 - 2004)
9. **Aldermaston:** 3 MoD investigations (2000 - 2003) and 4 CAA investigations (1999 - 2004)
10. **Dungeness:** 6 CAA investigations (1999 - 2004)
11. **Berkeley:** 8 MoD investigations (2000 - 2003) and 7 CAA investigations (1999 - 2004)

Source: Ministry of Defence and Civil Aviation Authority
newscientist.com/news/news.jsp?id=ns99995036

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building bridges for global security

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ATTACKS ON NUCLEAR FACILITIES

"A terror group could acquire a stolen nuclear weapon, or enough material to develop a crude nuclear weapon."

Dr. Mohamed ElBaradei, Director-General of the IAEA, *Washington Post*, 30th January 2005

Many nuclear facilities in the UK are vulnerable to terrorist attack. A terrorist group with significant resources could attack and damage nuclear power plants. For example 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 hijacked 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. The terrorists would aim to create a criticality or loss of coolant accident, or both, leading to a massive release of radioactivity from the reactor core or the spent fuel elements.

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. However, it is hard to think of a nuclear terrorist attack which could, at least in theory, be more catastrophic than a successful attack on either the tanks at Sellafield that contain the liquid fission products separated from spent reactor fuel elements by the two reprocessing plants or on the stores holding the plutonium separated by the reprocessing plants.

A smoke plume from an explosion at Sellafield that released either around 17% of the high level waste (Cs -137) in tanks or less than 1% of the plutonium (~ 0.2 tonnes) stored at Sellafield would be approximately ten times as devastating as Chernobyl and require evacuation of an area which could include Newcastle or Manchester, depending on the wind direction.[1] The potential danger is increased by there being more than tenlocations around the country where over two tonnes plutonium is stored.

The industry's insistence that their reactors and storage facilities are "robust" is dubious. Perhaps the government will pay more attention to Report 222 of the Parliamentary Office of Science and Technology (July 2004) before setting in motion a process which will increase the number of potential targets. The report makes chilling reading: "No reactors have been designed specifically to withstand the impact of a large commercial aircraft... Some of UK's older Magnox plants have design characteristics which may make them more vulnerable to terrorist attacks."

It seems irresponsible to be adding yet more potential targets before we have secured the existing ones.

"... plutonium from the first generation of UK civil reactors must be kept isolated from the environment and out of terrorist hands for at least one-third of a million years. Over such a period even a small yearly probability of a successful raid becomes a near certainty."

Dr. Frank Barnaby, Professor Keith Barnham and Malcolm Savidge, Evidence to the Commons Environmental Audit Committee, September 2005.

1. Frank Barnaby, Evidence to the Commons Defence Committee, July 2002.

Facts

Between 1993 and 2004 the IAEA confirmed 662 incidents involving illicit trafficking of radiological materials[2]

2004 recorded an increase in incidents involving nuclear materials[3]

About 7 kg of reactor-grade plutonium is required to build a simple implosion weapon[4]

4 to 5 kg of HEU is required to build a simple implosion weapon[5]

MoD official figures show that the weapons stockpile is 0.3 tonnes larger than the amount of plutonium the records indicate is available[6]

About 40 kg of weapons-usable uranium and plutonium have been stolen from poorly protected nuclear facilities in the former Soviet Union during the last decade[7]

A TERRORIST NUCLEAR BOMB

A nuclear power reactor inevitably produces plutonium as it generates electricity from uranium fuel. There are various grades of plutonium, each with different isotopic compositions depending on the way in which the reactor producing it is operated. Plutonium produced in civil nuclear power reactors operated for the most economical production of electricity is called reactor grade plutonium. Plutonium produced in military plutonium production reactors, specifically for use in nuclear weapons, is called weapon-grade plutonium.

It is now generally recognised that nuclear weapons can be made from reactor-grade plutonium, although those made using weapon-grade plutonium are somewhat more effective. It is for this reason that reactor-grade plutonium is normally subjected to national and international security and safeguards measures in an effort to detect and deter its diversion or acquisition by countries or terrorist groups.

According to Matthew Bunn, who chaired the US National Academy of Sciences analysis of options for the disposal of plutonium removed from nuclear weapons: “For an unsophisticated proliferator, making a crude bomb with a reliable, assured yield of a kiloton (equivalent to the explosion of a thousand tonnes of TNT) or more – and hence a destructive radius about one-third to one-half that of the Hiroshima bomb – from reactor-grade plutonium would require no more sophistication than making a bomb from weapon-grade plutonium.” In fact, as Bunn pointed out: “In some respects it would actually be easier for an unsophisticated proliferator to make a bomb from reactor-grade plutonium (as no neutron generator would be required).”

That reactor-grade plutonium can be used to fabricate nuclear weapons was proved by the British who exploded such a device in a test in Australia in 1956 and by the Americans who exploded at least one such device in the 1960s.

The critical mass of a fissile material, such as plutonium, is the minimum mass necessary to sustain a nuclear-fission chain reaction and, therefore, to produce a nuclear explosion. No explosion occurs in a mass of plutonium below the critical mass. If the mass is more than critical (i.e. it is super-critical) the fission chain reaction is sustained for as long as the mass of plutonium remains super-critical. The critical mass of a bare sphere of reactor-grade plutonium metal is about 13 kilograms, a sphere of about six centimetres in diameter. The critical mass of a bare sphere of weapon-grade plutonium metal is about 11 kilograms.

If the sphere of plutonium metal is surrounded by a shell of material, such as beryllium or uranium, neutrons that escape from the sphere without producing a fission event are reflected back into the sphere. A reflector, therefore, reduces the critical mass. The reduction can be considerable. A thick reflector will reduce the critical mass by a factor of two or more. Modern nuclear weapons contain less than 4 kilograms of weapon-grade plutonium.

Two or three people with appropriate skills could design and fabricate a crude nuclear explosive, using a cricket ball-sized sphere of reactor-grade plutonium.

2. http://www.iaea.org/NewsCenter/Features/RadSources/PDF/chart1.pdf
3. http://www.iaea.org/NewsCenter/Features/RadSources/PDF/chart2.pdf
4. “Preventing Nuclear Terrorism.” *Union of Concerned Scientists*, April 2004.
5. Ibid.
6. http://www.mod.uk/publications/nuclear_weapons/accounting.htm
7. Bruce Blair, “Nuclear Materials: more control is vital”. *Center for Defense Information*, July 2002.

MOX FUEL

Plutonium oxide separated from spent reactor fuel elements can be mixed with uranium oxide to produce mixed oxide (MOX) nuclear fuel. MOX is manufactured at Sellafield and transported by boat and train to Japan and Europe. MOX fuel is at its most vulnerable during transportation and risks of sabotage or hijacking must be considered. Having obtained a quantity of MOX fuel by diversion or theft, a terrorist group would have little difficulty in making a crude atomic bomb.

The necessary steps of chemically separating the plutonium dioxide from uranium dioxide, converting the dioxide into plutonium metal, and assembling the metal or plutonium dioxide together with conventional explosive to produce a nuclear explosion are not technologically demanding and do not require materials from specialist suppliers. The information required to carry out these operations is freely available in the open literature.

The storage and fabrication of MOX fuel assemblies, their transportation and storage at conventional nuclear power stations on a scale envisaged by the nuclear industry will be extremely difficult to safeguard. The risk of diversion or theft of fuel pellets or whole fuel assemblies by personnel within the industry or by armed and organised terrorist groups is a dreadful possibility.

A new round of nuclear power stations increases the targets for nuclear terrorism, increases the availability of MOX fuel, and increases the availability of reactor-grade plutonium.

Nuclear facilities and nuclear materials may be tightly controlled but the risks of nuclear terrorism are simply too great.

These results are based on a survey of over 80 experts in the field of non-proliferation, counter-proliferation, diplomacy, military affairs, arms inspections, intelligence gathering and other national security fields

Average results from the "Lugar Survey on Proliferation Threats and Responses"[8]	
Nations added to the nuclear weapons club during the next 10-years?	**4**
Nations added to the nuclear weapons club during the next 20-years?	**7.5**
If a nuclear attack occurred during the next 10-years, would it be carried out by (a) government or (b) terrorists?	**a. 21% b. 79%**
Are terrorists more likely to (a) acquire a working nuclear weapon or (b) manufacture one?	**a. 45% b. 55%**
Have international non-proliferation efforts (a) improved, (b) stayed about the same, or (c) regressed during 2004?	**a. 32% b. 21% c. 47%**

8. Senator Richard G. Lugar, "The Lugar Survey on Proliferation Threats and Responses", June 2005. http://lugar.senate.gov/reports/NPSurvey.pdf

Factsheet 2

Secure energy: options for a safer world

EFFECTIVE SAFEGUARDS?

Nuclear Reactors

Generation I
Early prototype reactors, of the 1950s and early 1960s (e.g. Magnox)

Generation II
Commercial reactors of the 1970s and 1980s (e.g. AGRs, PWRs and Boiling Water Reactors)

Generation III
Advanced light water reactors that will soon mature (e.g. Westinghouse AP 1000)

Generation IV
The nuclear industry hopes these will include such advanced reactor types as sodium-cooled and lead-cooled fast breeder reactors

INTRODUCTION

A major concern with a nuclear renaissance is that in the medium- and long-term, the nuclear industry will press for the construction of so-called Generation IV reactors that the nuclear industry hopes will be the core of any nuclear renaissance.

Generation III reactors will use mixed plutonium-dioxide and uranium-dioxide (MOX) nuclear fuel. No Generation III reactors have been built, but a number of designs are available, the Westinghouse AP 1000 being the most advanced. If Britain or any other industrialised country decides to build new nuclear reactors, they will be Generation III designs that are fuelled by MOX. MOX fuel itself is a source of terrorism concern.

Generation IV reactors will be fuelled with plutonium, with only a small input of uranium. The plutonium will be of a type suitable for use in the most efficient nuclear weapons. The consequences of the widespread use of Generation IV reactors for nuclear weapon proliferation and nuclear terrorism are very serious indeed. A nuclear renaissance based on Generation III and IV reactors will increase the use of plutonium as a nuclear fuel.

The safeguards agencies claim that a commercial plutonium-reprocessing plant can be safeguarded with effectiveness of about 99%. This means that, even on the most optimistic assessments, at least 1% of the plutonium throughput will be unaccounted for.

REPROCESSING PLANTS

But the proliferation of Generation III and IV nuclear reactors is not the only concern. Plutonium to fuel these reactors has to be produced by reprocessing spent nuclear fuel in facilities such as the THORP reprocessing plant at Sellafield. There will therefore inevitably be a far greater demand for reprocessing facilities in order to provide the increased demands for plutonium. But there is a major problem with this process: large commercial reprocessing plants cannot be safeguarded effectively. Safeguarding the plutonium in spent nuclear reactor fuel elements before reprocessing is relatively simple. It is just a matter of counting the number of the elements in their store – in a cooling pond, for example. For many years, the elements are so radioactive that they must be handled with remote equipment – they are self-protecting. Safeguarding them is a matter of unit accountancy plus surveillance with video cameras.

Once the plutonium is removed from spent reactor fuel elements in a commercial reprocessing plant, however, safeguarding it is quite a different matter. Commercial reprocessing plants deal with a large amount of plutonium – typically, up to about 10 tonnes per year. The separated plutonium can be used to fabricate effective nuclear weapons. There is no clear distinction between the commercial use of plutonium and its military use.

On 29th May 2005 The Independent revealed that a leak of nuclear liquor containing 20 bombs worth of plutonium went undetected at Sellafield for up to nine months.[9]

A good nuclear weapons designer could construct a nuclear weapon from 3 or 4 kg of this reactor-grade plutonium. About 250,000 kg of civil plutonium have been reprocessed world-wide so far, theoretically enough to fabricate about 60,000 nuclear weapons. It must be emphasised that this is not a matter of the efficiency and competence of the inspectors or of the operators of safeguards instruments. Even with the best available and foreseeable safeguards technology it is not possible to get the precision necessary.

The safeguards agencies claim that a commercial plutonium-reprocessing plant can be safeguarded with effectiveness of about 99%. This means that, even on the most optimistic assessments, at least 1% of the plutonium throughput will be unaccounted for. Some independent experts estimate that, in practice, a more realistic figure for the effectiveness of safeguards on a commercial plutonium-reprocessing plant is 95% and that at least 5% of the plutonium throughput will be unaccounted for.

What do these figures imply? According to recent estimates, the potential material unaccounted for (MUF) at the Japanese reprocessing plant now under construction at Rokkasho-Mura will be around 50 kg per year. This plant, which will include the most up-to-date safeguards technology available, is designed to allow the application of the most effective safeguards possible today. The plant will have the capacity to reprocess about 800 tonnes of spent fuel a year, producing about 8 tonnes of plutonium. The effectiveness of safeguards on the plant, according to these estimates, is more than 99%. Nevertheless, even on these very optimistic estimates, the potential material unaccounted for still amounts to about a nuclear weapon's worth a month.

In August 2004, a leak started, as a hairline crack, in a pipe connected to the accountancy tank at the front end of the THORP reprocessing plant at Sellafield and complete failure of the pipe occurred in mid-January 2005. Solution, containing spent reactor fuel elements dissolved in nitric acid, leaked into a cement secondary containment chamber. The leak was not detected until April 2005, eight months after it began, by which time about 83,000 litres, containing about 160 kg of plutonium, had leaked out. Opportunities to detect the leak – cell sampling and level measurements – were missed. That this incident could have occurred is another example of the inadequacies of the safeguards system for reprocessing plants.

It would be relatively easy for a state with a commercial reprocessing plant to divert a significant amount of plutonium whilst the plant is under IAEA safeguards. The spread of reprocessing facilities therefore inevitably increases the opportunity for and risk of the diversion of plutonium for nuclear weapons programmes.

The US$21 billion Rokkasho Reprocessing Plant, Japan
Image, courtesy of IAEA photo library

"Can Japan expect that if it embarks on a massive plutonium recycling program that Korea and other nations would not press ahead with reprocessing programs?"[10]

9. http://news.independent.co.uk/environment/article223695.ece
10. Diplomatic Cable. US Ambassador to Japan to US Secretary of State Christopher, March 1993.

The operators would not be able to state with any certainty whether or not a few kilograms of their plutonium was missing.

MEASUREMENT

The first measurement, as opposed to an estimate based on calculation, of plutonium in the reprocessing plant is made on samples taken from an accountancy tank at the beginning of the process. Using mass spectrometry, the ratio of the amount of plutonium to the amount of uranium is determined. From the calculated amount of uranium and the measured uranium/plutonium ratio, the amount of plutonium is calculated. There may be errors in each stage of this operation. For example, some plutonium will remain in the parts of the fuel elements not dissolved in the nitric acid (called "the hulls"). The amount is very difficult to estimate.

The operators of the reprocessing plant will, therefore, be uncertain about the precise amount of plutonium produced by the plant. The uncertainty is called the "material unaccounted for" or MUF. Because of the plutonium that has gone missing.

If for example, the police contact the operators and say that a terrorist or criminal group has contacted them and provided some evidence that they have acquired some plutonium, enough to fabricate a nuclear explosive. The evidence could be, for example, a very small sample of plutonium. The operators would not be able to state with any certainty whether or not a few kilograms of their plutonium was missing because the amount that may be missing will be within the MUF. Given that plutonium can be used to fabricate nuclear weapons, any significant amount of plutonium unaccounted for should be unacceptable; commercial reprocessing should, therefore, be stopped.

Conclusions

A plutonium economy and terrorist targets

A new generation of plutonium powered nuclear reactors and reprocessing plants to feed them will create an international plutonium and MOX economy: a global trade in a substance that can just as easily be fashioned into nuclear weapons made in facilities that cannot be effectively safeguarded.

The risk of plutonium being diverted for a clandestine state programme is extremely serious in itself, but as the plutonium-MOX economy grows, the risk of plutonium finding its way to a terrorist group dramatically increases with it.

A new generation of plutonium powered nuclear reactors would increase the number of targets for a nuclear terrorist attack because reprocessing produces high-level radioactive waste and excess plutonium that has to stored, stores that can be targeted.

Reprocessing spent nuclear fuel to produce plutonium for MOX nuclear fuel is not even economic; it is far cheaper to use uranium dioxide.

A British decision to build a new round of Generation II nuclear reactors will encourage a market for such reactors and the growth of a plutonium-MOX economy. Instead the British government should seriously consider ending reprocessing.

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SECURE ENERGY: OPTIONS FOR A SAFER WORLD

OxfordResearchGroup

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He is now a freelance defence analyst, and is a prolific author on military technology. In addition to the numerous Briefing Papers he has written for Oxford Research Group and other organisations, his books include: *The Invisible Bomb* (Tauris, 1989), *The Gaia Peace Atlas* (Pan, 1989), *The Automated Battlefield* (Sidgwick & Jackson, 1987), *Star Wars* (Fourth Estate, 1987), *Future Warfare* (Michael Joseph, 1986) and *How to Build a Nuclear Bomb* (Granta, 2003).

About the ORG "Secure Energy: Options for a Safer World" project

These factsheets are the first in a series Oxford Research Group will publish during 2005. The information contained within is drawn entirely from publicly available sources. These factsheets are not intended to scaremonger, but to present a independent assessment of some of the risks which should be considered when deciding on the future of the UK's energy provision.

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