Making the World Safe for Nuclear Energy

John Deutch, Arnold Kanter, Ernest Moniz and Daniel Poneman

The discovery of secret programmes in Libya, Iran and North Korea to produce uranium and plutonium in forms suitable for nuclear weapons compels a fresh look at the tools available to curtail the continuing threat these weapons pose to humankind. Libya has admitted, renounced and is dismantling its extensive nuclear weapons programme. Iran has partially admitted secret efforts and proclaims peaceful intent in developing electricity supply in the face of American-led supply impediments. European nations and the International Atomic Energy Agency (IAEA) have engaged in a process aimed at bringing Iran into compliance with international non-proliferation norms, though it remains unclear whether Tehran will comply fully in the end or continue a 'cheat and retreat' strategy.[1] North Korea has abandoned its non-proliferation commitments, asserted that it has separated substantial plutonium and now boasts of possessing its own nuclear deterrent.

In addition to state-based proliferation, acquisition of nuclear explosives by terrorists or organised crime is of heightened concern. We know from documents discovered in Afghanistan after the overthrow of the Taliban regime that al-Qaeda considers obtaining nuclear weapons to be a religious duty, presenting a risk of catastrophic terrorism on a scale that would dwarf the attacks of 11 September 2001.[2] There is also the danger that a few kilograms of the hundreds of tonnes of highly enriched uranium and separated plutonium left over from the former Soviet arsenal might be stolen or illicitly sold.

John Deutch, Institute Professor at the Massachusetts Institute of Technology, served as Under Secretary of Defense for Acquisition & Technology, Deputy Secretary of Defense, and Director of Central Intelligence in the Clinton Administration. He also served as Director of Energy Research and Under Secretary of Energy in the Carter Administration. **Arnold Kanter**, Senior Fellow at the Forum for International Policy, served as Special Assistant to the President for National Security Affairs from 1989 to 1991, and as Under Secretary of State for Political Affairs from 1991 to 1993. **Ernest Moniz**, Professor of Physics and Director of Energy Studies, Laboratory for Energy and the Environment at the Massachusetts Institute of Technology, served as Under Secretary in the United States Department of Energy. **Daniel Poneman**, Senior Fellow at the Forum for International Policy, served on the National Security Council staff under Presidents George H.W. Bush and Bill Clinton with responsibilities for non-proliferation policy.

Survival, *vol. 46, no. 4, Winter 2004–05, pp. 65–80*

At the same time, the world may be on the verge of a new phase of widespread deployment of nuclear power. The rapidly growing global demand for electricity, the uncertainties of the natural gas supply and price, concern about air pollution and the immense challenge of dramatically lowering greenhouse gas emissions that lead to global warming are all factors behind the reconsideration of nuclear power. After a long hiatus, interest in building nuclear power stations is stirring in countries from the United States and some European states to China.

Interest in building nuclear power stations is stirring

To succeed, nuclear energy must overcome a host of hurdles. Two outstanding problems are the high capital costs of nuclear reactors and the disposal of nuclear waste products. Unquestionably, however, the prospects for nuclear energy to play a larger role in our energy future would be devastated by *any* nuclear-weapons incident associated with the nuclear-power fuel cycle anywhere in the world. It is crucial that the pursuit of carbon-free electricity from nuclear energy does not mask efforts to pursue a nuclear weapons capability.

Much recent discussion – including proposals from IAEA Director Mohammed El Baradei and President George W. Bush, and the June 2004 G-8 commitment to strengthen Nuclear Supplier Group guidelines and to refrain from inaugurating new fuel-cycle technology transfers as those guidelines are developed – has called for 'evolution' of the Non-Proliferation Treaty (NPT) implementation framework.[3] But the careful balancing of divergent national interests in the NPT suggests that any effort to amend the treaty – especially one that further curtailed access to nuclear technology – would open a Pandora's box of simmering complaints that would be more likely to erode than strengthen the international force of the treaty. Therefore, a more pragmatic approach than amending treaties is needed. We believe that a set of commercial arrangements among nuclear-fuel service suppliers and electrical utilities that own or may purchase nuclear power stations, backed up by international institutional arrangements, may help ensure that nuclear-generated electricity remains available to all, but that nuclear weapons do not spread beyond their current possessors.

The fuel-cycle risk

The reactors that produce electricity do not present the principal proliferation risk. Rather, the uranium enrichment technology used to make nuclear fuel can also make highly enriched uranium (HEU), one of the two significant weapons materials. The second, plutonium, is

separated from irradiated fuel by reprocessing technology after the fuel is withdrawn from the reactor. Obtaining HEU or plutonium is the key step to acquiring a nuclear weapon.

The North Korean, Iranian and Libyan programmes can all be traced back several decades to Pakistan's theft of European centrifuge enrichment technology developed for nuclear reactor fuel production. India diverted heavy water from a commercial plant, employed it in a research reactor and then separated the plutonium for its so-called 'peaceful' nuclear explosion in May 1974. Furthermore, about 200 tonnes of separated plutonium from reprocessed power reactor fuel have accumulated in several countries, presenting a possible target for theft or diversion. The danger associated with plutonium separation from spent nuclear fuel increases as the natural protection provided by heat and intense radioactivity abate with the succeeding decades.

Governments argue that deploying these enrichment and reprocessing technologies for nuclear power is permitted under Article IV of the NPT (which pledges support for peaceful nuclear activities in non-nuclear-weapons states), so long as safeguards agreements are in place with the IAEA.[4] Such an interpretation of the NPT could effectively defeat the treaty's purpose of slowing proliferation. It would allow a country to come to the brink of a weapons capability within the treaty framework, and then renounce the treaty and sprint, with nuclear material in hand, for the bomb. A better interpretation – indeed, the only one that invests each NPT article with independent meaning as part of a coherent whole – is that Article IV promotes sharing nuclear technology *only* to the extent consistent with the non-proliferation aims codified in Articles I and II of the Treaty. The mere existence of safeguards agreements does not prove that a government is not seeking nuclear weapons, any more than does mere NPT membership, as the clandestine nuclear programmes of Iran, Iraq, Libya and North Korea all amply demonstrate. Where nuclear weapons are concerned, form must not be permitted to defeat substance.

For example, a government accepting IAEA inspections and safeguards over its declared nuclear facilities might establish an undeclared nuclear facility using the same technology and clandestinely produce the nuclear material. Clearly this would constitute an NPT violation. Extensions of the current safeguards regime, such as general adherence to the 'Additional Protocol' that permits the IAEA to inspect suspected, but undeclared, facilities, and adoption of more rigorous inspection procedures, would help address this problem.[5] So would increasing the role that assessments of relative proliferation risk at safeguarded facilities play in decisions on when and where to carry out inspections. Nevertheless, there is widespread concern that, even with

such measures, proliferation risks will not be reduced to acceptable levels in the face of substantial global growth in nuclear fuel-cycle deployment.

The proposal: Assured Nuclear Fuel Services Initiative

Here is how our proposal for an Assured Nuclear Fuel Services Initiative (ANFSI) would work. Countries that do not currently possess uranium-enrichment or plutonium-reprocessing facilities would agree not to obtain any such facilities or related technologies and materials for an extended period of time. By the same logic, countries that do possess such facilities would agree not to provide them, or related equipment or technology, to countries that do not. In exchange, during this period they would receive, on attractive terms, guaranteed cradle-to-grave fuel services – specifically, fresh nuclear fuel supply and spent fuel removal – under an agreement signed by all those governments in a position to provide such services. The IAEA would apply safeguards to any fuel-cycle activities covered by the agreement in addition to its traditional safeguard duties on the reactors in the user states. Fuel-service transactions themselves, however, would be between commercial entities negotiating commercial contracts.

The Assured Nuclear Fuel Services Initiative offers something for everyone. Nuclear supplier states would obtain revenues and increased confidence in avoiding a proliferation incident in a third country whose actions could put the large and potentially growing fleet of nuclear power stations in operation around the world at risk (a 'proliferation Chernobyl'). User states would obtain cost-effective, guaranteed access to nuclear fuel and guaranteed relief from the burden of dealing with nuclear-waste management. And the world would gain an added measure of safety from the risk of weapons proliferation that the spread of inherently dangerous fuel-cycle facilities would bring.

This institutionalisation of 'fuel-cycle states' and 'user states' poses obvious challenges: the security of fuel supply to user states; aspirations for fuel-cycle status as an indicator of technological leadership and for associated export revenue; and the political asymmetry, particularly when viewed against the backdrop of NPT distinctions between nuclear- and non-nuclear-weapons states. Yet these challenges, while difficult or perhaps even politically impossible to resolve at the level of principle and theory, may be far more tractable if they are addressed pragmatically and incrementally, in the context of a realistic pace of global nuclear-power deployment today and in the foreseeable future.

For example, as the nuclear marketplace has evolved, a division between suppliers and customers already exists. The United States, the European Union, Japan, Canada, China, India and Russia account for

about 85% of world nuclear energy capacity today, which is about 365,000 megawatts. There is no serious expectation that this total will change much for 10–15 years. There is no shortage of fuel-cycle capacity to serve this market. Indeed, imports of Russian-origin enriched uranium into Europe and the United States are currently limited on trade protection grounds. If Russia could freely market enriched uranium in the West, today there would be substantial enrichment overcapacity. For countries with relatively small nuclear energy programmes (less than 25,000 megawatts or so), economics will almost always make indigenous enrichment and reprocessing facilities a higher cost option compared to purchasing fuel services on the international market.

Significant growth in nuclear power is quite possible in coming decades, increasing the market for fuel-cycle services. A detailed scenario developed by the MIT Study Group on the Future of Nuclear Power shows, however, that the share of nuclear power in these same countries that now account for 85% would still account for 80% of world nuclear capacity by 2050.[6] In practice the membership of fuel-cycle states need not expand for some time to come.[7] Beyond this group, only South Korea has and will have a large enough nuclear power deployment to entertain fuel-cycle development on economic grounds (of course, its situation is tied to broader issues on the Korean Peninsula). Other countries, such as Brazil or Indonesia, could conceivably have substantial programmes around 2050.

Non-NPT signatories would continue to be excluded entirely from the ANFSI regime. NPT signatories that choose not to become user states should also find their nuclear options constrained, as the rules of the regime should ensure that regime members would not accept nuclear materials or services from governments outside the ANFSI. Nor should ANFSI members provide materials or services for new nuclear power plants to countries outside the regime.

This reality suggests starting the new arrangements with a simple 'stay-put' rule with regard to fuel-cycle status; that is, states already performing nuclear fuel services for commercial customers on the international market would be considered fuel-cycle states, while all others would be considered user states. This has the advantage of offering a relatively quick start without tortuous negotiations about 'permanent' criteria for fuel-cycle and user states. Fuel-cycle state status should be formally revisited at some prescribed time, far enough into the future to provide the stability and security that motivate the creation of the regime, but not so far as to deter governments from joining for fear of forfeiting their long-term options to develop a different nuclear industry. Given the long planning horizon common among utilities, manufacturers and nuclear fuel services providers in the nuclear industry

– ten years is common – it would be plausible to launch the regime for an initial ten-year term, with a commitment to review the process in 2015. A somewhat longer initial term, such as 15 years, would be even better.

Ten or fifteen years hence we should have a much clearer picture of the future of nuclear energy and thus of the need for additional fuel-cycle facilities. By that time, governments will also have a better idea about their country's future energy needs, environmental challenges (including global warming), the role of nuclear power and progress in nuclear waste disposal. Moreover, the state of nuclear-weapons proliferation could be very different. In short, it is at least ten years too early to make definitive decisions about how to reorder the global alignment of nuclear suppliers and users. Attempting to do so will almost certainly ignite debates and passions that are more likely to strangle than to promote the prospects of this regime.

Security of supply

Concern among user states about capricious cut-offs of fuel supply vital to any nation's economy suggests that market mechanisms alone will not be sufficient. We propose that market forces be supplemented by government-to-government assurances that fuel services to users not be withheld for any reason other than a material violation of international non-proliferation commitments, that is, under the NPT and IAEA safeguards measures. Such governmental assurance, in turn, may need to be backed up by stand-by arrangements, whereby one nuclear supplier will step in should the first fail to perform.

In addition to national and commercial assurances, however, the credible assurance of reliable supply will likely require a firm multilateral guarantee. The most appropriate vehicle would be the IAEA: authorised by the UN Security Council to assume a guarantor role, ensuring access to the contracted fuel services and perhaps serving a coordinating role on the nuclear side similar to that played by the International Energy Agency in cases of supply disruption in the oil markets. By analogy, a 'nuclear fuel reserve' could be built up over time if this were viewed as important. The diversity of nuclear-fuel suppliers competing for markets suggests that the demand to fill such a reserve could be met at a reasonable price within a few years. Moreover, long-term contracts with fixed financial terms could help dispel concerns about price volatility during the stay-put period.

Technological leadership

Some governments may assert a need to pursue uranium enrichment or plutonium reprocessing activities in order to accrue the economic benefits

of advancing along the global technology curve. The argument may take many forms. A government could claim that it is pursuing fuel-cycle technologies either to lower the costs or otherwise increase the benefits of nuclear power. More generally, a government could argue that the rising tide of technology in a vanguard sector such as nuclear energy could have spillover effects that would stimulate economic development in other sectors.

These arguments in favour of fuel-cycle technology development and deployment are not compelling, at least during the 'stay-put' period of 10–15 years. Least persuasive is the argument in favour of fuel-cycle activities as a leading edge of a nation's technological revolution, and hence a central driver of its economic development. The technology in question is not exactly new. It was a twentieth-century phenomenon dating to the 1940s and the Manhattan Project in the United States. The chemical processes of plutonium separation are widely understood and present no extraordinary challenges. Uranium enrichment technologies are far more challenging but also quite specialised, and the spillover benefit to other areas would not rival those from investments in information technology or biotechnology as economic drivers.

The technological justification for enrichment and reprocessing to reduce nuclear costs also fails to carry much weight. Fuel services represent a small part of the cost of nuclear power, so even significant cost reductions from technological advances would confer little overall economic benefit.[8] Technological advances could only have a substantial impact on the economic benefits of nuclear energy ten or more years down the road.

For example, laser isotope separation research – actively pursued for many reasons, such as medical diagnostics and treatment – has long occasioned hopes for a much cheaper way to enrich uranium. Although that optimism has significantly faded, some work on laser separation technology continues, for example, in Australia. A second 'disruptive' technology pathway might develop if ideas about advanced fuel cycles built around new types of reactors, fuels, and reprocessing technologies prove attractive. Even the optimists agree, however, that such fuel cycles are several decades away, and even then only with a robust – and expensive – R&D programme starting now.

Practically speaking, then, user-state participants in the regime would not likely sacrifice technological advances that promised substantial economic benefit for at least the next decade or more. Moreover, any risk of such sacrifice could be mitigated. How? We would propose that an R&D programme in nuclear fuel cycle technologies should be pursued as an international collaborative programme of interested fuel-cycle and

user states during the 'stay-put' period. This programme would lead to a clearer view about the prospects for such fuel cycles in 10–15 years. The collaboration structure can also assure participating countries that they will not 'fall behind' other nations in technological development. To the contrary, this programme would provide most user states with more technological insight than they could plausibly obtain on their own.

Precisely because of its technological benefits to participating states, the R&D programme would itself need to be managed so as to minimise proliferation risk. Adherence to the Additional Protocol would be required for participation. In addition, the R&D programme should have an extended period of laboratory research, conceptual design, and modelling and simulation rather than large-scale demonstration facilities.

Finally, since the Assured Nuclear Fuel Services Initiative would be a voluntary programme, governments would retain the option to develop uranium enrichment and plutonium reprocessing technologies once the initial term of the initiative expired in 10–15 years.

Asymmetry and incentives

The proposed arrangement would be voluntary and, for the time being at least, not enshrined in the NPT. For some group of nuclear 'haves' (including the five Permanent Members of the UN Security Council, all nuclear-weapons states) to attempt to coerce another group of 'have-nots' into forswearing fuel-cycle activities would stimulate charges and counter-charges as to which nations had most lived up to the letter and spirit of the NPT, generally undermining the prospects for progress. Given that the decision by non-nuclear weapon states under this arrangement to commit to refrain from fuel-cycle activities goes beyond the current requirements of the NPT, it is appropriate to offer incentives to encourage such commitments. Both economic and political incentives lie at the heart of the proposal. The goal would be to make the incentive so clearly compelling that refusal by a candidate user state would cast a spotlight on its intentions and greatly improve the prospects for coordinated international response.

The principal benefit for the user state and concomitant obligation on the fuel-cycle states is the removal of spent fuel, presumably (although not necessarily in all cases) to the country of origin. In most places, this relieves the reactor operator and the government of a major headache. Countries with relatively few nuclear power plants still must go through a daunting programme of site characterisation to analyse the environmental impact and persuade the public and their elected representatives of the long-term safety and stability of the geological formations and engineered structures for the ultimate disposal of spent

nuclear fuel and waste products. The service should be carried out on commercial terms. The likely cost of such service is not daunting: American utilities are currently charged 0.1 cents per kilowatt-hour (kW-h) for the permanent disposal of spent nuclear fuel, a small fraction of the cost of nuclear-generated electricity.[9]

An obvious uncertainty is how receptive the fuel-cycle states will be to spent fuel return. We cannot answer this question today, since no country is yet successfully operating a 'permanent disposal' facility. Nevertheless, several indicators suggest that the problem should be manageable. First, a robust growth scenario for nuclear power is very unlikely unless spent-fuel disposal programmes are operating successfully in several countries over the next 10–15 years. Second, the principle of spent fuel return for proliferation reasons is already well established; for example, the United States accepts return of highly enriched research reactor fuel of US origin. Third, Russia has declared its intent to bring back Russia-origin spent fuel, has specifically planned to do so for the Iranian reactor under construction at Bushehr and has modified its environmental law to accommodate storage of even third-party spent fuel.

The principle of spent fuel return is well established

Finally, the scale should be kept in mind. The amount of spent fuel produced by all possible user states is about 20% of that in fuel-cycle states and is likely to remain so for a long time. Therefore, the spent fuel challenge for the fuel-cycle states would not be qualitatively affected by taking back spent fuel from the user states. The receiving fuel-cycle state would manage the spent fuel just as it does its own – for example, the United States would directly dispose of the spent fuel in a geological repository, while France or Russia would probably choose to reprocess the fuel and recycle the separated plutonium in domestic reactors. All commercial fuel-cycle facilities would be subject to IAEA oversight.

Additional incentives for participation

Although spent fuel removal is, by itself, a powerful incentive, it may also be necessary to provide additional incentives to persuade user states to undertake long-term commitments to import foreign supplies of enriched uranium fuel while simultaneously committing not to build their own uranium enrichment facilities during the same period. Enrichment services are a small part of nuclear power costs, about $10 million annually for a 1,000-megawatt plant, or about an eighth of a cent per kW-h of electricity. As an extreme case, even if these costs were fully subsidised, and even if the most ambitious expansion of nuclear power

brought world nuclear capacity levels to 200,000 megawatts in user countries by 2050, the cost of enrichment services in user countries would be about $2bn annually, not an absurd amount for the supplier states to pay collectively to avoid proliferation risk, especially considering that the subsidised work would be done in their own countries. For the next couple of decades, the total cost would be an order of magnitude less.

Nevertheless, we are not advocating such a direct payment, recognising that the call on direct public outlays can raise complications, and especially problems of political sustainability. The relatively small amount suggests that other, more creative approaches that do not require direct public expenditure may also be found. The most obvious mechanism would be for the fuel-cycle states to offer credits or price discounts on enrichment services provided to a participating user state. This would not necessarily produce any market-distorting effect, since competitive market forces would normally induce fuel suppliers to discount the price of their services in exchange for their customers entering into a stable, long-term supply arrangement.

In addition, government insurance and export credit institutions in the fuel-cycle states could restrict the insurance, guarantees, and financing they now provide exclusively to fuel transactions among states participating in this regime. This could create a useful economic incentive to persuade nuclear plant operators in user states to urge their home governments to adhere to the regime. While it could be contended that such use of government credits 'distorts' the operation of free markets, the use of government credits to promote national policy aims is well established and widely accepted, never more so than where the national policy in question seeks to protect citizens from the threat of nuclear weapons. The initial commercial benefits from accepting this non-proliferation condition on access to government credit could multiply over time, as deregulation and cross-border integration of energy markets allowed increasing returns to low-cost electricity producers.

As already noted, global warming has provided an important impetus for revived interest in nuclear power, since it is virtually free of carbon dioxide emissions. As the community of nations comes to deal with stringent limitations on greenhouse gas emissions, it is generally accepted that some form of 'carbon credits' will be traded in order to meet the challenge most economically. Under a carbon-credit system, the regulatory authority may, for example, give each company a cap or quota on the amount of pollutant it may emit. If the company exceeds that cap, it must offset its emissions by buying equivalent credits – essentially a right to pollute – from companies that reduce their emissions below their

own cap, and thus have excess credits to sell.[12] To date, nuclear power has not been considered a candidate for such credits. A powerful reinforcement for the non-proliferation regime advocated here would come from a worldwide agreement to assign carbon credits to new nuclear power plants in user states, since they would likely displace fossil fuel-burning power plants. A 1,000-megawatt coal plant emits nearly two million tonnes of carbon annually (almost eight tonnes of carbon dioxide); a modern natural gas plant emits nearly half as much.

A nascent carbon credit market in Europe has had carbon permits priced at about $50 per tonne of carbon (which is still much less than the current cost of actually removing the carbon after combustion). If the user-state nuclear power plant were credited with avoiding carbon emissions at the average of coal and gas plants, the carbon credit would be worth about 0.8 cents per kW-h, more than the entire fuel and spent fuel disposal cost combined. This would confer considerable economic benefit to those enrolled as user states without requiring explicit outlays by the fuel-cycle states.

There are certainly other possible approaches. The point is that there are many practical steps that can be taken to structure the relationship of fuel-cycle states to user-states in a very attractive way, that not only encourages participation in the regime, but also brings international scrutiny to those whose motivation in fuel-cycle development includes nuclear weapon ambitions.

If a voluntary fuel-cycle regime did come into being and gained widespread adherence of both supplier and user states, it would be appropriate for regime members, the IAEA Board of Governors and the UN Security Council to question why a nation with no evident energy or economic justification for uranium enrichment or plutonium reprocessing capabilities might wish to pursue either, to raise questions at the IAEA and in the UN about such conduct, and to deny access to nuclear technology, equipment or materials to any government that could not persuade the international community that its actions and intentions were benign.

It is important to recognise that a fuel-cycle regime of the kind proposed would not become the only mechanism to address proliferation concerns. It would, however, provide a commercially attractive and politically reassuring way of addressing the energy concerns of the vast majority of NPT parties that do not harbour nuclear weapons ambitions.

Early test cases: Iran and Brazil

For this proposal to gain widespread adherence, it needs to be demonstrated in practice. Conversely, if additional countries undertake

enrichment or reprocessing over the coming years, the proposal will have been overtaken by worrying events. In this context, two cases stand out: Iran and Brazil. Neither country has a nuclear energy programme of a scale to justify an independent nuclear fuel-cycle capability, and this raises questions about their motivations.

Iran's secret fuel-cycle activities involving both uranium and plutonium pose a clear proliferation threat and are flatly inconsistent with its obligations under the NPT and its IAEA safeguards agreement. The Iranian national energy plan calls for up to six nuclear reactors over two decades. The first is nearing completion at Bushehr with Russian assistance, with little visible progress towards additional plants. The United States has long asserted, quite vigorously, that various Russian organisations were assisting Iran with other nuclear fuel cycle activities that could facilitate Iran's development of nuclear weapons. Although this situation has led to strained relations between Russia and the United States, it is now time to re-energise the US–Russia dialogue so as to encourage and support a Russian–Iranian fuel cycle–user state arrangement along the lines of the Assured Nuclear Fuel Services Initiative. The US–Russia dialogue, in turn, should be coordinated with the European Union's efforts – led by the United Kingdom, France and Germany – to bring Iran into full compliance with its international non-proliferation obligations.

Russia and Iran have in principle agreed already to long-term fresh fuel supply and spent fuel removal for the Bushehr reactor. The United States can help by securing Russia's commitment to block any nuclear fuel-cycle assistance to Iran in exchange for Washington's endorsement of storage of spent fuel from other countries in Russian facilities under IAEA inspections. This could bring substantial revenues to Russia. If Iran's enrichment and other weapon-related activities could be stopped, fully and transparently, then Iran would gain the fuel-cycle incentives at the heart of our proposal. Rather than being isolated because of its nuclear activities, Tehran would be able to satisfy its stated nuclear power ambitions while at the same time claiming leadership in strengthening global non-proliferation norms. Failure to halt its dangerous nuclear activities, on the other hand, should persuade all nuclear suppliers to refrain from further nuclear cooperation with Iran and to consider tougher penalties.

Brazil also presents an early and difficult test of the practicality of our proposal. Brazil has a new enrichment facility under construction that is intended to provide some of the enrichment services for its two nuclear power reactors. Brazil abandoned its clandestine nuclear weapons development programme in 1990 and ratified the NPT in 1998, but it has

not signed the Additional Protocol. Candidates in the last presidential campaign, including the winner, Luiz Inacio Lula da Silva, made statements that raised concerns about a possible reawakening of nuclear ambitions. This ambiguity has not been dispelled since the election. It defies belief that a plant of the size under consideration will be economically competitive or viable in the fuel-cycle services market of the next 10–15 years.

The Brazilian enrichment facility needs to be stopped, but it will not be easy. Brazil has sunk resources and, more importantly, national prestige into building the plant. Like Iran, Brazil sees itself as a leader among the developing economies. The challenge is to convince the Brazilians that they will derive political and economic benefit from an early choice of user-country status under our proposal. The alternative should be the same nuclear isolation proposed for Iran if it pursues fuel-cycle capability. Here, the United States again has a crucial role, especially since its relationship with Brazil is friendly.

It is important to recognise the limits of an Assured Nuclear Fuel Services Initiative. Our proposal would not necessarily solve the hard cases, but would help identify them by training a spotlight on governments that eschew cheap and reliable fuel supplies in favour of a more expensive and less reliable search for 'independence' through the acquisition of dangerous fuel-cycle technologies. That spotlight could help focus governments' attention to the development of coordinated policies to combat nuclear weapon-related efforts through all the diplomatic, economic and, if necessary, military instruments required for the task.

An Assured Nuclear Fuel Services Initiative will be difficult to develop and implement, but failure to thwart the proliferation of fuel-cycle facilities to more nations would bring unacceptable nuclear dangers to the world. At the same time, we believe that this initiative is less ambitious and more practical than many fuel-cycle proposals, such as those that seek to use governments and multilateral institutions to build or operate sensitive portions of the nuclear fuel cycle. Such proposals have been vigorously advocated for decades, but never implemented. The Assured Nuclear Fuel Services Initiative seeks to use existing commercial arrangements and international market incentives for nuclear fuel services as a means to minimise weapon proliferation risks, all under the watchful eye of the International Atomic Energy Agency. It relies on self-interest, not on virtue, and hence has a better prospect for success.

Our proposal relies on self-interest, not virtue

Iran and Brazil are the key cases that need to be addressed promptly, in order to test the viability of this or any proposal for limiting the spread of fuel-cycle states. The United States must show leadership, and practical steps must be taken in concert with other nations to offer Brazil and Iran reasons to change course. There is time during a 'stay-put' period of 10–15 years to work out the detailed agenda, but very little time to head off developments that would seriously compromise such work. This effort can make the world safe for nuclear energy, and safer from nuclear weapons.

Notes

1 See, for example, Dr Mohamed El Baradei, 'Statement to the Forty-eighth Regular Session of the IAEA General Conference 2004',Vienna, Austria, IAEA General Conference, 20 September 2004); Dr Mohamed El Baradei, 'Introductory Statement to the IAEA Board of Governors', Vienna, Austria, 14 June 2004.

2 Bin Laden issued a statement in 1998 entitled *The Nuclear Bomb of Islam* in which he wrote that 'it is the duty of Muslims to prepare as much force as possible to terrorise the enemies of God', cited in 'Could worse be yet to come?', *The Economist*, 1 November 2001.

3 Mohamed El Baradei, 'Towards a Safer World', *The Economist*, 16 October 2003; 'G-8 Action Plan on Non-Proliferation', Sea Island Summit, 9 June 2004. For a broad historical treatment of options for institutional arrangements governing the nuclear fuel cycle, see Lawrence Scheinman, 'The Nuclear Fuel Cycle: A Challenge for Nonproliferation', *Disarmament Diplomacy*, no. 76, March/April 2004.

4 Article IV, Section 2, of the Treaty on the Non-Proliferation of Nuclear Weapons, signed 1 July 1968, provides that '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. Parties to the Treaty in a position to do so shall also cooperate in contributing alone or together with other States or international organizations to the further development of the applications of nuclear energy for peaceful purposes, especially in the territories of non-nuclear-weapon States Party to the Treaty, with due consideration for the needs of the developing areas of the world.'

5 The terms of the Additional Protocol are set forth in the 'Model Protocol Additional to the Agreement(s) between State(s) and the International Atomic Energy Agency for the Application of Safeguards' (Vienna, Austria: International Atomic Energy Agency, September 1997). Available at www.iaea.or.at

6 *The Future of Nuclear Power – An Interdisciplinary MIT Study* (Cambridge, MA: Massachusetts Institute of Technology, 2003), available at http://web.mit.edu/nuclearpower/

7 India would not qualify as a fuel-cycle state as it is not a member of the NPT.

8 The global enrichment business is about four to five billion dollars per year, and the reprocessing business is about half that. Without established long-term contracts and/or a large domestic customer base, there will be very little market room for new technologies to break into the existing commercial market for a number of years.

9 The Nuclear Waste Fund was created under the Nuclear Waste Policy Act of 1982 and requires that consumers of nuclear-generated electricity pay one-tenth of a cent per kilowatt-hour of electricity used.

10 John J. Fialka, 'Emission-Credit Trading Rises, Anticipating Kyoto Protocol', *The Wall Street Journal*, 18 October 2002.