The Nuclear Renaissance:

Nuclear weapons proliferation and terrorism

A policy brief for the ippr Commission on National Security for the 21st Century

by Frank Barnaby
Emeritus Consultant to the Oxford Research Group

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Introduction

Global climate change is one of the greatest challenges we face this century. There is an overwhelming consensus among climate scientists that the world is heating up because of human activities that emit greenhouse gases, particularly carbon dioxide, into the atmosphere (see IPCC 2007), and few serious commentators doubt that urgent action is needed to prevent catastrophic changes in the climate.[1]

There are two schools of thought about the best way to deal with global warming. One wants to bring about a social revolution, to make society less consumerist and less materialistic and to lower the consumption of energy in the process. The other is less ambitious, and perhaps more realistic. It believes in the use of technology to solve the problem by expanding the use of nuclear fission reactors and renewable energy sources, by developing a way to capture and store carbon dioxide emitted by existing fossil fuel power stations, and, in the long term, by creating a new and relatively carbon-free source of energy such as nuclear fusion.

More radical ideas include: reflecting sunlight by creating artificial clouds to reduce the amount of sunlight reaching the Earth's surface, mainly at the Arctic; growing phytoplankton in the oceans to capture large amounts of carbon dioxide; and using machines ('scrubbers') to absorb carbon dioxide from the atmosphere.

Each of these broad social and technological solutions has its difficulties. A sustainable social revolution would take generations to bring about. Meanwhile, a technological fix, though attractive in some respects, will also require time and considerable financial resources to overcome very difficult technical problems; namely, the fact that appropriate technology has not yet been developed.

Britain's Prime Minister Gordon Brown is an enthusiastic advocate of a reliance on technology, backing both nuclear power and carbon capture and storage (CCS) technologies together with improvements in energy efficiency (Grice 2008). Many other political leaders are looking to nuclear power as the best way to reduce the emissions of greenhouse gases. We must therefore expect to see a large increase in the global use of nuclear power for electricity generation: what has become known as a nuclear renaissance.

At present, there is a surprising lack of academic debate and research about the global, regional and national security consequences of the spread of nuclear knowledge and technology, and about how the international and regional communities can cope with this spread. There is general agreement that in the nuclear renaissance many countries will have access to plutonium that could potentially be used to fabricate nuclear weapons, both by countries and by terrorists, since the information needed to produce nuclear weapons is widely available. But there is still a poor understanding of the range of risks present in an unregulated nuclear world.

Research is urgently needed on how to control these risks. An obvious control measure would be to strengthen the Nuclear Non-Proliferation Treaty (NPT). This will involve the questions: How can the nuclear-weapon powers be persuaded to give up their nuclear weapons? Is the abolition of nuclear weapons feasible or a pipe-dream? Should non-nuclear-weapon countries be encouraged to develop civil nuclear technology? If so, under what conditions? What measures would be justified to prevent a country acquiring nuclear weapons? Would military action ever be justified?

Another area in which further research is necessary is around the threat of nuclear terrorism. This presents a large number of questions, including: How likely is it that a terrorist group will acquire nuclear weapons? Which terrorist groups would be able to develop them? Can nuclear terrorism be prevented? If not, what measures should be put in place to cope with it? How can the large amount of radioactive material around the world be made secure? How can nuclear terrorism be countered?

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1. For an example of a view different from the consensus see Svensmark and Calder 2007.

What measures should be put into place to deal effectively with nuclear terrorist attacks? And how will all these issues be affected by the nuclear renaissance?

While these questions are beyond the scope of this discussion paper, the material below discusses some of the more serious security issues that will be associated with a nuclear renaissance, including:

- The shortage of high-quality uranium for use as nuclear fuel
- The consequences of the use of fast breeder reactors (FBRs) and the widespread use of plutonium to fuel them
- The increased risk in a plutonium economy of the spread of nuclear weapons to both countries and terrorist groups.

Before discussing these security implications, the paper sets the context by describing important elements of the nuclear fuel cycle and by addressing issues related to uranium supply and the changing technology being used in nuclear power reactors.

Scientific context

The nuclear fuel cycle

The production of fuel for nuclear-power reactors is based on uranium, which is found in a large number of minerals (chemical compounds) and is embedded in different types of rock, seawater, fresh water, and soil. Most uranium is dispersed through the rocks of the Earth's crust and only a small fraction is found in ores that contain significant concentrations.[2]

However, there is no major difficulty in the mining of uranium ores. About two thirds of the world's current known economically recoverable resources of uranium are found in five accessible countries – Australia (24 per cent), Kazakhstan (17 per cent), Canada (9 per cent), the USA (7 per cent) and South Africa (7 per cent) (World Nuclear Association 2007). The complexity comes in the processing of uranium, a fact that has been helpful to date in terms of non-proliferation.

Once mined, the ores are processed in mills to extract the uranium in the form of yellow uranium oxide (U_3O_8), called yellow cake. After production, yellow cake is refined and purified and sent to conversion plants where it is converted to uranium hexafluoride. This hexafluoride is sent to a uranium-enrichment plant where the concentration of uranium-235 is increased from the natural value of 0.72 per cent to between about 3 and 5 per cent.[3] After enrichment, the hexafluoride is normally converted into uranium dioxide (UO^2), the basic fuel used for most current nuclear reactors.

Enrichment is not a straightforward operation (World Nuclear Association 2008a). Because the isotopes uranium-235 and uranium-238 are chemically identical, they cannot be separated and enriched by a chemical method; a physical method must be used. Modern commercial uranium enrichment plants use gas centrifuges as the physical method.

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[2] The concentration of uranium in ores varies over a wide range. The richest ores contain about 20 per cent uranium (about 200 grammes of uranium in a kilogramme of rock). But some ores containing no more than 0.13 grammes of uranium per kilogramme of rock are currently being mined.

[3] There are two main types of uranium atoms. About 99.3 per cent is of the isotope uranium-238 and 0.7 per cent is of the isotope uranium-235. Uranium-235 is a fissile isotope, fissile material being the essential ingredient for both nuclear power and nuclear weapons production. When uranium is enriched to very high levels, typically 90 per cent of U-235 or above, it provides the fissile material necessary in the production of a nuclear explosive device. Enriched to lower levels (3-5 per cent of U-235), it provides the fissile material required for nuclear power.

These centrifuges depend on the very small difference in mass between uranium-235 and uranium-238 atoms, with a rapidly spinning centrifuge being used to separate the two isotopes. The centrifuge is a cylindrical drum rotating at very high speeds. The heavier uranium-238 atoms concentrate at the outer radius of the rotor and are made to flow in one direction, while the uranium-235 atoms are enriched near the central axis of the drum and made to flow in the opposite direction. The enriched uranium-235 is then collected through an exit orifice.

The output of uranium isotopes per centrifuge is very small. A commercial centrifuge plant is therefore designed with a large number of centrifuges in cascade to produce a useful amount of enriched uranium. The very slightly enriched uranium from the first centrifuge in the cascade is fed into the input nozzle of the second centrifuge, the slightly more enriched uranium-235 from the second centrifuge is fed into the third, and so on, until the required degree of enrichment is obtained.

The enrichment process requires sophisticated technology and only a small number of countries operate significant uranium-enrichment plants today, namely Argentina, France, Iran, Japan, Pakistan, Russia and the USA. Germany, the Netherlands and the UK jointly run URENCO, a uranium-enrichment company.

This limited dispersal of the technology of enrichment has historically buttressed the global nuclear non-proliferation regime, since the technology to enrich uranium is one of two keys to the production of nuclear weapons (the other is the ability to reprocess spent nuclear fuel to separate and extract plutonium from it, to which we return later). However, the planned shift to the use of more plutonium and less uranium in nuclear reactors threatens to sweep aside the old safeguards.

The long-term supply of uranium

According to the International Atomic Energy Agency (IAEA) and the Organisation for Economic Cooperation and Development (OECD), the known recoverable uranium resources are 4.7 million tonnes (OECD and IAEA 2008). This figure includes uranium ores that are of relatively low grade, occur at great depths, involve lengthy transportation distances and are harder to mine.

The world's current nuclear-power reactors consume uranium at the rate of 65,000 tonnes a year (World Nuclear Association 2008c). If this rate stays constant, known uranium reserves will last for less than 70 years. Given that the richest uranium ores are depleted first (because these usually generate the largest profits for the mining companies) the net energy extracted from uranium ore will also decrease over time.[4] At the current rate of consumption, the highest quality uranium ores will be depleted within a decade and the average grade will fall below 0.1 per cent.

It is also very unlikely that new uranium resources of high quality will be discovered in the next few decades. This is mainly because uranium deposits that are relatively near the surface and therefore mineable using the least energy emissions of greenhouse gases have already been discovered. Deposits at greater depths require more energy to be mined, and are of poorer quality.

According to calculations made by Jan Willem Storm van Leeuwen, an expert on uranium resources, assuming that world nuclear capacity remains constant at 372 GW, the net energy from uranium will fall to zero by about the year 2070 (Storm van Leeuwen 2007 and 2008). Assuming that world nuclear share remains constant at 2.2 per cent of world energy supply, and that energy demand will increase to meet the needs of a rapidly growing human population, the net energy benefit will fall to zero by about 2050.

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4. The net energy, a measure of the quality of the uranium ore, is the energy produced per tonne of uranium fuel minus the energy used to produce the reactor fuel elements. If the purpose of expanding the use of nuclear power is to meet energy needs while mitigating climate change, the *quality* of the world's uranium resources is therefore much more important than the *quantity* of these resources, at least for as long as fossil fuels are used to drive the uranium mining and reactor fuel production process.

Moves to a plutonium economy

This is not a rosy picture in terms of uranium supply, given the heavy reliance of current third-generation reactors on uranium.[5] A fourth generation of reactors is going to be necessary, and is likely to be at the heart of the coming renaissance in the global nuclear industry.

Fourth-generation (Generation IV) reactors include very advanced reactor designs, such as the Fast Breeder Reactor which produces (or breeds) more nuclear fuel than it uses (see Nuttall 2005). In these designs, when the uranium-238 surrounding the reactor captures fast neutrons from the core, enough U-238 is converted to plutonium-239 (itself a fissile material) to fuel another FBR. This plutonium 239 can be isolated for use as part of a reprocessing of spent nuclear fuel aimed at separating reusable from unusable reactor waste. In theory, a family of FBRs should eventually be self-sufficient in fuel with only a small injection of uranium. The FBR has therefore been seen as the solution to the coming shortage of high quality uranium.

Fast Breed Reactors do not breed very fast. Foreseeable designs are likely to produce FBRs that will take 30 years to produce enough nuclear fuel (the doubling time) to operate another FBR (Rodriguez and Lee 1998). However, by using well-designed FBRs, the utilisation of uranium could eventually reach about 70 per cent, compared with less than 1 per cent in light-water reactors. India is now actively developing FBRs and plans to construct four. Japan has built a research FBR at Joyo and a pilot one at Monju, in Tsuruga. China is constructing a prototype FBR.

This switch to FBRs is worrying for two reasons. First, earlier attempts to construct and operate FBRs in France, India, Japan, Russia, the UK and the US have had a chequered history. The first British FBR, the Dounreay Fast Reactor (DFR), first went critical in 1959 at Dounreay, Scotland. The second was the Prototype Fast Reactor (PFR), which started operating in 1976, also at Dounreay. The British FBR programme closed down in 1994 when the Government stopped financing it.

Germany constructed two FBRs, but both were closed down in 1991. The biggest, built at Kalkar, Rhine-Westphalia, was completed in 1985 but was never operated because of political opposition and concerns about safety. Japan's Monju FBR began operating in 1994 but was shut down in December 1995 following a leak of the sodium coolant and a fire. It may not be restarted because of doubts that large quantities of liquid sodium can be handled safely.

Second, the switch to FBRs will allow more nuclear reactors to come on stream, which in turn generates a range of new security challenges. For example, if the world is using 3,000 GW of nuclear electricity in 2075, and if this is generated via the earlier once-through nuclear cycle using light-water reactors, approximately 600 tonnes of plutonium (a by-product of the process) will be produced annually (Feiveson 2003). However, if this nuclear capacity is provided by FBRs, as the nuclear industry predicts, more than 4,000 tonnes of plutonium will have to be fabricated into fresh reactor fuel each year (ibid). This would be enough plutonium to produce at least a million nuclear weapons.

Large amounts of plutonium will be needed if the world comes to rely on FBRs, because plutonium provides a much larger fraction of the nuclear fuel used in them than do the current ordinary reactors, which are fuelled just with uranium (in the form of uranium dioxide).

Any country that chooses to operate fourth-generation reactors in the future will have relatively easy access to plutonium (usable as the fissile material in the most efficient nuclear weapons) and will have competent nuclear physicists and engineers who could design and fabricate such weapons. Because they could produce a nuclear force in a short time – months rather than years – these countries would need to be regarded as latent nuclear-weapon powers. It must also be expected that some of them will take the political decision to become actual nuclear-weapon powers.

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5. The first generation of reactors were the early prototype reactors of the 1950s and 1960s, mainly used to obtain plutonium for nuclear weapons. The second generation were the commercial reactors constructed in the 1970s and 1980s and the third generation are most of the reactors being built right now to replace or add to them.

Fabricating a nuclear weapon from plutonium

The fuel pellets in MOX fuel assemblies are composed entirely of pure reactor grade plutonium and depleted uranium, both present as dioxides and fused together by heat to form a ceramic. The material is designed to be soluble in fairly concentrated nitric acid for ease of reprocessing. The chemical separation of plutonium dioxide from uranium dioxide in MOX fuel pellets is facilitated by the fact that these elements have very different oxidation/reduction chemistries.

The procedures required would be simple and well within the technological capabilities of a moderately sophisticated terrorist organisation. The simplest method to separate plutonium from MOX is ion-exchange using an ion-exchange resin (Chen et al 2005). The plutonium dioxide, once separated, could then be converted to plutonium metal. The plutonium dioxide or the plutonium metal could be used in a primitive design to make nuclear explosive.

There will also be a heightened risk that terrorists will acquire plutonium, fabricate a nuclear weapon and detonate it. Eminent physicists with knowledge of the characteristics and production of nuclear weapons have no doubt that effective nuclear weapons can be fabricated from reactor-grade plutonium produced by civil nuclear-power reactors (Mark et al 1987).

This risk is already being significantly enhanced by the increased use of mixed oxide (MOX) fuel – a mixture of uranium dioxide and plutonium dioxide used in some of the newer nuclear reactors now replacing those that are obsolete. Some current (second generation) light-water reactors in Belgium, France, Germany, India and Switzerland use MOX fuel elements in a fraction (normally about a third) of their cores. If a terrorist group acquired MOX fuel, it could relatively easily separate the plutonium dioxide from the uranium dioxide by means of straightforward chemistry, and use the plutonium to fabricate a nuclear weapon (see box). It would only take two or three people with the appropriate skills to design and fabricate a crude nuclear explosive (Stober 2003), as shown by the Nth Country experiment.[6] They would not need to have access to classified documents, since the nuclear physics data needed to design a crude nuclear device is already available in open-source literature (Lovins 1990).

The operations involved would require some skill, but many terrorist organisations have shown themselves capable of sophisticated planning and the application of scientific principles. The construction of the conventional explosive device that destroyed the PanAm jumbo jet over Lockerbie on 21 December 1988 required detailed planning and scientific skills, as did the construction of the Sarin nerve gas weapon used in the Tokyo underground by the AUM group on 20 March 1995. Indeed, the preparation of Sarin for that attack involved considerably more complex chemistry and greater acute danger to the operators than that required for the separation of plutonium from MOX. The chemistry is even less sophisticated than that required for the illicit preparation of designer recreational drugs. Moreover, ruthless terrorists are likely to be relatively unconcerned about their safety or about polluting the environment (with plutonium, for example) other than to the extent that accidents or releases may reveal their clandestine activity.

Other dangers posed by nuclear terrorists include: the production and detonation of a radiological weapon, commonly described as a 'dirty bomb', to spread radioactive material; attacks on nuclear-power reactors or on radioactive waste tanks and plutonium stores at a reprocessing plant like Sellafield to spread radioactivity; and the sabotage or hijacking of transporters of nuclear materials. Apart from a dirty bomb, all of these types of nuclear terrorism have the potential to cause large numbers of deaths. Of these options, nuclear terrorists would probably prefer to set off a nuclear explosion because of the great damage it would do, perhaps using a stolen nuclear weapon or more likely using a nuclear explosive fabricated from acquired fissile material.

The most primitive terrorist nuclear device would be a dirty bomb, consisting of a conventional high explosive (for example, semtex, dynamite or TNT), some incendiary material (like thermite) surrounding the conventional explosive, and a quantity of a radioisotope, probably placed at the centre of the explosive. When the conventional high explosive is detonated the radioactive material would be vaporised. The fire ignited by the incendiary material would carry the radioactivity up into the atmosphere. It would then be blown downwind, spreading radioactivity as it went. Generally, the explosion of the conventional explosive would be the most likely cause of any immediate deaths or serious injuries. Areas as large as tens of square kilometres might be contaminated with radioactivity to levels above those recommended by national radiological protection authorities for the exposure of civilians to radioactivity and these would have to be evacuated and decontaminated, a very lengthy and expensive operation (Barnaby 1997).

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

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6. The Nth Country experiment showed that three post-doctoral students with no nuclear knowledge could design a working atom bomb. See Burkeman 2003 for more information.

Policy options in a nuclear renaissance

The nuclear renaissance will lead to the spread of plutonium to many countries, as MOX fuel is increasingly used as a nuclear fuel and as plutonium is used to fuel future FBRs. The fact that this plutonium can be used by countries to fabricate nuclear weapons and by terrorists to make nuclear explosives is an obvious threat to global security.

The international community urgently needs to do two things to reduce the plutonium threat. First, and most important, is to strengthen the Non-Proliferation Treaty by action at the next NPT Review Conference in 2010. Second, steps must be taken to discourage new countries from obtaining the capability to enrich uranium and/or to reprocess spent nuclear fuel, the most sensitive elements of the nuclear fuel cycle as far as nuclear-weapon proliferation and terrorism are concerned.

Two major proposals have been put forward to reduce the plutonium threat: the Global Nuclear Energy Partnership (GNEP) and the Nuclear Fuel Bank. However, both are discriminatory in the sense that they allow the countries that already have enrichment and reprocessing technologies to maintain them but try to prevent those countries that do not now have them from acquiring them.

Some countries want the option to acquire nuclear weapons if they later take the political decision to do so and, therefore, to acquire enrichment and/or reprocessing technologies. A number of these, and especially Iran, will not be willing to give up the option of acquiring them, arguing that Article IV of the NPT gives them an inalienable right to do so under international IAEA control.

The Global Nuclear Energy Partnership (GNEP)

The proposed GNEP, announced by the US Department of Energy (DoE) on 6 February 2006, would be an international partnership to reprocess spent nuclear fuel in a way that renders the plutonium in it usable for nuclear fuel but not for nuclear weapons (US Department of Energy 2007).

The United States has proposed to work with other advanced nuclear nations to develop new proliferation-resistant recycling technologies in order to minimise proliferation concerns. Partner nations will develop a nuclear fuel services programme to provide nuclear fuel to developing nations in exchange for their commitment not to enrich uranium or reprocess spent nuclear fuel.

On 16 February 2006 the United States, France and Japan signed an arrangement to conduct research into the development of sodium-cooled FBRs in support of the GNEP. On 16 September 2007 11 more countries signed the GNEP Statement of Principles. These countries were Australia, Bulgaria, Ghana, Hungary, Jordan, Kazakhstan, Lithuania, Poland, Romania, Slovenia and Ukraine. Since then Canada, Italy, the Republic of Korea, Senegal and the United Kingdom have joined (World Nuclear Association 2008b).

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

Some uranium suppliers are strongly opposed to the GNEP. For example, South African Minerals and Energy Minister Buyelwa Sonjica stated that: 'Exporting uranium only to get it back refined, instead of enriching it in South Africa, would be "in conflict with our national policy"' (Agence France Press 2007). Suppliers argue that to add value to the raw uranium, by enrichment, for example, would considerably increase their profit.

If the GNEP goes ahead and the Americans reprocess spent reactor fuel elements, it will reverse 30 years of US government policy. In 1977 President Jimmy Carter banned reprocessing in the US because of concerns that the plutonium separated from the civil reactor fuel elements would be used to fabricate nuclear weapons. Some believe that such a reversal of American government policy is urgently required but the opposition to it is probably sufficiently great to make it ineffective.

A nuclear fuel bank under international safeguards

The second proposal is to set up a nuclear 'fuel bank' or 'reserve', administered by the IAEA (IAEA 2006). The fuel bank would assure a back-up supply of fuel for nuclear-power reactors on a non-discriminatory, non-political basis, thereby reducing the need for countries to develop their own uranium enrichment and plutonium reprocessing technologies. The fuel bank would, it is proposed, be set up in a way that would not disrupt the existing commercial market in nuclear fuels.

In his Nobel Prize speech on 10 December 2005, IAEA Director General Mohamed El Baradei argued that the controls over operations for producing the nuclear material that could be used in weapons should be tightened, observing that 'any country has the right to master these operations for civilian uses. But in doing so, it also masters the most difficult steps in making a nuclear bomb. To overcome this, I am hoping that we can make these operations multinational – so that no one country can have exclusive control over any such operation' (El Baradei 2005).

To this end, El Baradei has suggested that a reserve fuel bank should be set up under IAEA control, to ensure that all countries receive the fuel that they need for legitimate and peaceful nuclear activities. It is to be hoped that this system would remove the incentive for individual countries to develop their own fuel cycle, and stimulate the creation of effective multinational arrangements for enrichment, fuel production, waste disposal and reprocessing (El Baradei 2005).

Both the United States and Russia have stated that they are willing to make nuclear material available for a fuel bank administered by the IAEA. Russia has proposed the establishment of international centres under a Global Nuclear Power Infrastructure (GNPI) to provide nuclear fuel cycle services, including the enrichment of uranium, in a non-discriminatory way, supervised by the IAEA.

In the words of Tariq Rauf, Head of the IAEA's Verification and Security Policy Coordination Section, the establishment of a nuclear fuel bank under international safeguards 'is an either/or situation; if we don't make it work, then we must prepare to live in a world where dozens of countries have the capability and key ingredients to make nuclear weapons' (IAEA 2006).

As with the GNEP, the discriminatory nature of the nuclear fuel bank may considerably reduce its effectiveness, and, for many countries, its acceptability. The fact has to be faced that a country intent on acquiring fissile material and/or the technology to produce it, and that is able to pay for it, is likely to succeed.

Strengthening the Non-Proliferation Treaty (NPT)

Given the strong objections to the proposals currently on the table to reduce the plutonium threat, the option of strengthening the NPT therefore seems the most likely to succeed. The NPT could be reinforced through more active steps towards nuclear disarmament. With 188 Parties, the NPT is almost universal, and an important barrier to the spread of nuclear weapons.[7] The challenge is to strengthen it so that it may serve as a more effective backdrop to the two policy suggestions highlighted above.

The NPT is a bargain. The non-nuclear-weapon Parties are committed not to acquire nuclear weapons and to submit safeguards to IAEA to verify that they are complying with their commitment; in exchange, the five NPT nuclear-weapon Parties are committed to give the other Parties total access to peaceful nuclear technologies and to engage in nuclear disarmament negotiations aimed at the ultimate abolition of their nuclear weapons. The main problem over the past 40 years has been that the nuclear-weapon Parties to the NPT have not fulfilled their part of the bargain, and have shown few credible signs of being willing to get rid of their nuclear weapons. With a growing number of latent nuclear-weapon powers, the world is moving into an unregulated state of nuclear anarchy.

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[7] Only three countries, India, Israel and Pakistan, have not joined the NPT. North Korea was a Party to the treaty but withdrew from it in 2003.

Ken Booth, Professor of International Politics at the University of Wales, has aptly described this world as one of 'radical nuclear multipolarity' (Booth 2007). Booth agrees that by far the best, and probably the only, way to prevent the world community from falling into a state of total nuclear anarchy is to strengthen the NPT. Every five years a NPT Review Conference takes place to assess how the treaty can be strengthened and to check how well the Parties are fulfilling their obligations under the treaty.

The next Review Conference is in 2010. The treaty is fragile and the 2010 conference may be a make or break event for it. If the NPT is to be significantly strengthened, the nuclear-weapon Parties must, at the minimum, agree at the 2010 Review Conference to make verified reductions of their nuclear arsenals and to take their nuclear forces off alert (or to stand them down).

The negotiation of a Fissile Materials Cut-off Treaty, banning the further production of fissile materials for use in nuclear weapons, must also be started. Bringing the Comprehensive Nuclear-Test-Ban Treaty into force would also help as would a treaty defining adequate negative security assurances to non-nuclear-weapon countries.

The established nuclear-weapon powers should negotiate a treaty to prohibit the use of nuclear weapons against non-nuclear-weapon Parties to the NPT. For example, the US has made a nuclear non-use pledge, known as a negative security assurance, by which it agrees not to use nuclear weapons against non-nuclear-weapon NPT Parties, except if attacked by such a state associated or allied with a nuclear-armed state. But at the same time, the US refuses to rule out the use of nuclear weapons in response to attacks using biological or chemical weapons.

The NPT will be strengthened only if the non-nuclear-weapon Parties are convinced that the nuclear-weapon Parties genuinely intend to get rid of their nuclear weapons, while measures to set up and extend the Global Nuclear Energy Partnership and an international nuclear fuel bank will only work in the context of a preserved and strengthened NPT.

Some supporters of nuclear weapons suggest that abolishing them could endanger world security because, by deterring threats, these weapons prevent war and stabilise international relations. The elimination of nuclear weapons, it is said, may also considerably increase the probability of conventional war (Graham and Mendelsohn 1999).

However, a number of eminent people, including some who have held very senior posts in the US and UK governments and who have not traditionally been in favour of nuclear disarmament, have called for the abolition of nuclear weapons (see Schultz et al 2007 and Quinlan 2007). They have been supported in this call by authoritative academics (see Kearns 2007 and Perkovich and Acton 2008).

The argument in favour of nuclear weapons also fails to take into account the real danger of a large increase in the number of nuclear-weapon powers and the associated threat from nuclear terrorism. Both of these dangers will be increased by the expansion in use of nuclear power, particularly if based on Fast Breeder Reactors and plutonium.

We are now at a crossroads. Unless we take steps to turn ideas like the Global Nuclear Energy Partnership and the international nuclear fuel bank into reality and unless we change the political climate around the NPT with some concrete progress on nuclear disarmament among the NPT nuclear weapons states, we are going to move into Booth's world of 'radical nuclear multipolarity'. To make that move as a deliberate security strategy because of some misplaced faith in the continued value of nuclear deterrence would be, at the least, ill-advised. To do so as a knee-jerk reaction to our need to manage the challenge of climate change would be unforgivable.

We urgently need the security dimensions of a renaissance in the global nuclear industry to be elevated in public debates both on UK energy strategy and on the emerging international energy order to which UK strategy will contribute. And we urgently need serious political energy directed at delivering the policy innovations outlined above.

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