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SECURE ENERGY?

CIVIL NUCLEAR POWER, SECURITY AND GLOBAL WARMING

Edited by Frank Barnaby and James Kemp

With a Foreword by Jürgen Trittin

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Al Gore on civil nuclear power

"There are serious problems that have to be solved, and they are not limited to the long-term waste-storage issue and the vulnerability-to-terrorist-attack issue. Let's assume for the sake of argument that both of those problems can be solved.

We still have other issues. For eight years in the White House, every weapons-proliferation problem we dealt with was connected to a civilian reactor program. And if we ever got to the point where we wanted to use nuclear reactors to back out a lot of coal – which is the real issue: coal -- then we'd have to put them in so many places we'd run that proliferation risk right off the reasonability scale. And we'd run short of uranium, unless they went to a breeder cycle or something like it, which would increase the risk of weapons-grade material being available."

Al Gore (*Grist Magazine*, 2006) *

*** www.grist.org/news/maindish/2006/05/09/roberts/**

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* "The Energy Challenge: Energy Review Report 2006." *Department for Trade and Industry*. July 2006. CM6887. Paragraph 5.124, p. 120.

Foreword

"One of the worst ideas, circulating in many corners of the global discussion, is the call for an expansion of nuclear power as a means of climate protection."

Finally, global warming has arrived where it should have been for a long time: on the top of the international political agenda. Finally, the period of denial, ignorance and repression of facts is over. Climate protection has left expert circles and activist scenes and has entered the mainstream and the minds of citizens all over the world. And finally, global warming has been recognised as an economic and a global security problem of almost unprecedented magnitude.

This growing awareness certainly does improve our chances of stopping global warming at a certain level through coordinated international action. But unfortunately, these belated insights have led to unreasonable suggestions. One of the worst ideas, circulating in many corners of the global discussion, is the call for an expansion of nuclear power as a means of climate protection. This recommendation is a clear-cut case of fighting one risk with an even bigger one.

Most of the times, when we discuss the hazards of nuclear power, we think of the dangers of a meltdown at nuclear plants and the problem of the disposal of radioactive nuclear waste. We might also think of further disadvantages like the dependency on massive subsidies or the limited availability of uranium in the long run. All these are bad enough but an even worse aspect of nuclear technology is the creation of massive security risks such as nuclear weapons proliferation and nuclear terrorism. In the broad public debate, a naive optimism over nuclear power's peaceful application is still fairly widespread.

India, Pakistan, Israel and now North Korea have succeeded in circumventing the Non-Proliferation Treaty (NPT) and the nuclear control mechanisms and have produced nuclear weapons. Nuclear reprocessing and enrichment technologies are much sought-after not only in Iran but also in South Africa and Brazil. And other states also have the technological potential to build nuclear weapons within a relatively short period of time. Parallel to this spread of highly dangerous technology, the international regime of the NPT is becoming weaker and weaker.

From the start, the NPT had considerable loopholes, especially in the monitoring of weapons-grade technologies, such as enrichment and nuclear reprocessing. Currently, the NPT is being called into question, not only by North Korea, but primarily by states who already own nuclear weapons. All nuclear powers – the USA, Russia, the UK, China, France – are no longer disarming, but planning to modernise their weapons arsenals – they are rearming. At the same time, the NPT is coming under pressure as a result of the nuclear agreement between the USA and India. The Nuclear Suppliers Group now has to decide whether the ban on the supply of nuclear materials to India should be lifted. If it is, this decision will strike at the very legitimacy of the non-proliferation regime. While demands are being made for Iran to renounce its rights under the NPT as a precondition for negotiations, India's nuclear armament is being rewarded by the West with the supply of uranium.

"decisions taken in the UK are perceived and taken into account worldwide."

The risks of proliferation and nuclear terrorism by both state and non-state actors are simply uncontrollable. This report by Oxford Research Group gathers an impressive amount of evidence for the high security risk of nuclear technologies. At the same time, it shows that hopes for the climate-protecting potential of nuclear energy are entirely misplaced. We all have to work hard to spread this combination of insights into the international energy discussion very quickly and effectively, for decisions about future energy technologies are made today and have consequences far into the future. Although matters of global warming and global energy security obviously cannot be solved by one nation alone, the UK discussion is crucial in the current context. An influential player in Europe, with a cultural and political proximity to the United States, decisions taken in the UK are perceived and taken into account worldwide.

As for the German experience, quoted favourably in this report, we can take pride in an extraordinarily successful boost in renewable energies over the past ten years. A mixture of strong political support, quickly progressing technology and ambitious green entrepreneurship has helped to create a very dynamic scene in renewable technologies. Public support for renewable energy is high, businesses are successful and over 200,000 jobs have been created. But even against this background of an impressive demonstration of energy alternatives, nuclear power has made a comeback in the public debates. It still does not convince a majority of the population, and there is no political majority in sight for a new nuclear build in Germany. But industry interests and its media allies are strong, so for now, nuclear energy is back in the game as a candidate. Therefore we need serious studies like this ORG report in order to gather the evidence and provide arguments for the political struggle against an unreasonable and potentially devastating technology.

Jürgen Trittin
German Federal Minister for the Environment, Nature Conservation and Nuclear Safety (1998-2005)

Berlin, March 2007

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Jan Willem Storm van Leeuwen (MSc, physical chemistry, Technical University Eindhoven) is senior scientist at Ceedata Consultancy. He works for the Open University at Heerlen, developing courses for chemistry teachers. He is secretary of the Dutch Association of the Club of Rome. He is one of the international group of expert reviewers of the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change, and has published numerous reports and articles on topics related to energy and environment.

Executive Summary

Is nuclear power dangerous? Can it help reduce CO_2 emissions? The short answer to the first questions is ‘very’: nuclear power is uniquely dangerous when compared to other energy sources. For the second question the answer is ‘not enough and not in time’.

Why then, is official support for nuclear power growing? Many decision-makers in the UK and elsewhere believe that the security risks can be managed. As this report will show, such confidence is misplaced. Unless the risks are thoroughly reviewed, we shall steer ourselves into uncharted and very dangerous waters.

This report compares (a) the security consequences of civil nuclear power to (b) its contribution to reducing CO_2 emissions. In 2006 the UK Department of Trade and Industry (DTI) published the results of a public consultation into energy policy, including the future of nuclear power, in a report called “The Energy Challenge”.[1] According to “The Energy Challenge” the benefits of (b) outweigh the costs of (a).

As far as the security risks associated with nuclear power are concerned, DTI tries to calm fears about security using the following two claims:

- “the international security situation is expected to remain at current levels in the medium to long term”; and
- the Office for Civil Nuclear Security (OCNS) “considers that new nuclear build would be unlikely to increase risks to the UK.”[2]

Where is the evidence for these claims? It is not to be found in “The Energy Challenge”. In 2004, the OCNS judged that: “security threats are seldom constant”,[3] and in 2002 the UK Performance and Innovation Unit of the UK Cabinet Office concluded that “concerns about radioactive waste and *low probability but high consequence* hazards may limit or preclude its use.”[4] (Emphasis added)

What changed between 2004 and the publication of “The Energy Challenge”? Having reviewed the evidence, ORG concludes that a civil nuclear power renaissance would:

- increase the risk of nuclear terrorism in the UK;
- make efforts to control the spread of nuclear weapons much harder;
- make an insignificant contribution to lowering CO_2 emissions; and
- make a negligible contribution to energy security.

In the face of uncertainty we must analyse influences on conflict and security, make judgements about future risks and implement appropriate policies. To this end the Ministry of Defence (MoD) Development, Doctrine and Concepts Centre (DDCC) published “Strategic Trends” (2003 / 2006). This reports sets out “a coherent view of how the world might develop over the next thirty years [to 2030] in ways that could alter the UK’s security.” The authors of this report had “access to most relevant UK intelligence.”[5]

DDCC is not as certain as DTI / OCNS that the security situation will remain "at current levels". In fact, DDCC is confident that the security situation will change for the worse: "Some of the conclusions are uncomfortable; but we nonetheless think we shall face them." Here are three excerpts relevant to the risks of nuclear power:

- "Terrorism is likely to become more widespread, extreme, international and autonomous."
- "Despite multilateral regulation it will be increasingly hard to control key technologies. Diffusion, collaboration and leakage will probably lead to a widening number of military and non-state actors accessing advanced military technologies."
- "Non-state actors are likely to acquire weapons of mass effect before 2015 and will be much harder to deter than state proliferators, making this a key security threat."

The Third edition (2006) states that:"Based on technological availability and historic examples, chemical, biological and radiological elements *will* be viable and credible possibilities for terrorist attack throughout the period, together with a lower possibility of nuclear use."[6] (Original emphasis.)

Chapter 1: A "new nuclear build would be unlikely to increase risks to the UK."

DTI did not feel it necessary to define "unlikely"; given the consequences, a more explicit explanation is justified. Chapter one of this report is an assessment of the effects a new nuclear build will most probably have on UK and international security.

Into the unknown: uranium reserves and the future of nuclear power

In section 1, Jan Willem Storm van Leeuwen presents evidence to show why the outcome of an expansion in civil nuclear power would be an increased risk of nuclear weapons proliferation and nuclear terrorism. The cause of this outcome relates to the availability of high-grade uranium ore for fuel: there is not enough sufficiently high-grade uranium ore in the earth's crust to fuel the anticipated global expansion in nuclear power. Industry will, therefore, rely on recovered fuel (Mixed Oxide Fuel (MOX) and plutonium) from spent uranium fuel, produced in reprocessing plants.

At the moment nuclear reprocessing takes place in a handful of plants like Thorp in England, Rokkasho Mura in Japan and La Hague in France. Until recently the USA avoided reprocessing because of fears over the security risks associated with it. One fear relates to the impossibility of accounting for all of the plutonium that goes through a reprocessing plant, i.e. some could be stolen or diverted without detection. A multiplication of reprocessing and the resulting international trade in weapon-useable materials would create more opportunities for states, criminal organisations or terrorists to acquire weapons-useable materials, which is currently the greatest obstacle to building a nuclear weapon.

"Until recently the USA avoided reprocessing because of fears over the security risks associated with it."

Keeping fissile materials out of the wrong hands

The problem with MOX and reactor-grade plutonium is that both materials pose serious proliferation hazards. In section 2.1 Frank Barnaby examines the extent to which certain checks and procedures (safeguards) at civil nuclear power plants prevent the theft or diversion of MOX and/or plutonium. What he finds is that it is impossible for safeguards to account for all weapons-useable materials processed at a plant, there will inevitably be some plutonium, for example, that might go missing.

If the police were called by an al-Qaida spokesman claiming to have acquired fifteen kilograms of reactor-grade plutonium from a reprocessing plant, the plant operators would not be able to confirm to the police with certainty whether the plutonium was missing or not. Not because of human error, but because physical limitations make it impossible to account for more than 99% of the plutonium throughput at a reprocessing plant. What goes missing is know as Material Unaccounted For or MUF.

Over a year, MUF from a state-of-the-art reprocessing plant like Rokkasho Mura could constitute enough fissile materials for twelve nuclear weapons. If a state decided to start diverting small amounts of plutonium from the reprocessing chain for future use in a weapons programme (or perhaps to sell), it would be very hard for IAEA inspectors to detect the diversion. Increasing the quantity of weapons-useable materials in storage and transit would increase the risk of theft to order or sell on the black-market.

Nuclear terrorism: an exaggerated threat?

> *"By 1997, officers in the Bin Laden Unit recognized that Bin Laden was more than just a financier. They learned that al Qaeda had a military committee that was planning operations against U.S. interests worldwide and was actively trying to obtain nuclear materials."*
>
> ("The 9/11 Commission Report." 2004. p.109)

Frank Barnaby introduces the subject of nuclear terrorism in section 1.3. There are two main types of nuclear terrorism. One is a direct attack against a nuclear facility or materials in transit, the other is stealing or otherwise acquiring fissile material and fabricating and detonating a primitive nuclear explosive. At its most extreme, a crude nuclear explosive could destroy key elements of Government and state. Imagine the effects of a small nuclear explosion on Capitol Hill or Parliament Square.

"If more and more states start indigenous nuclear research and power programmes, more opportunities for theft or diversion will be created."

Since 9/11 DTI and OCNS have introduced a number of measures to improve security at nuclear sites, such as better vetting procedures, the use of armed police at some power stations and some physical protection measures. Industry could make a nuclear site practically invulnerable, but to do so would make nuclear power exorbitant.

There are many locations around the world where nuclear weapons or weapons useable material is insecurely stored:[7]

> *"most civilian research reactors have very modest security – in many cases, no more than a night watchman and a chain-link fence – even when enough fresh or irradiated HEU for a bomb is present... Today roughly 135 operating research reactors in some 40 countries still use HEU as their fuel, and an unknown number of shutdown or converted research reactors still have HEU fuel on-site."*[8]

If more and more states start indigenous nuclear research and power programmes, more opportunities for theft or diversion will be created. This is an entirely predictable consequence of a nuclear expansion; it is also avoidable.

In section 1.4 Paul Rogers examines trends in mass casualty attacks and economic targeting over the past fifteen years and relates them to the risks of nuclear terrorism. Supporters of the expansion of nuclear power often point to the rarity of attacks involving nuclear facilities. Having examined trends in mass casualty and economic targeting, Paul Rogers shows that the evidence indicates that while paramilitary groups that are prepared to engage in mass casualty attacks are not endemic in society, there have been many more examples than is usually

"The military atom and the civil atom are Siamese twins."

Hannes Alven, Nobel Prize winning nuclear physicist

appreciated and that al-Qaida is far from unique in its willingness to cause large numbers of civilian deaths and damage to civilian infrastructure.

Of particular relevance to civil nuclear power is the increase in targeting of energy infrastructure. Given the fact that modern economies depend to such a remarkable extent upon the production and distribution of oil and gas, energy infrastructure represents a particularly valuable and soft target for paramilitary groups. A nuclear facility may be protected, sometimes with armed guards, but it remains a soft target. Owing to the potential of nuclear power to spread disproportionate fear, nuclear power plants are likely to become more, not less, attractive targets.

The point is that a new nuclear build would create many more sites / targets, some of which will be poorly secured, from which materials could be stolen. A new build would create many more scientists with the know-how to turn a civil nuclear programme into a weapons programme; some may share their expertise with the highest bidder or ideological bedfellows. The task of controlling the spread of HEU or plutonium (over the coming decades) would become much harder.

How difficult is it to build a nuclear bomb?

It would be easier than is generally assumed for terrorists or poor states to fabricate a nuclear weapon. In 1964, the US government chose two post-PhD physicists, Dan Stober and Bob Selden, with no nuclear knowledge and set them the task of designing a working nuclear weapon with no access to classified information.[9] The goal, they were told, was "to design an explosive with a militarily significant yield". To model their design, Dobson and Selden wrote their own codes, which they ran on a punch-card computer far more primitive than the cheapest home computer made today. Professional nuclear weapon designers checked their design. The two succeeded in designing an effective nuclear weapon.

It has been estimated that for al-Qaida to build a nuclear weapon (assuming it is assembled in the USA rather than transported across borders) would require up to nineteen people, cost approximately $10 million dollars, and take just over a year.[10]

Chapter 2. The "security situation is expected to remain at current levels in the medium to long term"

It is incredible that the authors of "The Energy Challenge" made this claim. It also contradicts assessments made by Ministry of Defence and Foreign and Commonwealth analysts. Do the authors of "The Energy Challenge" know something the rest of us do not?

From civil nuclear means to military ends: Iran, a case study

Civil nuclear power cannot be divorced from it military applications. In the words of Hannes Alven, the Swedish Nobel Prize winning nuclear physicist, the military atom and the civil atom are Siamese twins. In section 2.1 five Frank Barnaby analyses what is known about Iran's nuclear programme to show how a civil programme can be diverted to military ends.

Iran could produce fissile materials for nuclear weapons using three techniques at its disposal:

(1) By separating plutonium from spent fuel from the nuclear-power reactor at Bushehr
Once Bushehr is operational, plutonium could be chemically removed from the fuel elements that have been irradiated in the nuclear-power reactor. The plutonium could be used to fabricate nuclear weapons.

(2) By using plutonium produced in the planned heavy water research reactor at Arak being constructed to replace the 35-year old IR-40 research reactor now operating at Tehran. A new IR-40 will be a 40-megawatt heavy-water reactor, fuelled with natural uranium and cooled by heavy water. It will be a very efficient way of producing plutonium for use in very effective nuclear weapons.

(3) Iran could fabricate nuclear weapons from highly enriched uranium (HEU) produced in one of two gas centrifuge plants in Natanz.

"There is a very real danger of a nuclear arms race in the Middle East."

Iran is now producing low enriched uranium using gas centrifuges. It claims that this uranium will be used for fuel in nuclear-power reactors. An Iranian facility containing 3,000 centrifuges could produce about 40kg of highly enriched uranium per year – enough for two nuclear weapons. Whether Iran's nuclear programme is directed towards civilian or military ends is a political decision. In other words, Iran may take a gradual approach to acquiring nuclear weapons potential, or opt for a crash programme using clandestine facilities and methods, or stick to civilian goals entirely.

If there is a widespread expansion of civil nuclear power around the world, Iran may become the first of many states to develop a nuclear weapons capability in the 21st century. If Iran does acquire nuclear weapons it may well trigger a domino effect, whereby Egypt, Saudi Arabia, Turkey, and Syria embark on nuclear-weapon programmes or acquire nuclear weapons from another country.

The changing security context

In section 2.2 James Kemp outlines three key trends affecting the security background against which a global expansion on civil nuclear power may take place:[11]

- Climate change
- Competition over resources
- Global militarisation

Belatedly, political and military elites are beginning to recognise that climate change is more than an environmental issue. Imagine what might happen in Pakistan if and when the glaciers retreat causing severe water shortages. The region and world could be faced with a security nightmare: a severely stressed nuclear armed state in which radical Jihadists exercise power over the military?

Climate change will adversely affect food and water security in many parts of the world; create millions of migrants and refugees; push some states' ability to cope to the limit; and exacerbate conflicts and regional tensions. The instability and insecurity that climate change is likely to generate will make nuclear weapons more desirable to governments and military elites. This is especially so for elites who are vulnerable to states with more powerful conventional forces or nuclear weapons.

Current trends in global consumption and fossil fuel production point towards intensified competition over energy resources.[12] Given the scale and accessibility of the resources found in the Persian Gulf compared to other regions, combined with projections of global energy use, this volatile region will be at the centre of resource competition for many years to come.

This situation is likely to exacerbate demand for nuclear weapons because they can constitute a cost-effective way for elites (often with popular backing) to challenge (or preserve) the status quo. There is a very real danger of a nuclear arms race in the Middle East, the effects of which will be felt around the world.

The third root cause of global insecurity and conflict is global militarisation. Between 2001 and 2005 world military expenditure increased by 25% in real terms.[13] Two aspects of this trend are particularly worrying. Firstly, nuclear weapons proliferation and secondly, the full-scale weaponisation of space.

It is an uncomfortable fact that nuclear weapons are judged to be cost effective. Many poorer states can ill afford to train and equip effective conventional deterrents or develop space-based military technology. Unless action is taken soon, they may follow others down the nuclear weapons route. Moreover, the danger of accidental nuclear attack would rise substantially. It took many years to implement physical and procedural mechanisms that reduce the risk of accidental nuclear weapon launch. It is unlikely that such precautions would be prioritised under conditions rapid nuclear weaponisation.

"Nuclear power is not CO_2 free; its contribution to reducing global CO_2 emissions is marginal at best."

Chapter 3: Nuclear power and climate change

The final chapter of this report deals with whether nuclear can, as many of its supporters claim, make a significant contribution to global efforts to reduce CO_2 emissions. Some highly respected advocates of nuclear power agree that a new build would increase the risk of nuclear terrorism and weapons proliferation, but recommend a large-scale new build nonetheless.[14] In their judgement the risks from failing to reduce atmospheric CO_2 levels outweighs the consequences of nuclear terrorism or a regional nuclear war. This is a compelling argument, especially given the scale of the threat posed by climate change, but it is flawed: genuinely low-carbon energy sources are available and could be installed faster, at less cost and less risk to UK and global security.

The results from a comprehensive survey of nuclear energy are set out in section 3.1 by Jan WillemStorm van Leeuwen, and show why nuclear power is not the low-carbon energy source it has been presented as recently. Even if nuclear power were carbon free, its contribution to efforts to reduce global CO_2 emissions would still be negligible because nuclear power contributes less than 2.2% to world energy needs. To make a significant contribution, nuclear power generation would have to increase dramatically and quickly, i.e. hundreds if not thousands of nuclear reactors would have to be built globally over the coming couple of decades.[15] Nuclear power, however, is not CO_2 free; its contribution to reducing global CO_2 emissions is marginal at best.

This table shows the grams of CO_2 emitted per kilowatt hour (gCO_2 / kWh) of electricity generated by a nuclear power reactor using uranium fuel produced from an ore grade of 0.15% U_3O_8 (today's average) compared to other common energy sources.

Emissions from nuclear power lie somewhere between biomass and natural gas, meaning nuclear power should not be classed as a particularly low-carbon energy source. Furthermore, as the available average ore grade declines CO_2 (and other Greenhouse Gases) emissions from nuclear power will increase.

Technology (2005 - 2020)	gCO_2/kWh
Coal	755
Natural Gas	385
Biomass	29 – 62
Wind	11 – 37
Nuclear (OECD)	11 – 22
Nuclear (Storm and Smith)	84 – 122
Nuclear (ISA, Uni. of Syndey)	10 – 130
Nuclear (Extrern-E UK)*	11.5

* Construction only

What of Generation IV nuclear reactors?
The nuclear industry hopes to have mastered Fast Breeder or Generation IV nuclear technology by around 2050. These reactors would be fueled with plutonium and small amounts of natural uranium and would, in theory, 'breed' more nuclear fuel than they use; they would extend the time uranium would be available and produce less CO_2 emissions that current nuclear technology.

Two major problems with this technology make it very unlikely to become operational within the timeframes needed to make an effective contribution to reducing CO_2 emissions. Firstly, there are major technical and theoretical obstacles to running the Breeder system and even after 50 years of intensive research (and many billions of dollars) it seems extremely doubtful that these problems can be overcome. The second problem concerns nuclear weapons proliferation. The preferred fuel for Fast Breeder reactors would be ideal for use in the most efficient nuclear weapons.

If not nuclear then what?
Given the risks, it is unclear why the fortunes of nuclear power are rising so fast. It is certainly not because cost-effective and reliable alternatives do not exist. In section 3.2 Keith Barnham shows how the UK could provide reliable and cost-effective electricity to UK markets using wind and solar photovoltaics (PV), which alone could supply well over 30GW of installed capacity by 2020 – more than the 25GW DTI says will be needed by 2025.

Despite having much less favourable wind resources, Germany is around ten years ahead of the UK in exploiting wind power. The Germans already have more wind-power capacity than the current UK nuclear component. If the UK pursued similar policies to Germany by 2020 wind would provide well over six times the generating capacity British Nuclear Fuels Plc recently proposed for new nuclear build.

The current contribution of PV in the UK is one of the lowest per-capita in Europe. Again, the UK lags around behind Germany in exploiting PV by around ten years. If the UK growth followed the German trend for the last five years, the UK would achieve six GW capacity by around 2018, which is seven years before the six GW of new nuclear build proposed by DTI.

Conclusions

"It is often pointed out that terrorists need suceed only once whereas the security services have to succeed every time."

There is no sense in building more nuclear power plants and endangering people and international security unless the benefits of nuclear power are crystal clear, i.e. unless nuclear power would make a major difference to global CO_2 emissions without significantly increasing security threats. As the evidence in this report shows, nuclear power cannot make a major contribution to global reductions in CO_2 emissions, whereas its effect on global insecurity and the risks of catastrophic conflict or terrorism are there for all to see.

Introduction

"A new nuclear build would take us into uncharted and very dangerous waters."

All over the world the fortunes of civil nuclear power are rising – why? Many in government hope that nuclear power would increase energy security during a time of unstable competition and surging demand. Some claim nuclear power is key to reducing global CO_2 emissions. For others, it is because nuclear power opens the door to nuclear weapons.

This report asks two questions: how dangerous is nuclear power? And can it help reduce CO_2 emissions? The short answer to the first questions is 'very': nuclear power is uniquely dangerous when compared to other energy sources. For the second question the answer is 'not enough and not in time'.

By comparing the security consequences of civil nuclear power to its contribution to tackling climate change, Oxford Research Group shows that rather than making a positive contribution, an expansion of civil nuclear power would:

- make efforts to control the spread of nuclear weapons much more difficult
- increase the risk of nuclear terrorism;
- make a negligible short-term contribution to lowering CO_2 emissions; and
- make a negligible contribution to energy security.

Finally, we show that nuclear power is not needed. Germany, for example, already has more wind-power capacity than the UK nuclear component and within six years will have more solar powered capacity too. If the UK pursued similar policies, by 2020 wind would provide well over six times and solar three times the generating capacity major industrial players estimate for a nuclear new build.

Much of the disagreement about the security implications of nuclear power revolves around whether the risk of nuclear weapons proliferation and terrorism risks can be managed. Using the most recent research we can show that these risks will become much harder to manage. In fact a new nuclear build would take us into uncharted and very dangerous waters.

The foundation upon which we make this claim concerns the availability of high-grade uranium, i.e. there is not enough high-grade uranium in the earth's crust to fuel a large-scale nuclear expansion. Therefore spent fuel will have to be reprocessed in plants like Thorp (England) or Rokkasho Mura (Japan) to produce MOX fuel and reactor-grade plutonium. These materials are suitable for use in nuclear weapons, and will need to be securely stored and transported. Current stocks are a serious proliferation hazard and millions of dollars are spent trying to find and secure them. To produce more would be extremely risky.

Even the most advanced technology for preventing the theft or diversion of weapons usable materials from reprocessing plants cannot guarantee security. Such safeguards are accurate up to 99%. In a reprocessing plant such as Rokkasho Mura, one percent a year is enough for one nuclear weapon a month. If a state decided to start diverting small amounts of plutonium from the reprocessing chain for future use in a weapons programme (or perhaps to sell), it would be very hard for IAEA inspectors to detect the diversion.

For these reasons HMG should apply the precautionary principle. Tony Blair's justification for replacing the UK's nuclear weapons system is based on a version of this principle: in an uncertain future in which new nuclear weapons states and state sponsored terrorism are likely, the 'ultimate deterrent' is justified. Judged against this argument, building more nuclear power plants is self-defeating in the extreme: they would increase the very threats nuclear weapons are intended to deter.

Chapter 1 “NEW BUILD IS UNLIKELY TO INCREASE RISKS TO THE UK”*

Section 1.1 Into the unknown: fueling civil nuclear power?

Storm van Leeuwen

Introduction

According to “The Energy Challenge”: “Realising the potential benefits of new nuclear build would naturally be dependent on the availability of fuel.”[14] But what determines the availability of fuel as a net energy resource? DTI and most official sources use economics to work this out. For example, uranium found in seawater is not viewed as a resource because it would cost more to extract than could be made by selling it. But if the market value increased significantly, it might become economic. Thus, DTI and others can claim that there is enough uranium to fuel 2004 world generating capacity for 85 years.[16]

“The reactor itself is the only part of the process chain producing virtually no CO_2.”

The availability of uranium fuel is determined by the amount of energy that can be generated from 1kg of natural uranium minus the energy needed to recover it from the ore. This has very little to do with economics and everything to do with:

- the concentration of uranium in a deposit (the ore grade); and
- the energy used in the full nuclear energy cycle.

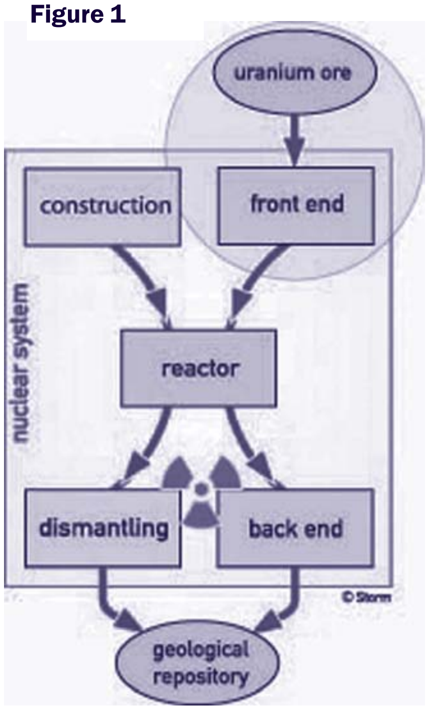
When the energy consumption of the nuclear energy system as a whole (see figure 1) is taken into account, it is possible to calculate the ore-grade at which the nuclear energy system consumes as much energy as it can deliver to the electricity grid. At this point nuclear energy reaches what is know as the ‘Energy Cliff’ where there is no net gain from nuclear power. Nuclear power will reach the Energy Cliff sooner than is widely believed.

The nuclear energy system

To generate useful energy from uranium a complex system of industrial processes is needed. The nuclear system is the most complex and extensive of all energy systems. The three main parts of the nuclear system, also called the nuclear process chain, are:

1. The sequence of processes needed to convert uranium-bearing rock into nuclear fuel.
2. Construction, operating, maintenance and refurbishment of the nuclear power plant.
3. Waste management, dismantling of the reactor after its retirement, construction of a geological repository to isolate the radioactive waste from the biosphere, and safe disposal of all nuclear waste, including dismantling waste, in the repository.

Figure 1

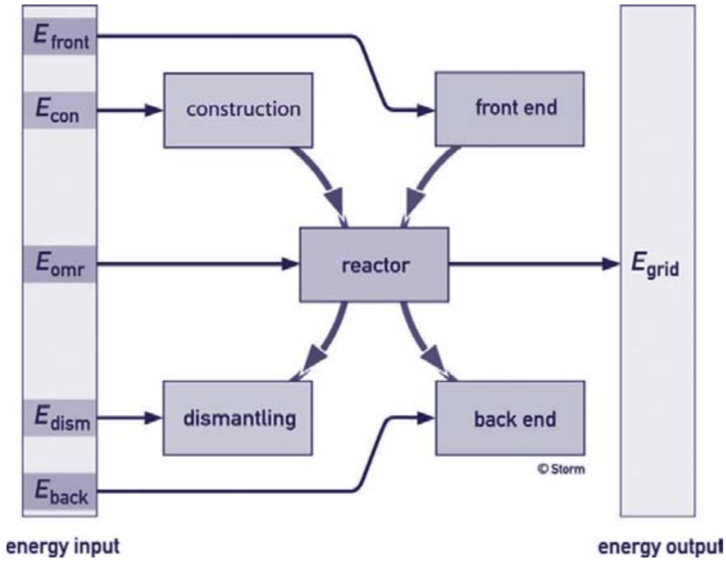


Each of the main parts of the nuclear system comprises a number of industrial processes. Each process consumes electricity, fossil fuels, materials and chemicals, and emits CO_2 and other greenhouse gases. The reactor itself is the only part of the process chain producing virtually no CO_2 (see section 3.1).

To work out how long until nuclear power falls off the Energy Cliff, the energy consumed by each element of the nuclear system has to be analysed.

* “The Energy Challenge: Energy Review Report 2006.” *Department for Trade and Industry*. July 2006. CM6887. Paragraph 5.124, p. 120.

Figure 2: how the nuclear system uses energy



In this analysis all energy inputs are quantified, and the output is measured at the connection with the grid. The energy inputs for construction (E_{con}) and dismantling (E_{dism}) are fixed. The inputs for the front end (E_{front}), for reactor operation, maintenance and refurbishment (E_{omr}) and for the back end (E_{back}) of the nuclear fuel chain depend on the operational lifetime of the reactor. The output of the system is the electricity (E_{grid}) put by the nuclear power plant into the grid.

The energy inputs and outputs of the nuclear system are either 'fixed' or 'running'. Fixed energy investmentsare not influenced significantly by the operational lifetime of the reactor, which includes the energy for construction (E_{con}) and the energy for decommissioning and dismantling (E_{dism}).[17]

Running energy investments are dependent on the operational lifetime of the reactor. They include the energy inputs E_{front} from producing nuclear fuel from uranium, energy E_{omr} consumed by operating, maintaining and refurbishing the reactor, and the energy inputs E_{back} of the activities needed to isolate the radioactive waste from the environment indefinitely.

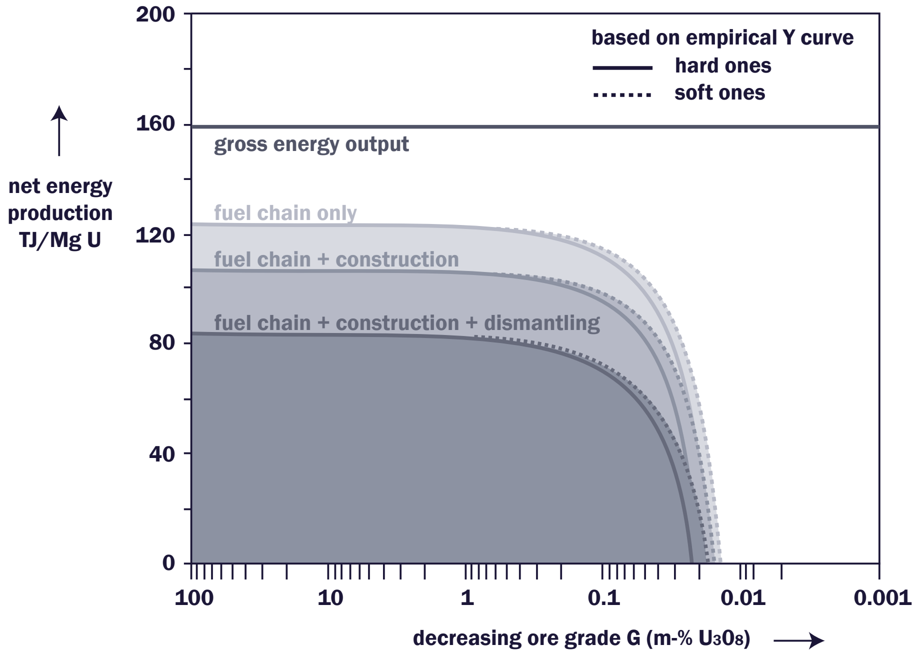
The output of the system is the electricity E_{grid} the nuclear power plant puts into the grid. This amount is not equal to the net energy delivered to society, for a part of the delivered electricity is used to maintain the system itself. By analysing each element of the nuclear system it is possible to quantify the net energy nuclear power puts in the grid, and move one step closer to finding out when nuclear power will reach the Energy Cliff.

When will nuclear power reach the energy cliff?

To take the final step and answer this question, one more variable needs to be factored in: the ore-grade of the uranium reserves used to produce fuel. Ore-grade determines the quantity of energy required to extract one kg of pure uranium from its ore. The quantity of energy that can be generated from one kg of natural uranium has a fixed value. The energy needed to recover the uranium from the rocks in the earth's crust increases with decreasing ore grade. At a certain grade the extraction energy equals the gross energy produced in the reactor. Using ore at that critical grade (0.02% U_3O_8, compared to an average today of 0.15%) the nuclear system as a whole produces no net energy.

In figure 3 the energy consumed by the nuclear system has been subtracted from the energy output. Calculating the balance between net energy production of the nuclear system and the grade of the uranium ore feeding the system leads to the Energy Cliff.

Figure 3: the Energy Cliff



The horizontal axis represents the decreasing uranium ore grade on a logarithmic scale. The vertical axis is the value of the net energy extractable from a kilogram of uranium. The net energy content is defined as the gross energy production per kilogram of natural uranium minus the energy consumption of the nuclear system itself.

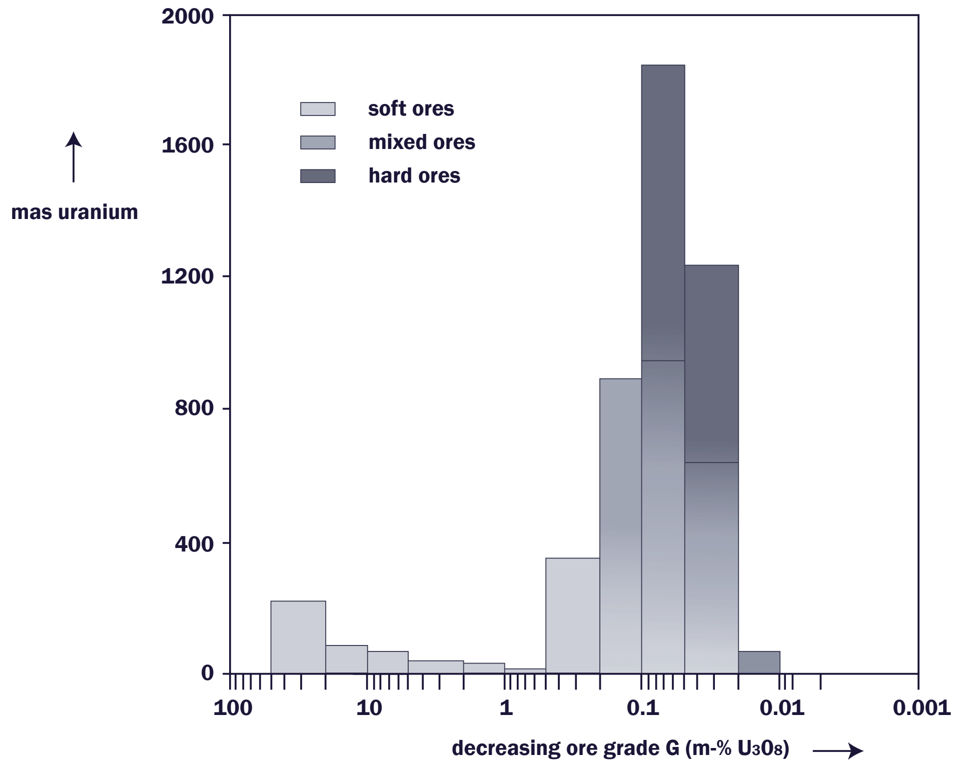
The uppermost curve refers to the fuel chain only: decommissioning and dismantlement of the reactor are excluded. In the lower curves the nuclear fuel chain is accounted for along with construction, and construction plus dismantling. This diagram shows that construction and dismantling barely have an effect on the Energy Cliff. The curves are based on empirical data. At grades below 0.013% no scientific data are available.

What do we know about world reserves of uranium?

The "Red Book" is the standard source for data on worldwide recoverable uranium resources.[18] According to the "Red Book" the total amount of uranium resources jumped from about 3.6 Giga grams (Gg) in 2005 to 4.7 Gg in 2006. The increase from 3.6 to 4.7 Gg is due almost completely to the inclusion of the higher price category of 80-130 USD/kgU. This category comprises uranium ores of relatively low ore grades, greater depth, longer transport distances and/or harder to mine. Virtually no new discoveries of uranium deposits have been added to the listed resources since 2005. Overall, the "Red Book" cites very little data on ore grades or other physical qualities.

"From a geologic point of view the chances of finding new, large, high-quality deposits are slim."

Figure 4: world known uranium reserves of 2006



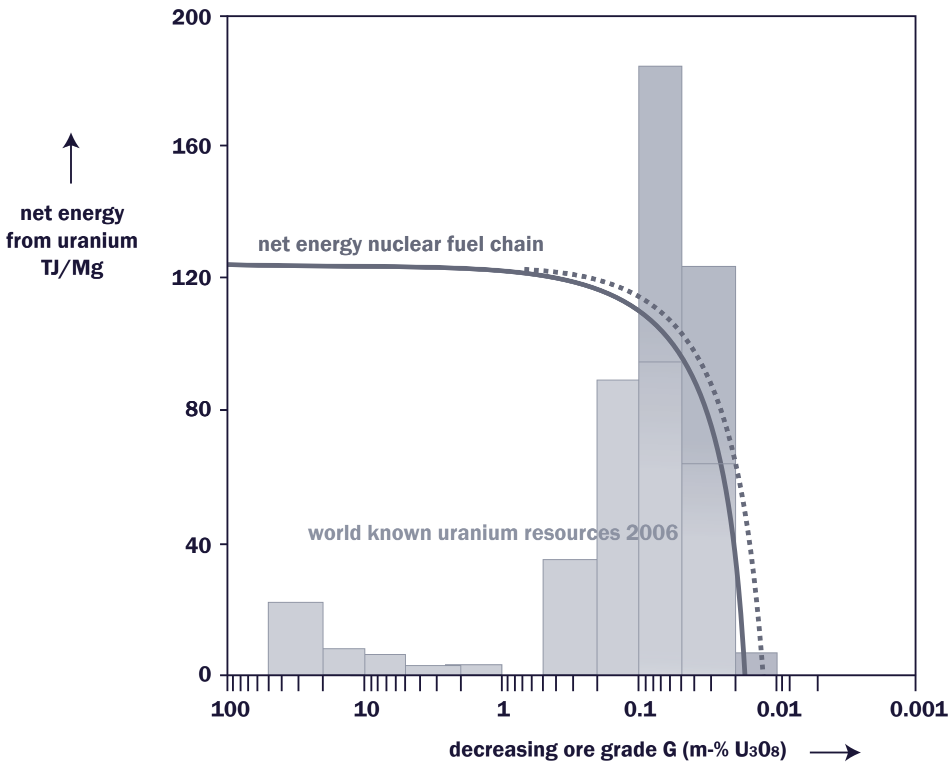
The total amount of uranium represented by this diagram is 4743 Gg, or 4.743 million metric tonnes. This figure comes from the official statistics of the IAEA and NEA (Nuclear Energy Agency). Note that the horizontal axis has a logarithmic scale, with decreasing ore grade, and the vertical one a linear scale. The quantity of uranium present in a resource at a given grade range is represented by the height, not the area of a bar. The width of a bar represents only the range of ore grades. Data on ore-grade comes from a large range of sources, including the World Nuclear Association.

The prospect of new finds

New uranium deposits almost certainly will be found. Higher uranium prices will stimulate more exploration and more exploration will lead to new discoveries. That's the economic part of the story, but does little to help us understand how much energy that can be derived from uranium ore.

The highest quality uranium deposits, i.e. the easiest discoverable and easiest accessible (physically and chemically) are known already. From a geologic point of view the chances of finding new, large, high-quality deposits are slim. No indications on the existence of such deposits have been published up to now. Even if a new Canada-sized rich deposit would be discovered, it would add only six to seven years of high-quality uranium supply to the current world demand.

Figure 5: the ore-grade Energy Cliff relationship



Plotting the diagram of the Energy Cliff on to the diagram of the world known recoverable uranium resources, results in this graph. As it turns out the largest known recoverable resources are nearest to the verge of the Energy Cliff. The bar diagram shows the amounts of the world known recoverable uranium resources and their ore grade distribution from figure 4. The curve represents the net energy production of the nuclear system as function of the ore grade. Actually it is the highest curve from figure 4 and ignores the energy costs of construction and dismantling.

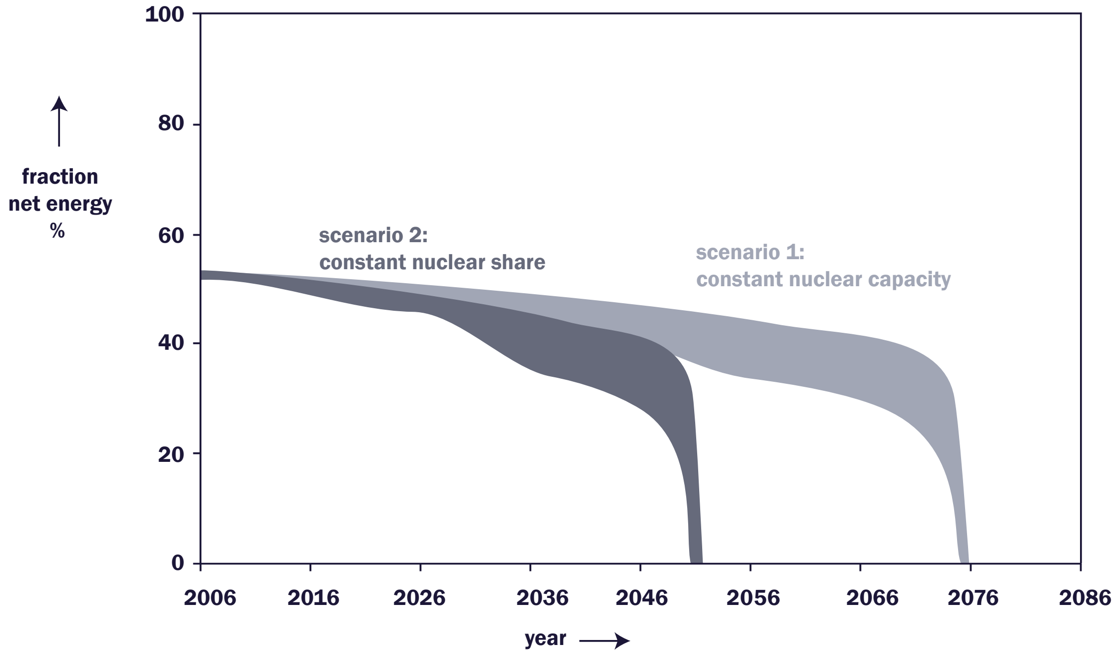
The Energy Cliff approaches

We now come to the crunch question: how long until uranium ore will no longer constitute a fuel for nuclear power generation? Figure 6 shows the net energy from uranium ore over time against two scenarios:

Scenario 1
World nuclear capacity remains constant at current level: 370 GW. The nuclear share declines to < 1% of world energy supply by 2050 as world energy demand rises 2-3% a year.

Scenario 2
World nuclear share remains constant at current level: 2.2% of world energy supply. The world nuclear capacity increases by 2-3% a year (7.5-10 GW/a) to keep pace with rising world energy demand. This scenario corresponds with the 'High' scenario from the IAEA in 2005.

Figure 6: When will nuclear power fuelled using uranium reach the Energy Cliff?



As the richest ores are exploited first the net energy extracted from uranium ore will decrease. The drop of the mean ore grade below 0.1%, within three decades, incurs a significant drop of the net energy from uranium. The nuclear system may fall off the Energy Cliff by about 2050 or 2070, depending on the scenario.

Can Generation IV 'breeder' reactors deliver?

These facts lead some in the nuclear industry to argue for the development of Generation IV nuclear reactors. These reactors are fueled using plutonium with only a small input of uranium. In theory, they produce more nuclear fuel than they use – they 'breed' plutonium-239. Generation IV nuclear reactors would be between fifty and a hundred times more efficient than those in operation today, and would therefore constitute a genuinely low-carbon energy source.

"If there is an increase in reprocessing it will lead to an international trade in weapons-useable nuclear materials."

Fifty years of intensive research in seven countries (USA, UK, France, Germany, former USSR now Russia, Japan and India), with investments of tens, if not hundreds of billions of dollars so far have failed to demonstrate that the breeder cycle is technically feasible.

At present three fast-neutron sodium-cooled reactors (LMFR) are more or less operational, one in Monju in Japan, another in Beloyarsk-3 in Russia and one in Phénix in France.[19] Only the Russian reactor is operating and it has a history of large and serious accidents. Although designed as breeders, none of the three actually bred. It is not clear whether the French and Japanese reactors, out of operation for years, will ever be restarted.

There are serious doubts over the feasibility of Generation IV nuclear reactors. Even if the enormous technical hurdles are overcome in the comming years, it is very doubtful whether these reactors would contribute to reducing global CO_2 emissions for decades to come.

Conclusions

The shortage of high-grade uranium points towards three scenarios:

- nuclear power is phased out;
- the nuclear industry turns to MOX fuels and reactor-grade plutonium; or
- Generation IV reactors begin generating significant amounts of electrcity.

What does this have to do with nuclear weapons proliferation? If fuel for reactors cannot be produced from uranium ore, then industry will have to rely on large scale reprocessing of spent fuel to manufacture MOX (a mixture of uranium and plutonium oxides) and reactor-grade plutonium to fuel nuclear reactors. Both materials can be used to produce a nuclear weapon.

At the moment nuclear reprocessing takes place in a handful of plants like Thorp in England, Rokkasho Mura in Japan and La Hague in France. Until recently the USA avoided reprocessing because of fears over the security risks associated with them, e.g. the impossibility of accounting for all of the plutonium which goes through a reprocessing plant, meaning that some could be stolen or diverted without detection by IAEA inspectors or plant operator (see section 1.2).

If plans for new nuclear plants are fulfilled, there will inevitably be a major increase in demand for reprocessing facilities to produce and sell MOX and plutonium fuels. If there is an increase in reprocessing it will lead to an international trade in weapons-useable nuclear materials. MOX and reactor-grade plutonium would require more secure deposits and secure transit around the world. Such a scenario would constitute a major security risk.

So far as Generation IV reactors are concerned, even if the enormous technological and commercial hurdles could be overcome, the very serious security problems remain unresolved. This technology would lead to the production and distribution of super-weapons grade plutonium. Keeping nuclear weapons useable materials out of the wrong hands is hard enough today, without increasing the availability by constructing reprocessing plants and Generation IV reactors.

Note on methodology

To read the full report upon which these findings are based, including a detailed description of the methodology, go to **http://www.stormsmith.nl/**

The Integrated Sustainability Analysis (ISA) of The University of Sydney reviewed the report* of Storm van Leeuwen and Smith 2005, upon request of the government of Australia. The numerical conclusions are very close to our results, though the ISA authors disagree with us on one point, which is the methodology to estimate the energy requirements of construction and dismantling. We still think our methodology is sound, it is validated extensively in the 1980s by a number of well-known experts. ISA does not contradict our main conclusions concerning uranium. Even using the lower figures of the energy requirements of construction and dismantling, as proposed by ISA, the conclusions with regard to the scenarios of uranium depletion, CO_2 emission rise and net energy decline by the years remain unaffected. For an evaluation see **http://www.lbst.de/publications/studies__e/2006/EWG-paper_1-06_Uranium-Resources-Nuclear-Energy_03DEC2006.pdf**

* **http://www.dpmc.gov.au/umpner/docs/commissioned/ISA_report.pdf**

Section 1.2 Keeping nuclear materials out of the wrong hands

Frank Barnaby

Introduction

On January 25 2007, the BBC reported that a Russian man was arrested in a sting operation involving US agents in Georgia. This man was offering to sell 100g of weapons grade uranium, which he claimed was just a sample. The source of the uranium has not been confirmed, partly because Russian officials have failed to cooperate with the investigation.[20]

Effective safeguards

Reprocessed nuclear fuels (MOX and reactor-grade plutonium) are produced by reprocessing spent nuclear fuel in facilities such as the THORP reprocessing plant at Sellafield. MOX and reactor-grade plutonium can be used to produce nuclear weapons. There is a major security problem with reprocessing: it is impossible to guarantee that weapons-usable materials are neither stolen nor diverted.

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, so 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. The first measurement 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 a commercial reprocessing plant do not know whether or not an amount of plutonium has gone missing."

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 nature of the errors involved, the value of the MUF will usually not be zero even if no illegal diversion of plutonium has occurred. The fact that there is a MUF means that the operators of a commercial reprocessing plant do not know whether or not an amount of plutonium has gone missing.

Commercial reprocessing plants deal with a large amount of plutonium – typically, up to about ten 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.

To date, about 250,000 kg of civil plutonium has been separated worldwide, 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 one per cent 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 five per cent of the plutonium throughput will be unaccounted for.

What do these figures imply? According to recent estimates, the potential MUF at the Japanese reprocessing plant now under construction at Rokkasho-Mura will be around 50 kg per year. This plant 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 eight tonnes of plutonium. The effectiveness of safeguards on the plant, according to these estimates, is more than 99%. Even on these very optimistic estimates, the potential MUF still amounts to about a nuclear weapon's worth a month.

Problems in the UK

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.

Conclusions

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 quite 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 plutoium finding its way to a terrorist group dramatically increases with it. In addition, an international trade in these materials increases the number of targets for a nuclear terrorist attack because reprocessing produces high-level radioactive waste and excess plutonium that has to be stored, and some stores can be targeted.

Section 1.3 The risk of nuclear terrorism

Frank Barnaby

Introduction

*In July 2006 a Daily Mirror reporter planted a fake bomb on a train carrying a deadly cargo of nuclear waste. **

A major reason for opposing a nuclear expansion is that it would increase the risk of nuclear terrorism. There are number of nuclear terrorist activities that a group may execute:

- stealing or otherwise acquiring fissile material and fabricating and detonating a primitive nuclear explosive;
- attacking a nuclear-power reactor to spread radioactivity far and wide;
- attacking high-level radioactive liquid waste tanks;
- attacking plutonium stores
- attacking nuclear materials in transit; and
- making and detonating a radiological weapon, commonly called a dirty bomb, to spread radioactive material.

Apart from exploding a dirty bomb, all of these types of nuclear terrorism have the potential to cause large, or quite large, numbers of deaths and disruption. At its most extreme, a crude nuclear explosive detonated in Parliament Square or Capitol Hill would cause catastrophic damage to those Governments. That the risk of all these types of nuclear terrorism will increase if more nuclear-power stations are built is, assuming the business-as-usual scenario, a matter of fact.

A new build would increase the risk because it would:

- create potential targets for terrorists, from waste tanks and generators at nuclear sites to moving targets such as 'waste trains' and MOX transporters;
- it would increase the availability of MOX and reactor-grade plutonium for use in a dirty bomb or crude nuclear weapon; and
- spread of the knowledge, materials and technology needed to develop nuclear weapons.

"A crude nuclear explosive detonated in Parliament Square or Capitol Hill would cause catastrophic damage to Government"

Attacks on nuclear facilities

Many nuclear facilities in the UK and elsewhere are vulnerable to terrorist attack. Terrorists could target a reactor or spent fuel pond by using a truck carrying high explosives and exploding it near a critical site; 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. 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 unacceptable. 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

* see, **http://www.mirror.co.uk/catchall/tm_method=full%26objectid=17422378%26siteid=89520-name_page.html**

"The industry's insistence that their reactors and storage facilities are 'robust' is dubious."

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) or 1-3% of the plutonium (~ 0.2 te) stored in tanks 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.[21] The potential danger is increased by there being more than ten locations round the country where plutonium is stored in comparable quantities.

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.[22] 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 ttacks". It seems irresponsible to be adding yet more potential targets before we have secured the existing ones.

A terrorist nuclear bomb

The military demand that their nuclear weapons are highly reliable and explode with a yield that can be accurately predicted. A terrorist group would be much less demanding and satisfied with a relatively unsophisticated device, much easier to design and fabricate than the very sophisticated nuclear weapons required by the military.

There are three designs of crude nuclear explosives, adequate for most purposes of a terrorist group intent on nuclear terrorism. First, a gun-type nuclear explosive device using highly enriched uranium. This is the simplest crude device to design and construct and the most likely one to produce a powerful nuclear explosion. But it would be harder for a terrorist group to acquire highly enriched uranium than plutonium.

Second, an implosion type of nuclear explosive device using a solid sphere of plutonium metal as the fissile material will be discussed. This is essentially a crude version of the atomic bomb that destroyed Nagasaki. It is the most difficult of the three to design and construct. But it is within the capabilities of a significantly large terrorist group to do so.

Third, an implosion type device using plutonium oxide as the fissile material will be described. This is perhaps the most likely nuclear device to be constructed by terrorists because of the increasing and widespread availability of plutonium oxide. It may also be the most attractive of the three designs to terrorists because of the threat of the widespread dispersion of large amounts of plutonium even if the device produces no nuclear explosion.

A primitive nuclear explosive using highly enriched uranium

Luis Alvarez, a nuclear-weapon physicist, has emphasised the ease of constructing a nuclear explosive with highly enriched uranium:

> *"With modern weapons-grade uranium, the background neutron rate is so low that terrorists, if they have such material, would have a good chance of setting off a high-yield explosion simply by dropping one half of the material onto the other half. Most people seem unaware that if separated highly-enriched uranium is at hand it's a trivial job to set off a nuclear explosion.... even a high school kid could make a bomb in short order".*

A crude nuclear weapon using highly enriched uranium should explode with an explosive power equivalent to that of a few hundred tonnes of TNT. It might have an explosive yield of a few thousand tonnes. To put this in context, the largest conventional bomb used in World War II contained about ten tonnes of TNT; it was christened "the earthquake bomb". And the terrorist bomb that destroyed the Murrah Federal Building in Oklahoma weighed about three tonnes.

A primitive nuclear explosive using MOX

"A terrorist group may find it easier to acquire civil plutonium than highly enriched uranium."

Plutonium oxide separated from spent reactor fuel elements can be mixed with uranium oxide to produce mixed oxide (MOX) nuclear fuel. It is produced to extract as much energy from uranium fuel rods as possible, theoretically making the nuclear energy system more efficient. 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. The US Department of Energy classifies MOX fuel as 'Stored Weapons Standard' and requires stringent security during transport. UK authorities set lower security standards.

Having obtained a quantity of MOX fuel by diversion or theft, a sufficiently resourced terrorist group would be able to fabricate 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 primitive nuclear explosive using reactor-grade plutonium

A terrorist group may find it easier to acquire civil plutonium than highly enriched uranium. The amount of plutonium available from civil reprocessing plants will rapidly increase, particularly as more reprocessing capacity becomes operational. As the amount of plutonium separated from spent nuclear-power reactor fuel elements increases, it will be stored in a number of countries and become easier to obtain plutonium illegally. The risk that a terrorist group may acquire plutonium and fabricate a nuclear device must be taken very seriously.

There is some disagreement about whether a nuclear bomb can be constructed using plutonium from civil nuclear reactors. Eminent and highly competent physicists, with much knowledge of the characteristics and production of nuclear weapons, such as Richard L. Garwin, Theodore Taylor, J. Carson Mark, Harold M. Agnew, Wolfgang K. H. Panofsky, and Michael M. May to name just a few, have stated that effective nuclear weapons can be fabricated from reactor-grade plutonium.

Conclusions

A new round of nuclear power stations increases the targets for nuclear terrorism, increases the availability of MOX fuel and reactor-grade plutonium, and makes it harder to control nuclear weapons proliferation. Given the limitations of safeguards and other security measures at nuclear power and reprocessing plants, a decision to build more nuclear power plants undermines the regional and international security as well as fueling trends which would direct us towards a world with 20 or 30 nuclear weapons states.

Section 1.4 Nuclear terrorism: an exaggerated threat?

Paul Rogers

Introduction

> *"By 1997, officers in the Bin Laden Unit recognized that Bin Laden was more than just a financier. They learned that al Qaeda had a military committee that was planning operations against U.S. interests worldwide and was actively trying to obtain nuclear materials."*
> ("The 9/11 Commission Report". 2004. p.109)

That was ten-years ago. Since then there are numerous instances of al Qaida attempting to get hold of the materials and expertise for nuclear weapons production. Mercifully, they have failed.

There is no doubt that terrorists such as al-Qaida would commit nuclear terrorism. "The 9/11 Commission Report" tells how in 1993 a senior al-Qaida operative purchased a three foot cylinder of what he believed to be weapons grade uranium from a former Sudanese military officer.[23] Following intelligence gathered after the fall of the Taliban, the US intelligence community "focused on the threat of nuclear terrorism to an unprecedented extent."[24] As recently as September 2006, al Qaida put out a call urging nuclear scientists to join its war against the West.[25]

Supporters of the expansion of nuclear power point to the rarity of attacks involving nuclear facilities in spite of the widespread use of nuclear power over the past fifty years. It is also claimed that mass casualty terrorism is actually very rare, apart from the specific example of the al-Qaida movement, and that paramilitary groups have hardly ever had any economic impact, having avoided economic targeting in favour of attacks on security forces and centres of political power.

This chapter shows that the evidence does not support these claims. Mass casualty attacks and economic targeting have been employed by a range of paramilitary and terrorist organisations and will probably become more common as time passes. Nuclear terrorism is not the preserve of al Qaida and its off-shoots. It also explores the recent history of two specific strands of terrorism, mass casualty attacks and economic targeting. It examines trends over the past fifteen years and relates them to the risks likely to develop if the civil nuclear power industry is subject to rapid expansion in Britain and elsewhere.

> *"A terror group could acquire a stolen nuclear weapon, or enough material to develop a crude nuclear weapon."*
>
> Dr. Mohamed ElBaradei, IAEA Director-General . *Washington Post.* 30th January 2005

Mass casualty terrorism

The best known examples of paramilitary attacks designed to cause death and injury on a large scale have been in the past five years and include the 9/11 attacks in New York and Washington, followed by many other incidents including major attacks in Bali, Madrid, Casablanca and London, with failed attempts including planned attacks in Singapore, Los Angeles, Rome and Paris. Before that, groups linked to al-Qaida had bombed US embassies in Nairobi and Dar es Salaam, with the former killing over 250 people.

While these demonstrate the capacity of the dispersed and diffuse al-Qaida movement to engage in mass casualty attacks, there have been other significant examples in recent years, none of them directly connected with the present-day al-Qaida movement.

Paris, December 1994

Just before Christmas in 1994, an Air France Airbus A300 was hijacked by four members of a radical Algerian group at Algiers Airport. Over two days of negotiation, the plane, with 239 passengers and crew was allowed to fly to Marseilles where the hijackers demanded that the plane be refuelled. The aim of the hijackers was reported to be to crash the plane on the centre of Paris, killing themselves, all the passengers and crew and large numbers of people on the ground. Instead, the aircraft was stormed by a French commando unit and all the hijackers were killed. Three passengers were killed during the incident.

Tokyo, March 1995
The first major attempt to use chemical weapons to cause mass casualties was the release of Sarin nerve agent into the Tokyo subway system on 20th March 1995 by members of an extreme religious sect, the Aum Shinrikyo. Fortunately, a combination of impure chemicals, an inadequate release system and the extent of the air circulation system on the subway meant that the attempt to kill hundreds or possibly thousands of people failed, but twelve people died and over 5,000 were made ill.

New York, February 1993
The first attempt to destroy the World Trade Center would, if it had succeeded, have killed around 30,000 people. A radical Islamist group attempted to use a massive truck bomb in the underground car park under the North Tower to bring the whole tower down over the Vista Hotel and into the South Tower, destroying that as well. Although the attack failed to achieve it aims, partly because of the nature of the structure of the Center, massive damage was done to the base of the structure, and the Vista Hotel came close to collapse. Six people died in the attack and over 1,000 were injured, mainly through smoke inhalation.

These are the most notable of the many examples of attempts to kill large numbers of civilians, stemming from religious, separatist or political motives. There are numerous other examples, including many actions by Sendero Luminoso Maoist guerrillas in Peru, Chechen rebels in Moscow, Palestinian radicals in Israel, and Zionist paramilitary groups in Palestine before partition. They demonstrate that while paramilitary groups that are prepared to engage in mass casualty attacks are not endemic in society, there have been many more examples than is usually appreciated.

"While para-military groups that are prepared to engage in mass casualty attacks are not endemic in society, there have been many more examples than is usually appreciated."

Economic targeting

Iraq, 2003-06
The termination of the Saddam Hussein regime and the subsequent occupation of the country by US forces and their coalition partners did not lead to an era of peace and security. Instead a bitter insurgency developed that, in its first three years, cost well over 40,000 lives and hundreds of billions of dollars. A specific but largely overlooked aspect of the insurgency has been the persistent and highly effective use of economic targeting by insurgent groups, especially against the Iraqi electricity supply and oil production.

By early 2006, electricity supplies to Baghdad averaged four hours a day, one quarter of the level before the war, and access to safe drinking water across the country as a whole was down by a quarter. The most substantial effect was on the supplies of oil, the cornerstone of plans to rebuild the Iraqi economy. So effective were the insurgents that oil production in early 2006 was still below the levels achieved by the Saddam Hussein regime operating under sanctions, even though huge efforts had gone into securing and rebuilding the oil infrastructure.

Britain and Northern Ireland, 1992-97
By the early 1990s, there was a stalemate in the 25-year conflict in Northern Ireland and the Provisional IRA (PIRA) developed a policy of economic targeting in Britain. Immediately after the 1992 General Election, a campaign of bombing of city centre targets and major transport links started, including two highly destructive bombs in the City of London in 1992 and 1993, and the bombing of the M1/A5/North Circular Road interchange in north west London in 1992.

The campaign was directed partly at undermining London's position as financial capital of Europe and caused consternation and deep unease in city and government circles. From 1992 to 1994 the campaign continued and resumed for over a year in 1996-97 after a ceasefire. Later attacks included bombs at Canary Wharf and the centre of Manchester and there were frequent disruptive attacks on airports, railway lines and motorways. One particular attempt that was pre-empted involved a plan to blow up the key electricity switching stations around London, potentially causing huge disruption of electricity supplies to Greater London for months.

The PIRA campaign over five months was not aimed at causing great loss of life but had a major effect on government thinking, encouraging both Conservative and Labour governments to devote much more effort to resolving the conflict in Northern Ireland. It remains one of the most effective examples of economic targeting, pointing to the vulnerability of modern urban industrial states to this kind of action.

One of the major security developments of the last fifteen years has been the evolution of what is often termed "asymmetric warfare" in which paramilitary groups that may be relatively weak in terms of weapons and other military capabilities avoid engaging in open conflict with superior forces and seek instead to target weak points in states. Some of the examples are listed above but there are many others. It is fair to say that this is now a trend that is gathering momentum and is seen as "the weak taking up arms against the strong" as one US military analyst put it in the early 1990s.

Energy targeting

One of the major trends in paramilitary targeting is the increasing prevalence of attacks on energy infrastructure. Iraq is the best-known example but there are many others. In addition to the PIRA attempt to blow up electricity stations around London, PIRA also attacked a gas plant in Warrington and attempted to bring down high voltage power lines near Birmingham. In October 2002, suicide bombers attacked the French supertanker Limburg off the coast of Yemen and oil company offices and residential areas in Saudi Arabia have been attacked several imes since 2003.

A recent failed attempt on the massive oil processing plant at Abqaiq is a clear indicator of the trend. Saudi Arabia has the world's largest oil reserves and is also the largest exporter. Most of the fields are located close to the Persian Gulf coast and two-thirds of Saudi Arabia's total crude oil production goes through a single plant at Abqaiq. Described as the jewel in the crown of the Saudi oil industry, Abqaiq processes "sour" crude into "sweet" crude mainly by removing hydrogen sulphide in a series of huge hydrogen-desulphurisation towers. The plant was attacked on 24 February 2006 by a suicide squad driving two car bombs supported by a 4x4 attack vehicle. Guards were killed by gunfire and the explosions but the company claimed that neither of the car bombs detonated within the main plant. This is disputed by local sources that claim that one car got into the main plant, missing the most important facilities but causing substantial damage. In any case, the key point is that the Abqaiq attack was the first occasion in which a heavily guarded oil plant was attacked in Saudi Arabia.

The overall message is that the production and distribution of oil and gas underpin modern economies to a remarkable extent and, as such, represent a particular soft target for paramilitary groups. In addition to pipeline attacks in many countries, including Nigeria and Colombia, there have been attempted attacks on oil tanker traffic, on oil companies in Saudi Arabia and Yemen

"Paramilitary groups have shown a particular ability to target transport systems in recent years"

and on the world's largest oil processing plant at Abqaiq, together with the sustained disruption of oil production and distribution in Iraq. There is little doubt that this trend towards attacks on "soft" energy facilities will increase.

Conclusions

The United States is pursuing its global war on terror with great vigour, while devoting little or no attention on the underlying conditions that lead to support for groups such as the al-Qaida movement. It has terminated regimes in Afghanistan and Iraq, has undertaken military action in countries such as Yemen, Sudan and Pakistan, and may be building up to a confrontation with Iran. In such circumstances, and with many thousands of civilians already killed as a result of these policies and close to 100,000 detained without trial since 9/11, an inevitable response from paramilitary groups is to play to their strengths, with these increasingly involving asymmetric warfare.

It is in this context that the proliferation of civil nuclear power programmes is so unwise. If a country such as Britain decides to build a new generation of nuclear reactors it will encourage other countries to do likewise. For the present, nuclear power expansion is limited to just a few countries such as Finland and China, but a UK decision could change all that, serving to help legitimise nuclear power at a time of public unease. With such an expansion will come specific risks set out in part two, such as fissile material being used to produce crude nuclear bombs or radiological weapons.

There is, furthermore, a particular issue with the transport of nuclear waste. In Britain, for example, radioactive waste is transported on mainline rail routes across much of the country. With nuclear power stations dispersed around the coast of Britain, the transport of waste to the Sellafield site requires the use of a network of routes that involves transit through cities such as London, Edinburgh and Bristol by trains with minimal security. Paramilitary groups have shown a particular ability to target transport systems in recent years, and even hugely expensive security measures could not be guaranteed to provide sufficient insurance against attacks.

Trends in mass casualty terrorism and economic targeting, especially the trend towards the targeting of energy facilities, point to the particular dangers of the expansion of civil nuclear power. Such a combination makes it particularly unwise for Britain to build a new generation of nuclear power plants.

Chapter 2 THE "SECURITY SITUATION IS EXPECTED TO REMAIN AT CURRENT LEVELS IN THE MEDIUM TO LONG TERM"

Section 2.1 From a civil nuclear means to military ends: Iran, a case study

Frank Barnaby

Introduction

A country that produces fissile material – enriched uranium, plutonium or both – for civil nuclear power programme could use it to fabricate nuclear weapons. The technology required to develop and fabricate nuclear weapons is the same as that used in civil nuclear technology. The country may, of course, choose to establish a separate, and probably clandestine, programme to produce fissile material specifically for nuclear weapons.

There are a number of reasons why a country may decide to acquire nuclear weapons. The political leaders of some countries may believe that they need them to solve their country's real or perceived security needs. North Korea may fit into this category. Israel became convinced soon after it was founded in 1948 that some Arab countries were intent on destroying it. Israel was, therefore, intent on developing nuclear weapons, as a deterrent or as a weapon of last resort. It began to do so in the 1950s and deployed some in the 1973 war.

Prestige is another reason why a country acquires nuclear weapons. The fact that all permanent members of the United Nations Security Council are nuclear-weapon powers is not lost on non-nuclear states. Nuclear weapons can give a state a dominant position in its region. Conversely, the risk of loss of prestige, of remnants of great power status, is a reason why countries with nuclear weapons, such as France and Britain, will not give them up.

Political leaders may want nuclear weapons for domestic political reasons – to boost their political power or to distract their people from social or economic problems. India may have acquired nuclear weapons partly for this last reason, partly to impress Pakistan, and partly to improve its security against China.

There may also be a 'domino effect' in some regions: if one country acquires nuclear weapons, neighbouring countries may feel obliged to follow suit. Pakistan, for example, felt itself to be under great pressure to get nuclear weapons when India did so.

The case of Iran

Iran is a good example of the difficulty of distinguishing between a nuclear programme undertaken for civil purposes and a military nuclear programme. There is no firm evidence that Iran intends to fabricate nuclear weapons. It says that its current developments are for purely peaceful purposes – to produce nuclear fuel for civil nuclear-power reactors. But many suspect that Iran wants, and will get, nuclear weapons.

If Iran is developing nuclear weapons it is probably doing so because it feels threatened by the Americans. Also, Iran may want to increase its power, prestige and influence in its region. If Iran does acquire nuclear weapons it may well trigger a domino effect. Egypt, Saudi Arabia, Turkey, and Syria may embark on indigenous nuclear-weapon programmes or acquire nuclear weapons from another country.

Iran is now operating indigenously the entire nuclear fuel cycle. It mines uranium ore and mills it. It operates a uranium conversion facility that converts yellowcake into uranium dioxide that is in turn converted to uranium hexafluoride gas. The facility is also able to fabricate nuclear fuel for reactors. Uranium hexafluoride gas in enriched using gas centrifuges to produce enriched uranium fuel for a nuclear-power reactor.

The origins of Iran's nuclear programme date back to 1959 when, under Shah Mohammad Pahlavi, Iran purchased a research reactor from the United States. The Shah had ambitions to develop nuclear weapons. However, the Iranian revolution in 1979 disrupted the Shah's programme and, until the end of the Iran-Iraq war in 1988, few believed that Iran had any intention of pursuing nuclear weapons.

The Shah planned to construct up to 23 nuclear power stations across the Iran by 2000 with American assistance. The location of the first nuclear plant was to be Bushehr; it was to supply electricity to the city of Shiraz. In 1975, the German firm Kraftwerk Union signed a contract to build two 1,200 MWe nuclear reactors at Bushehr, to be completed in 1981.

"Few western observers are convinced that a large civil nuclear energy programme makes much economic sense for Iran."

After the 1979 Revolution, Iran told the IAEA that it planned to restart its nuclear-energy programme using nuclear fuel produced indigenously. Kraftwerk Union stopped construction work in January 1979, leaving one reactor 50% complete and the other reactor 85% complete. During the Iran-Iraq war, between 1984 and 1988, the Bushehr reactors were bombed repeatedly by Iraq.

In 1995, Iran signed a contract with Russia to resume work on the Bushehr plant, installing a 915-MWe VVER-1000 pressurized water reactor. The contract for the reactor sets the date of delivery to be no later than March 19 2004. But there have been significant delays, perhaps caused by American pressure on the Russians to stall delivery. The Russians announced recently that Bushehr would not be operational until October/November 2007.

Today, Iran's civil nuclear plans – to build seven nuclear power reactors, with a total generating capacity of about 7,000 megawatts of electricity – are regarded as ambitious. Iran has very large oil and gas reserves. Why then, people ask, does Iran need nuclear power?

Why would Iran want nuclear power?

Since the time of the Shah, Iran has argued that it needs nuclear power to satisfy increasing demands for electricity. Iran insists that it needs to sell its oil to obtain foreign currency, pointing out that its oil reserves are finite and that nuclear power is a sensible investment for the future. Few western observers are convinced that a large civil nuclear energy programme makes much economic sense for Iran. But, in the face of such scepticism, Iran has repeatedly emphasised that its nuclear programme is entirely peaceful.

The Iranians insist (correctly) that they have an absolute right to develop and use peaceful nuclear technology as spelt out in Article IV of the NPT. Article IV states that:

> *"Nothing in this Treaty shall be interpreted as affecting the inalienable right of all the Parties to the Treaty to develop research, production and use of nuclear energy for peaceful purposes without discrimination. ... All the Parties to the Treaty undertake to facilitate, and have the right to participate in, the fullest possible exchange of equipment, materials and scientific and technological information for the peaceful uses of nuclear energy".*

Iran has violated its Safeguards Agreement with the IAEA, required by the NPT, by failing to report some of its nuclear activities to the Agency, as the Safeguards Agreement requires. None of these activities are in themselves illegal or even particularly note-worthy; it is the failure to report them to the IAEA that is illegal and this has fuelled suspicion over Iran's intentions. Furthermore, like any country with a long experience in nuclear physics and engineering and has been operating nuclear research reactors for decades, Iran has a cadre of trained personnel whose skills could be utilized in a nuclear weapons programme. This combination – of a somewhat dubious track record and access to vital qualified human resources – sustains acute concern over Iran's nuclear activities.

To date, Iran does not have the fissile material (highly enriched uranium or plutonium) needed to produce nuclear weapons. However, once it took the political decision to acquire nuclear weapons and had produced enough fissile material, Iran would be able to fabricate nuclear weapons in a relatively short period of time – perhaps under two years.[26]

How could Iran acquire fissile materials for a weapon?

"The Israeli reactor at Dimona, used to produce plutonium for Israel's nuclear weapons, is the same type of reactor as the one planned for Arak."

By separating plutonium from spent fuel from the nuclear-power reactor at Bushehr
Once Bushehr is operational, plutonium could be chemically removed from the fuel elements that have been irradiated in the nuclear-power reactor. (The reactor will use uranium dioxide as nuclear fuel. Plutonium is inevitably produced as the uranium fuel is used up. Nuclear fission occurs in the uranium, heat from fission produces steam in water circulated around the reactor core and the steam is used to operate turbines to produce electricity.) The plutonium could be used to fabricate nuclear weapons.

The Russians have essentially completed the 1,000 megawatt-electrical light-water reactor, of the Russian VVER type, at Bushehr, Halileh. The reactor is scheduled to start up in September 2007: The Bushehr reactor will use low enriched uranium (about 3.5% in uranium-235) as fuel. The core of the reactor will hold about 103 tonnes of uranium contained in 193 fuel assemblies. If operated to generate electricity, the Bushehr reactor will produce about 250 kilograms of plutonium per year. This is enough to build between 40 and 50 nuclear weapons a year. There will be enough plutonium in four irradiated fuel assemblies to produce a nuclear weapon.

The Bushehr reactor is, according to Iran, the first of a series of seven power reactors planned to generate 6,000 megawatts of electricity. It is reported that Iran intends to build a second power reactor at the Bushehr site of a similar type, again with Russian assistance. Iran says that it is interested in establishing a capability to produce low-enriched uranium so that it has an indigenous supply of nuclear reactor fuel for its reactors and the possibility of export to other counries.

By using plutonium produced in the planned heavy water research reactor at Arak being constructed to replace the 35-year old IR-40 research reactor now operating at Tehran.
A new IR-40 will be a 40-megawatt (thermal) heavy-water reactor, fuelled with natural uranium and cooled by heavy water. It will be a very efficient way of producing plutonium for use in very effective nuclear weapons. The Israeli reactor at Dimona, used to produce plutonium for Israel's nuclear weapons, is the same type of reactor as the one planned for Arak. The Iranians say that the purpose of the new reactor will be the same as that of the old one – to produce radioactive isotopes for medical, industrial and agricultural uses.

Plutonium could be removed chemically from the fuel elements and then used to fabricate nuclear weapons. IR-40 could produce about eight kilograms of plutonium annually, enough to fabricate two nuclear weapons a year. However, plutonium from the Arak research reactor is unlikely to be available before about 2011 to 2014.

Iran could fabricate nuclear weapons from highly enriched uranium (HEU) produced in one of two gas centrifuge plants in Natanz

Iran is now producing low enriched uranium using gas centrifuges. It claims that this uranium will be used for fuel in nuclear-power reactors. By recycling uranium hexafluoride gas in the gas centrifuges, the concentration of the uranium-235 isotope in the uranium could be increased to ver 90%, suitable for use in nuclear weapons. For use as nuclear fuel, the concentration is about 3.5%.

Iran is constructing two gas centrifuge plants at Natanz, 40km from Kashan. One is a Pilot Fuel Enrichment Plant (PFEP) and the other is a large commercial-scale Fuel Enrichment Plant (FEP). Iran has acknowledged that components for gas centrifuges have been produced and tested in the workshop of the Kalaye Electric Company in Tehran.

"Iran demon-strates the difficulty of interpreting a country's nuclear activities"

On 11 April 2006, Iranian officials announced that uranium had been enriched at Natanz to a concentration of 3.5% in uranium-235 in a cascade of 164 gas centrifuges. In November 2006, a second cascade of 164 gas centrifuges was started up. And Iran has said it is adding more.

In April 2006 Iran announced that it planned to install 3,000 centrifuges at the FEP. The plant is being constructed partly underground. Iran has announced plans to install eventually more than 50,000 centrifuges at the FEP.

An Iranian facility containing 3,000 centrifuges could produce about 40kg of highly enriched uranium per year enough for two nuclear weapons. It will probably take Iran five years or so to reach this rate of HEU production.

Conclusions

It can be concluded that if Iran takes the political decision acquire nuclear weapons, it is unlikely to be able to do so within the next five years but probably could do so within about ten years. For those concerned about preventing the spread of nuclear weapons to countries that do not now have them, Iran demonstrates the difficulty of interpreting a country's nuclear activities. Are they purely peaceful or are they part of a military nuclear programme? Can we close the stable door before the nuclear horse has bolted?

Section 2.2 The security background to a nuclear new build

James Kemp

Introduction

The first of a new fleet of six nuclear reactors in the UK would be unlikely to generate electricity until around 2020. The last one may not come online for another ten years after that (under favourable conditions). It would be hoped that each plant would run for at least thirty years, which means that people in the UK could have to live with nuclear power plants until 2060 at least.

Incredibly, DTI and OCNS believe "the international security situation is expected to remain at current levels in the medium to long term". A review of major trends affecting the root causes of conflict, insecurity and political violence over the lifetime of a new nuclear strongly suggests that:

- al Qaida may be a foretaste of things to come; and
- that the chance that nuclear weapons will be used is growing.

Trends

The most important threats come in the form of trends containing the root causes of global and regional insecurity and conflict, including political violence and terrorism. If they are not effectively addressed, these trends have the potential to cause catastrophic suffering and destruction. Three of the most important trends we need to address are:

- climate change;
- competition over resources; and
- global militarisation.

It is not necessary to examine each one of these in detail here.[27] Suffice to outline the risks each trend presents and ask whether a new build would exacerbate these trends or not?

Climate change

Global warming will cause widespread food and water insecurity. The evidence indicates a shift towards rain falling more on the oceans and polar regions and less on tropical land masses.[28] A significant reduction in rainfall throughout these fertile lands would cause a drop in the food production where most of the world's food is grown and most of the world's population live.[28]

With such insecurity comes competition for scarce essential resources. Mass migration out of the tropics towards Europe and other industrialised regions will increase to unprecedented levels, potentially inflaming existing social and racial tensions. Countries directly affected by food and water insecurity will struggle to feed and maintain authority over populations and may be forced into competition with neighbouring states for resources.[30] With such competition comes the risk of internecine and regional conflict, and repressive domestic policies, often in regions where existing tensions are dangerous, such as south and East Asia.

Imagine what might happen in Pakistan if and when the glaciers retreat causing severe water shortages. Would the machinery of the state be able to cope with the stress? The region and world could be faced with a security nightmare: a failing nuclear armed state in which radical Jihadists exercise considerable power, probably within the security services and armed forces. There have already been three attempts on President Musharraf's life.

The instability and insecurity climate change is likely to generate will make nuclear weapons more desirable to governments and military elites because they constitute a cost-effective insurance policy in an uncertain world. This is especially so for elites who are vulnerable to states with more powerful conventional forces or nuclear weapons

Resource competition

"There is a very real danger of a nuclear arms race in the Middle East."

Current trends in global consumption and fossil fuel production point towards intensified competition for supplies.[31] Talk of reducing dependency on oil and natural gas from the Persian Gulf is increasingly common, and renewable energy and nuclear power are frequently put forward as partial solutions to this problem. But given the scale and accessibility of the resources found in the Persian Gulf compared to other regions, combined with projections of global energy use,[32] this region will remain vital to energy importing states. It will not be possible to reduce reliance Persian Gulf states for the dangers associated with resource competition to be reduced to a tolerable level unless radical action is taken to reduce fossil fuel demand.

Sustaining the power of Saudi Arabian elites and containing the influence of other players, such as Iran and al-Qaida, are central to the US-led policy for ensuring the reliable flow of oil and gas. Following the price hikes of 1973-74, Pentagon planners prioritised the development of a capability to deploy military forces to maintain control over the Persian Gulf region to secure the supply of oil and deny competitors control or influence in the region. Many states benefit (in the short-term) from and support this approach, whether they say so publicly or not.

This situation is likely to exacerbate demand for nuclear weapons because they could constitute a cost-effective way for elites (often with popular backing) to challenge an unfavourable status quo and the forces that sustain it. Iran's civil nuclear power programme is a case in point. Recent announcements from Jordan, Turkey and the statement issued by the Gulf Cooperation Council meeting (10th December 2006) demonstrate that the potential to develop nuclear weapons is increasingly sought in that region.[33] There is a very real danger of a nuclear arms race in the Middle East.

Global militarisation

Since 9/11 political elites have weakened a raft of tried and tested conflict prevention mechanisms, including arms control treaties, such as the Nuclear Non-proliferation Treaty and Biological and Toxin Weapons Convention. Compared to the 1990s there is a shift towards a strategic culture that favours the use of military force to secure national interests and protect vulnerabilities, and an apparent move away from strengthening legal and diplomatic structures for conflict prevention and management.

Of particularly concern is the evidence that we a moving towards a WMD strategic culture. In other words, a world in which the taboo against the possession and threat of nuclear weapons is weakening, and more and more states are looking to nuclear weapons as part of their arsenal. For example, the UK, France, China and Russia[34] are engaging in nuclear weapons modernisation programmes. Israel maintains a nuclear force; Pakistan and India are vigorously developing their smaller forces; North Korea probably has a small stock; and Iran is developing a civil nuclear programme, which could enable it to become a nuclear weapons state. Meanwhile, the USA is revising its nuclear posture so that its arsenal is useable in the Post-Cold War security environment.

> *"The overall impact of nuclear weapons modernisation in existing nuclear weapons states is likely to serve as a substantial encouragement to nuclear proliferation as states such as Iran, with their perception of vulnerability, deem it necessary to develop their own deterrents."*[35]

"It is an uncomfortable fact that nuclear weapons are judged to be cost effective."

Moreover, the danger of accidental nuclear attack would rise substantially. It took many years to implement physical and procedural mechanisms that reduce the risk of accidental nuclear launch. It is unlikely that such precautions would be prioritised under conditions rapid nuclear weaponisation.

Another major factor driving global militarisation is the weaponisation of space. With its technological and economic advantages the USA is pushing ahead with plans to assert military dominance over space. Neither China nor Russia would accept a situation in which the USA enjoyed superior offensive nuclear forces and defensive systems (including space-based lasers): this would constitute a near revolution in warfare and geopolitics. An enhanced and renewed arms race is one probable outcome, combined with the uncontrolled weaponisation of space.

Global militarisation, unless tackled effectively, will amplify vulnerabilities that political and military elites try to reduce. Some governments would reconsider nuclear weapons programmes and others would look into them for the first time. Elites may look to nuclear weapons as the only way to level the playing field in relation to overwhelming military might. This situation would be perilous.

The former Secretary of State Henry Kissinger, who is not known for being soft on defence or security, recently said in a joint article:

> *"Deterrence continues to be a relevant consideration for many states with regard to threats from other states. But reliance on nuclear weapons for this purpose is becoming increasingly hazardous and decreasingly effective. ... unless urgent new actions are taken, the U.S. soon will be compelled to enter a new nuclear era that will be more precarious, psychologically disorienting, and economically even more costly than was Cold War deterrence."*[36]

The question we must ask of the Government and industry is whether building new nuclear power plants would make the prospect Kissinger et al describe more or less likely? The evidence and experience points in one direction: that a new build would push us towards "a new nuclear era".

Conclusions

It is an uncomfortable fact that nuclear weapons are judged to be cost effective. Many poorer states that can ill afford to train and equip effective conventional deterrents may find nuclear weapons particularly tempting. A large-scale growth in nuclear power would make it easier for such states to acquire the deterrent they seek.

Much depends upon the health of the Nuclear Non-proliferation Treaty (NPT). At the heart of the NPT is a 'Grand Bargain', whereby states that did not possess nuclear weapons as of 1967 agree not to develop them, and states that possess them agree to relinquish them over time. This bargain is breaking down: nuclear weapon states (NWS) have not taken the necessary steps to convince non-nuclear weapons states (NNWS) that they are sincerely committed to nuclear disarmament. Unless NWS states take unambiguous steps towards abolishing their nuclear arsenals more and more states will seek the ultimate deterrent. The three trends outlined above point unequivocally towards more instability and insecurity. In the words of FCO's own White paper on "The Future of the UK's Nuclear Deterrent" (Dec. 2006):

> *"Our assessment of the potential security environment between 2020 and 2050 … highlights some trends that give rise to significant causes for concern. In spite of the success of arms control activities in slowing the proliferation of nuclear weapons, the number of states with nuclear capabilities has continued to grow. We do not assume that this trend will endure and we will continue to do all we can to slow or reverse it. But we cannot discount the possibility that the number of states armed with nuclear weapons may have increased by 2050."*[37]

One explanation for these pro-nuclear policies is that decision-makers mistakenly believe the security consequences of a large expansion of civil nuclear technology and materials can be managed. Another is that decision-makers believe a new build is inevitable and want a stake in future decisions regarding nuclear security and safety. Relying on the first explanation is a risky gamble; relying on the second is a counsel of despair and will bring about the very outcome we all most fear.

CHAPTER 3 NUCLEAR POWER AND GLOBAL WARMING

Section 3.1 CO_2 emissions from nuclear power

Storm van Leeuwen

Introduction

Global warming is without doubt humanity's greatest challenge. In responding to this challenge, we need to accept that radical action is needed. Nuclear power has been put forward as part of a sensible energy policy for reducing CO_2 emissions, sometimes by unexpected people including Patrick Moore, the co-founder of Greenpeace.[38] Given the way this claim is reported it is understandable that many people assume that it is correct. This assumption can and should be questioned.

"The Energy Challenge" asserts that nuclear energy would help the UK to meet our CO_2 emissions targets (in conjunction with other measures) because:

- CO_2 generated per kilowatt hour is comparable to wind power, and
- there is plenty of high-grade ore available for uranium fuel production.

This chapter presents the evidence from a comprehensive energy analysis of the nuclear system,[39] which found that:

- if world nuclear generating capacity remains at today's level, then by 2070 uranium fuelled nuclear power would produce as much CO_2 as a gas-fired power station; and
- if world nuclear generating share remains at today's level, then nuclear power would generate as much CO_2 as a gas-fired power station by approximately 2050.

The claim of the nuclear industry that nuclear power emits low levels of CO_2 and other greenhouse gases is not based on scientifically verifiable evidence. Emissions of greenhouse gases other than CO_2, often with Global Warming Potentials many thousands of times larger than carbon dioxide, by nuclear power never have been investigated and/or published. Absence of data definitely does not mean absence of greenhouse gas emissions.

Reducing CO_2 emissions?

Recovering uranium from the earth's crust involves a sequence of physical and chemical processes that use energy and produce CO_2,[40] both of which can be calculated reasonably accurately. Today, the average ore grade used to fuel nuclear reactors is 0.15% U3O8 (1.5 g uraniumoxide from 1 kg rock), the specific energy needs and CO_2 emissions of the nuclear cycle using this grade natural uranium can be calculated too.[41]

To work out how nuclear power might help tackle global warming, we have to calculate the quantity of CO_2 the nuclear system as a whole emits, compared to other energy sources. It is true that the operation of a nuclear reactor emits virtually no CO_2, but this is not true of the nuclear power system as a whole. In fact, nuclear power emits a lot more CO_2 than is commonly believed and, more importantly, CO_2 emissions from nuclear power will increase over time. Our calculations indicate that within 45 to 70 years (depending on the scenario) nuclear power will emit as much CO_2 emissions as a gas-fired power plant (see below for details).

Two main variables determine CO_2 emissions from nuclear power:

- the operational lifetime of the nuclear plant; and
- the quality of the uranium bearing ore from which uranium is extracted.

Operational lifetime

The operational lifetime is important because the nuclear system consumes a large fixed amount of energy, and therefore emits a fixed quantity of CO_2. If we assume an average operating lifetime of 35 years at a lifetime average load factor of 85% using uranium ore grade of 0.15%, then lifetime CO_2 emissions per kilowatt hour electricity (g CO_2/kWh) are between 84 and 122. Official nuclear institutes cite much lower values: 3 - 40 gCO_2-equivalents/kWh, including greenhouse gases other than CO_2. These numbers are based on unpublished, and so unverifiable, analyses.

According to our analysis:

1 The production of nuclear fuel from uranium ore, conditioning and disposal of the operational wastes contribute about **56 gCO_2/kWh**, using ores with grades of 0.15% uranium. This contribution to the specific CO_2 emission does not depend on the operational lifetime.

2 The construction of a nuclear power plant alone contributes **11.5 gCO2/kWh** (Sizewell B) to the lifetime-averaged emission rate.

3 Construction and dismantling of the nuclear power plant stand for a large energy debt as well as a CO_2 debt. Redemption of this debt contributes **28 – 66 gCO_2/kWh** (uncertainty range), under the most favourable assumed conditions. For comparison: a gas-fired combined-cycle power plant has an emission of about 385 gCO_2 / kWh.

Nuclear electricity generated from ores with a grade of 0.15% U, the world average at this moment, has a specific carbon dioxide emission of nearly **84 – 122 gCO_2/kWh**. How does this compare to other energy sources? OECD Nuclear Energy agency figures are cited in “The Energy Challenge”.

Table 1: gCO_2/kWh for different energy sources [42]

“With regard to nuclear power DTI appears to rely exclusively on nuclear industry data.”

Technology (2005 - 2020)	gCO_2/kWh
Coal	755
Natural Gas	385
Biomass	29 – 62
Wind	11 – 37
Nuclear (OECD)	11 – 22
Nuclear (Storm and Smith)	84 – 122
Nuclear (ISA, Uni. of Syndey)	10 – 130
Nuclear (Extrern-E UK)[42] *	11.5

DTI figures suggest that nuclear is comparable with wind. With regard to nuclear power DTI appears to rely exclusively on nuclear industry data. Evidence from independent sources seems to be absent completely. It should be noted that the IAEA (International Atomic Energy Agency), NEA (Nuclear Energy Agency), WNA (World Nuclear Association) and NEI (Nuclear Energy Institute) are organisations with a vested interest in nuclear power. These institutes are explicitly aimed at promoting nuclear power, and therefore are not necessarily independent scientific institutes.

* Construction only

Our figures indicate that today, nuclear gCO_2/kWh lie somewhere between renewable energy sources and fossil fuels. If the full nuclear chain is taken into account, as it should be, nuclear power emits much more carbon dioxide per delivered kilowatt-hour than wind power even when the contributions to the emissions from construction and dismantling of the nuclear power plant are omitted. The results of the study of Storm van Leeuwen & Smith[44] and confirmed by a recent study of Integrated Sustainability Analysis (ISA) of The University of Sydney[45] indicate specific emissions in the range of: 84-122 gCO_2/kWh (assumed lifetime 35 years at an average load factor of 85%). The ISA study found a range of 10-130 gCO_2/kWh (assumed lifetime 35 years at an average load factor of 85%).

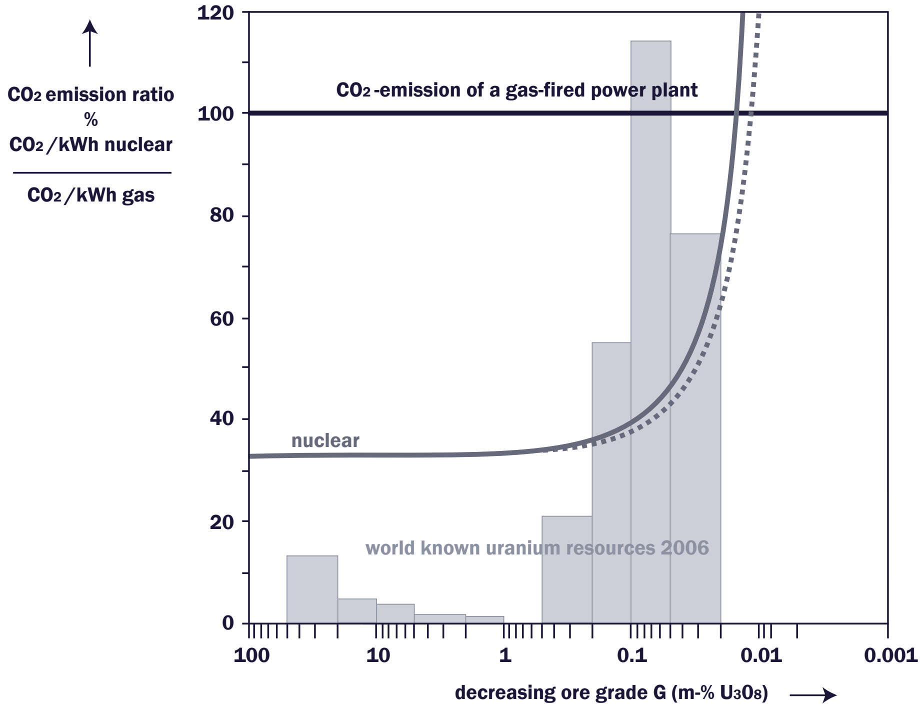
The order of magnitude of our results is confirmed by an ExternE study in the UK from 1998.[46] According to this study the construction of Sizewell B, a 1250 MW(e) PWR, produced 3740 Gg CO_2. The ExternE study assumes an operational lifetime of 40 years at an average load factor of 85%. If so, the construction of Sizewell B alone would cause a specific CO_2 emission of 10 gram CO_2/kWh. This corresponds with 11.5 gCO_2/kWh if a lifetime of 35 years at an average load actor of 85% is assumed. It should be noted that no nuclear power plant in the world ever reached an operational lifetime of 35 years at an average load factor of 85%, let alone 40 years.

DTI uses the unit gCO_2-eq/kWh, implying that all greenhouse gases are accounted for. That is true in case of solar and wind, but not in case of nuclear. We only investigated CO_2 emission, no other greenhouse gases, particularly CFCs, because no data are available. This might be a very important issue: the nuclear industry should prove there are no other GHG emissions, before any discussion on emission rights can come up.

Ore quality

The extraction of uranium from its ores as found in the ground consumes lots of energy, chemicals, materials and equipment. The energy requirements of uranium recovery depend on the ore grade: the lower the grade, the more rock has to be processed, the more energy is consumed, hence the more CO_2 is emitted.

Figure 1
The distribution of the known uranium resources and CO_2 emissions as function of the ore grade. As is clear from the table, most known uranium reserves have an ore grade of between 0.1 and 0.02. A large proportion of those resources are found in hard and mixed ores that require more work to process than softer one.



If we assume a gas-fired power station emits 100% CO_2, then nuclear power using today's average ore grade of 0.15% would emit approximately 30% CO_2. As the ore grade declines, the CO_2 emissions increase. At an ore grade of between 0.01 and 0.02% U_3O_8, CO_2 emissions from nuclear power equal that of a gas-fired power plant.

The calculated values of the specific CO_2 emission of nuclear power show a large uncertainty range. This range is partially due to physical variations of the observed systems, but mainly due to large uncertainties in the processes itself, particularly those of the back end of the nuclear process chain. Any statement of only one fixed value of the specific CO_2 emission of nuclear power is misleading and not scientifically founded.

CO_2 emissions from nuclear power over time

To get an idea of the future potential of nuclear power, we used two simple scenarios:

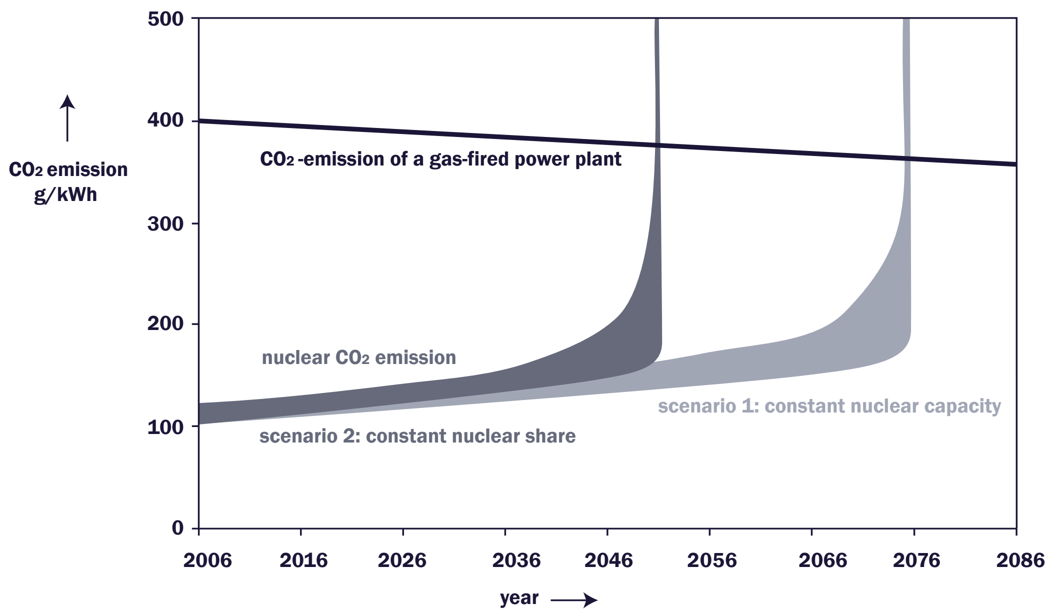
Scenario 1
World nuclear capacity remains constant at current level, 370 GW. The nuclear share declines to < 1% of world energy supply by 2050, for the world energy demand rises with 2-3% a year.

Scenario 2
World nuclear share remains constant at current level, 2.2% of world energy supply. The world nuclear capacity has to increase by 2-3% a year (7.5-10 GW/a), to keep pace with rising world energy demand. This scenario corresponds with the 'High' scenario from the IAEA in 2005.

In both scenarios we assume the highest quality uranium ores being mined first, as these will usually generate the largest profits for the mining companies. Consequently the mean ore grade of the world uranium resources will decline with time. This observation has profound implications regarding the CO_2 emission rate and net energy production of nuclear power in the future.

In about 70 years (in scenario 1) to 45 years (in scenario 2) the nuclear CO_2 emission surpasses that of the gas-fired electricity generation. Scenario 2, which is the most likely scenario, is well within the operational lifetime of a new build in the UK.

Figure 2: CO_2 emissions over time



The CO_2 emission rate of nuclear power will climb during the next decades, due to declining uranium ore grades. The darker area represents the uncertainty range in the values. The uncertainty range is due to individual differences between mines and to uncertainties in the used data. Due to some optimistic assumptions in the analysis, the higher boundary of the uncertainty range may be more plausible than the lower one.

Conclusions

New nuclear build is not possible without an extensive set of subsidies and loan guarantees. One way to generate subsidies is selling carbon emission rights. The lower the accepted value of the nuclear greenhouse gas emission per kilowatt-hour, the more emission rights can be sold.

In Britain, and much of the rest of the world, nuclear power is repeatedly presented as a key element of efforts to reduce CO_2 emissions. David Miliband stated soon after being appointed UK Environment Secretary in an interview with the BBC (May 2006) that:

> *"If you believe that climate change is the number one issue facing the planet, which I do, it seems to me I cannot come and say 'by the way, I have taken off the table one way in which to generate power in a zero carbon way'."*[47]

This claim is incorrect. Given the consequences of an expansion of nuclear power, it is essential that the CO_2 emissions of nuclear power are independently reviewed.

Section 3.2 If not nuclear, then what?

Keith Barnham

Introduction

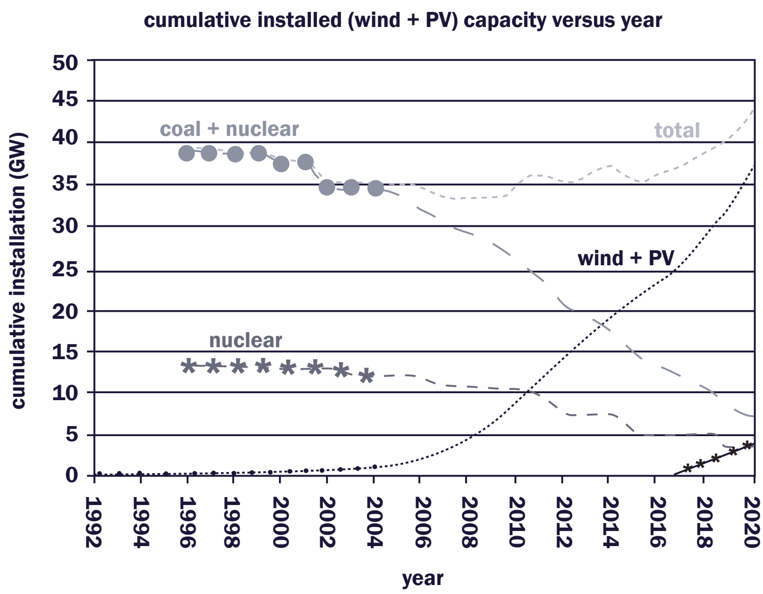
In “The Energy Challenge” the Department of Trade and Industry (DTI) states that six GigaWatts (GW) of new nuclear capacity will be needed by 2025. If a non-nuclear energy policy was pursued instead, could other energy sources compensate for the loss of nuclear power and reduce CO_2 emissions without creating problems for energy security?

Can the renewables deliver?

Figure 1 represents the future growth of wind and solar photovoltaics (PV) power capacity in the UK. These projections assume, as discussed in more detail below, that wind and PV follow the trend which Germany has established in recent years. It can be seen that wind and PV alone can supply well over 30 GW by 2020, which is significantly more than the 25 GW by 2025 “The Energy Challenge” states will be required in the UK. Furthermore, the wind and PV prediction dwarfs the six GW of new nuclear build, which the “The Energy Challenge” concluded would be necessary in 2025. Note that is is ignoring the very large contribution that wave, tidal, biomass could make and also energy efficiency plus combined heat and power CHP.

Figure 1: Projections of future UK wind and PV capacity

“The UK is particularly well provided for in terms of wind, wave and tidal power potential.”



Note that the 36 GW total of wind and PV in 2020 more than compensates for the loss of coal and nuclear capacity and is very much larger than the six GW of new nuclear build proposed by the government for 2020 or the cross hatched bottom right line which is the assumption of British Nuclear Fuels Plc. (BNFL).[48]

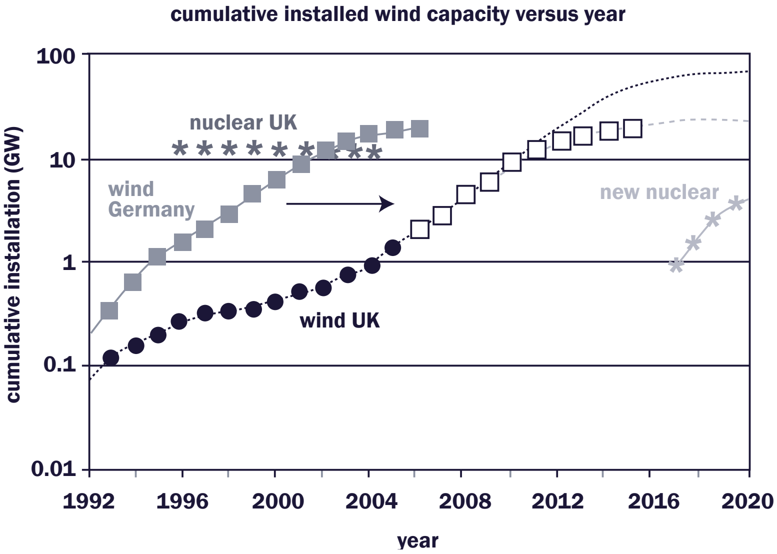
The potential for Wind Power in the UK

The UK is particularly well provided for in terms of wind, wave and tidal power potential. In fact the potential of the offshore wind alone has been estimated to be the highest in Europe at 70 GW.[49] This is close to the current total electrical power capacity in the UK.

In figure 2 we compare installed wind generating capacity in Germany and the UK. Despite having a much less favourable wind resource, Germany is around ten years ahead of the UK in exploiting wind power. The Germans already have more wind-power capacity than the current UK nuclear component.

"If the UK pursued similar policies to Germany then by 2020 wind would provide well over six times, the generating capacity of BNFL's optimistic estimate for new build also shown here."

Figure 2: Cumulative wind capacity



The UK wind capacity in 2005 is similar to that in Germany in 1996. Were the growth in wind installation in the UK to follow the trend actually achieved by Germany from 1996 to 2005 then one gets the lower "minimum" curve. The "maximum" curve assumes that the UK wind capacity will saturate at the off-shore wind capacity.

In fact UK wind-power capacity has been growing well recently. The "maximum" projection assumes that average trend of the last four years in the UK will continue before saturating at the level of the off-shore wind potential. The grid would require modification to cope. However, recent studies have shown that the current grid can manage with a very significant wind-power contribution.[50] On the lower projection UK wind-power capacity will be at least six times the optimistic assumption of BNFL for new nuclear build.

Note in particular that the lower of the two projections for UK wind power capacity based on the German performance over the last nine years extrapolates to 24 GW in 2020. Other studies independently found similar results: the British Wind Energy Association (representing 310 companies) has estimated a total onshore and offshore wind capacity of 24 GW for 2020.[51]

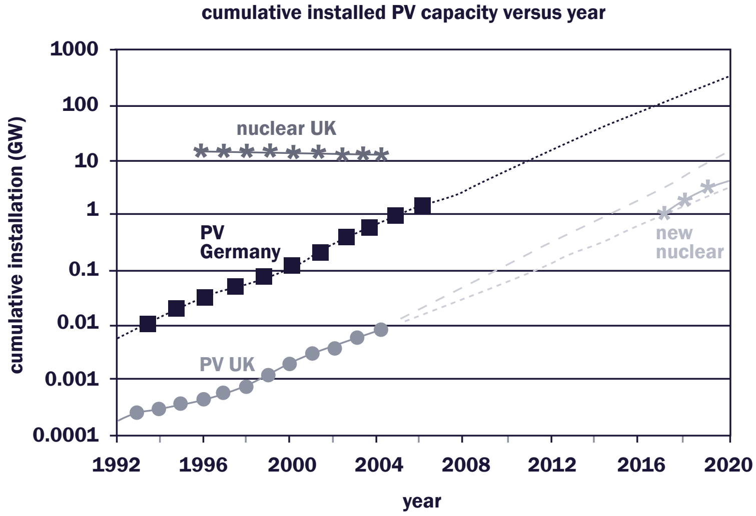
The potential for solar photovoltaic power in the UK

World wide the manufacture of PV cells has been growing at an increasing rate achieving an impressive 57% rise in the single year of 2004.[52] This is correctly described as an exponential increase because the cumulative total of production is a straight line on a graph like figure 3 where the installed capacity axis is in powers of ten. New nuclear build will only at very best be producing one new reactor a year by 2020 under optimistic assumptions. This produces a curve that gets less steep as time passes.

The exponential rise of PV has been going on for the last ten years world wide and is likely to continue with the arrival in the market of thinner, cheaper second generation cells and by third generation cells manufactured by very different technology used in optical communication technology.[53] Such exponential growth has been a feature of the introduction of many other semiconductor devices such as the mobile phone; they achieved major cost reductions with increasing volume of production.

The current contribution of PV in the UK is one of the lowest per-capita in Europe. The lower extrapolation in figure 3 shows what would happen if the growth rate of past years were maintained. The upper curve shows what would happen if policies like those in Germany were introduced. If UK growth followed the German trend for the last five years, then by around 2018 the UK would achieve six GW capacity.

Figure 3: Comparison of installed solar PV capacity in Germany and the UK



The extrapolations of the UK data have been made assuming the trend actually achieved in the UK in the last five years continues (lower line) or follows the trend actually achieved in the last five years in Germany (upper line).

How did Germany get so far ahead of the UK in installing wind power and PV?

Germany is around ten years ahead of the UK in both wind and PV. This was primarily achieved by means of a 'feed-in tariff', which guarantees a price for each kWhr (Kilo Watt Hour) of electrical energy generated renewably and fed into the grid. The size of the guaranteed price is falling but the installed capacity continues to rise exponentially. Other countries such as Greece, Italy, Spain, and states such as California are following this approach.

What's in the mix?

The supporters of nuclear power often argue that a sensible energy policy would include both nuclear and the sustainable energy sources such as wind and PV. The consequences of such a mix for renewable energy sources would be negative.

- An authoritative study from Warwick Business School has shown how new nuclear build will undermine funding for the renewables and delay the benefits of a decentralised energy system.[54]
- Support for nuclear usually ends up dominating government R & D spending. For example, UK government R&D expenditure September 2005,[55] show that the research council spend on photovoltaic R&D in 2004-2005 was £2.8m whereas in the hey-day of nuclear fission in 1991-92, government support was £73.5m a year. In 2004-2005 the research council R&D spend on nuclear fusion was £19.5m.
- A further example of the way government spending on nuclear power can crowd out other R & D was reported by the BBC. The Department of Trade and Industry took back a hefty £68M in one year from the research councils partly to fund British Energy's nuclear liabilities.[56]

Conclusions

Some highly respected advocates of nuclear power agree that a new build would increase the risk of nuclear terrorism and weapons proliferation, but recommend a large-scale new build nonetheless.[57] In their judgement the risks from failing to reduce atmospheric CO_2 levels outweighs the consequences of nuclear terrorism or a regional nuclear war. This argument, though strong in emphasising the scale of the threat posed by climate change is nevertheless seriously flawed. Genuinely low-carbon energy sources are available, as the data discussed above show and could be installed faster, at less cost and less risk to UK and global security. Of all the alternatives to fossil fuel burning, nuclear is by far the slowest, the most dangerous (section 1.2) and will not be a low carbon resource during the lifetime of any nuclear new build (section 3.1).

"Nuclear power is not needed. Other, safer and cleaner energy sources could provide for UK energy needs as set out in "The Energy Challenge"."

The same applies to many other countries around the world. A new nuclear build would not only increase international and regional insecurity and tension, it would also draw resources away from energy sources we will need to make a real difference to global CO_2 emissions.

Conclusions

Together, the evidence presented in this report constitutes a case against building new nuclear power stations and for halting nuclear reprocessing altogether. We do not claim that this evidence is definitive. But it is sufficiently compelling for us to recommend independent public inquiries into the following aspects of civil nuclear power before decisions are taken on its future:

- uranium reserves and the future of civil nuclear power;
- implications of a nuclear expansion for the risk of nuclear terrorism;
- implications of a nuclear expansion for the risk of nuclear weapons proliferation;
- current and potential CO_2 emissions from civil nuclear power; and
- emissions of Greenhouse Gases other than CO_2.

The recent High Court legal victory for Greenpeace (UK) against the legality of the UK Government's consultation on the future of nuclear power[58] indicates that the DTI may not be best suited to conducting such an enquiry.

One of the first objections to the conclusions of this report will be that the security risks are low probability, or 'unlikely', as "The Energy Challenge" would have it. There are two responses to this claim. Firstly and as we have shown, the evidence points to a significant increase in security risks over the lifetime of a new nuclear build. Secondly, the probability of nuclear terrorism on UK soil or nuclear weapons proliferation is not the sole basis upon which a judgement about the acceptability of nuclear power should be based. As the UK Cabinet Office Performance and Innovation Unit stated in 2002: the "low probability but high consequence hazards" of nuclear power need to be taken into account. In other words, given the potentially catastrophic consequences of nuclear terrorism, even low probability events must be taken extremely seriously.

There are two outstanding issues that this report has only touched on: energy security, and the significance of a UK decision to a worldwide nuclear revival. Regarding energy security, if a new nuclear build replaced all UK gas-fired electricity generating plants, it would help reduce our growing dependence on imported gas, but the change would not improve our security significantly. Fossil fuel exporting states in the Middle East and Russia would still be able to use energy as a lever to influence policy-makers in the UK, EU, USA and other dependent states. This situation is unstable and the risk of escalation cannot be ruled out. Today, around 90% of UK energy needs are met by fossil fuels, of which the UK will need to import more and more. "The Energy Review" reports that by 2020 the UK could be importing between 80-90% of total gas needs. The problem is that a large proportion of our imported fossil fuels are for transportation and space heating, neither of which depend much upon nuclear energy.

Radically reducing consumption of fossil fuels is the only way to make a significant difference to UK dependence upon Saudi Arabia and Russia, for instance. A new nuclear build would not make a real difference in time and is a distraction from genuine solutions.

As far as the influence of a UK decision is concerned, implementing a non-nuclear energy policy would be unlikely to lead to widespread policy reversals elsewhere. That said, the vast majority of plans to build new nuclear plants are at very early stages; the much touted world wide nuclear expansion is not inevitable. And as Jürgen Trittin states in the Foreword to this report:

> *"Although matters of global warming and global energy security obviously cannot be solved by one nation alone, the UK discussion is crucial in the current context. An influential player in Europe, with a cultural and political proximity to the United States, decisions taken in the UK are perceived and taken into account worldwide."*

Committing to a non-nuclear energy policy would create an opportunity for decision-makers to substantially support low-carbon energy sources and work through international bodies to reduce the serious security risks posed by civil nuclear power. Such a policy would strengthen the UK's moral authority in nuclear non-proliferation negotiations, and deny others the opportunity to accuse the UK of double standards.

The final nail in the nuclear coffin comes from recent research using state-of-the-art computer climate modelling. This work looked at the affect a small-scale nuclear war in the sub-tropics would have on the climate – primarily due to the release of carbon into the stratosphere.[59] This research found that such a war would reverse any progress we might make in reducing atmospheric CO_2 emissions. The technology ostensibly promoted to tackle global warming could become our undoing.

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The Future of Britain's Nuclear Weapons: Experts Reframe the Debate
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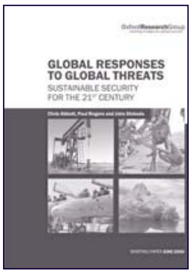
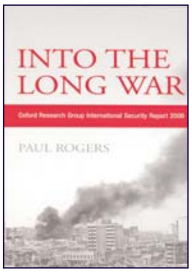
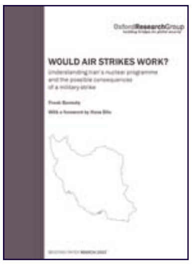
This Current Decisions Report provides a platform for pairs of public figures with long experience and specialist knowledge in their respective fields, to set out their contrasting positions on the key aspects involved in the Trident replacement decision. The report points to the need to reframe the debate in the post 9/11 global security environment, and move it resolutely beyond outdated and polarised Cold War thinking.



Global Responses to Global Threats: Sustainable Security for the 21st Century
Chris Abbott, Paul Rogers and John Sloboda, November 2006
Current security policies assume international terrorism to be the greatest threat to global security, and attempt to maintain the status quo and control insecurity through the projection of military force. The authors argue that the failure of this approach has been clearly demonstrated during the last five years of the 'war on terror' and it is distracting governments from the real threats that humanity faces.



Into the Long War
Paul Rogers, November 2006
Professor Paul Rogers' new book, "Into the Long War", provides a contemporary month-by-month analysis of events in Iraq since May 2005 and assesses how they impact on other countries including Afghanistan, Iran and the wider Middle East. The book charts a tumultuous period in the conflict, including a wider international perspective on the terrorist attacks in London and Sharm al Sheik, and an assessment of how US public opinion has changed as the war drags on.



Would Air Strikes Work? Understanding Iran's Nuclear Programme and the Possible Consequences of a Military Strike
Frank Barnaby, with a Foreword by Hans Blix, March 2007
Recent indications from the USA point towards possible military strikes against Iranian nuclear and military targets. The aim of such strikes would be to put back by many years any ambitions the Iranian regime may have for nuclear weapons. This report assesses Iran's nuclear programme; how that programme could be diverted towards military ends, and whether military strikes would succeed in preventing Iran developing nuclear weapons. It concludes that military strikes would most probably be deeply counter-productive.

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About this report

All over the world the fortunes of civil nuclear power are on the rising - why? Many in government hope that nuclear power would increase energy security during a time of unstable competition and surging demand. Some claim nuclear power is key to reducing global CO_2 emissions. For others, it is because nuclear power opens the door to nuclear weapons.

This report asks two questions: how dangerous is nuclear power dangerous? And can it help reduce CO_2 emissions? The short answer to the first questions is 'very': nuclear power is uniquely dangerous when compared to other energy sources. For the second question the answer is 'not enough and not in time'.

By comparing the security consequences of civil nuclear power to its possible contribution to tackling climate change, the authors show that rather than making a positive contribution, an expansion of civil nuclear power would:

- increase the risk of nuclear terrorism;
- make efforts to control the spread of nuclear weapons harder than it already is;
- make a negligible short-term contribution to lowering CO2 emissions; and
- make a negligible contribution to energy security.

Finally, we show that nuclear power is not needed. Germany, for example, already has more wind-power capacity than the UK nuclear component and within six years will have more solar powered capacity too. If the UK pursued similar policies, by 2020 wind would provide well over six times and solar three times the generating capacity major industrial players plan for nuclear in the UK.

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