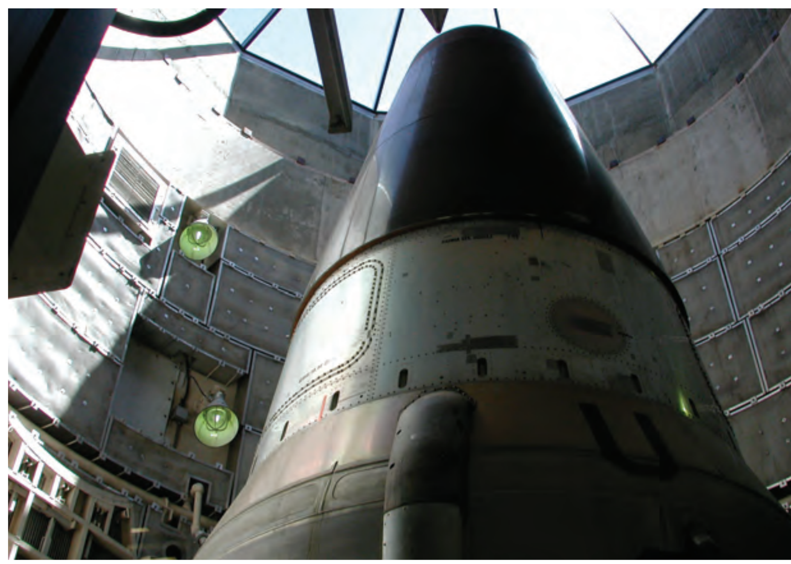
THE FUTURE OF NUCLEAR ENERGY TO 2030 AND ITS IMPLICATIONS FOR SAFETY, SECURITY AND NONPROLIFERATION

Part 4 – Nuclear Nonproliferation



TREVOR FINDLAY

CIGI
The Centre for International Governance Innovation
Centre pour l'innovation dans la gouvernance internationale

Addressing International Governance Challenges

The Future of Nuclear Energy to 2030 and its Implications for Safety, Security and Nonproliferation

Part 4 – Nuclear Nonproliferation

Trevor Findlay

CIGI's Nuclear Energy Futures Project is conducted in partnership with the Canadian Centre for Treaty Compliance (CCTC) at the Norman Paterson School of International Affairs, Carleton University, Ottawa. The project is chaired by CIGI Distinguished Fellow Louise Fréchette and directed by CIGI Senior Fellow Trevor Findlay, director of CCTC. CIGI gratefully acknowledges the Government of Ontario's contribution to this project.

Table of Contents

List of Tables and Figures

Technical Glossary

Units

BTU	British thermal unit
g	gram
kWh	kilowatt hour – a unit of electrical energy equal to the work done by one kilowatt acting for one hour
SWU	separative work unit – a measure of work done by a machine or plant in separating uranium into higher or lower fractions of U-235
t	tonne
We	watt (electric)
Wth	watt (thermal)

Elements and Compounds

C	carbon
CO2	carbon dioxide
Pu	plutonium
U	uranium
UF6	uranium hexafluoride

Metric Prefixes

k	kilo	10^3
M	mega	10^6
G	giga	10^9
T	tera	10^{12}

All dollar values in this report, unless otherwise noted, are in US dollars.

Foreword
By Louise Fréchette

2010 will be a pivotal year for nuclear issues. In April, President Obama will host a special summit on nuclear security. In May, parties to the Nuclear Non-proliferation Treaty will gather in New York for a review conference and in June, at the G8 Summit hosted by Canada, nuclear proliferation issues will occupy a prominent place on the agenda. New challenges to the nuclear nonproliferation regime by countries such as North Korea and Iran and growing concerns about the possible appropriation of nuclear material by terrorist groups arise at a time when there is much talk about a major increase in the use of nuclear energy for civilian purposes.

This so-called "nuclear renaissance" was the starting point of the Nuclear Energy Futures project which was initiated in May 2006. The purpose of this project was three-fold:

- to investigate the likely size, shape and nature of the purported nuclear energy revival to 2030 – not to make a judgement on the merits of nuclear energy, but rather to predict its future;
- to consider the implications for global governance in the areas of nuclear safety, security and nonproliferation; and
- to make recommendations to policy makers in Canada and abroad on ways to strengthen global governance in these areas.

The project commissioned more than a dozen research papers, most of which have been published in CIGI's *Nuclear Energy Futures Papers* series; held several workshops, consultations and interviews with key Canadian and foreign stakeholders, including industry, government, academia and non-governmental organizations; convened two international conferences, one in Sydney, Australia, and one in Waterloo, Ontario; and participated in conferences and workshops held by others. The project has assembled what is probably the most comprehensive and up-to-date information on possible additions to the list of countries that have nuclear power plants for civilian purposes. Along with this Survey of Emerging Nuclear Energy States (SENES), the project has produced a compendium of all the nuclear global governance instruments in existence today which will, I believe, prove to be a valuable reference tool for researchers and practioners alike.

The project was generously funded and supported by The Centre for International Governance Innovation and was carried out in partnership with the Canadian Centre for Treaty Compliance (CCTC) at Carleton University, Ottawa. I was very fortunate to have found in Dr. Trevor Findlay, director of the CCTC, the perfect person to oversee this ambitious project. I am very grateful to him and his small team of masters students at the Norman Paterson School of International Affairs, especially Justin Alger, Derek de Jong, Ray Froklage and Scott Lofquist-Morgan, for their hard work and dedication.

Nuclear issues are quintessential global issues. Their effective management requires the collaboration of a broad range of actors. Canada, with its special expertise in nuclear technology and its long history of engagement in the construction of effective global governance in this area, is particularly well placed to help deal with the new challenges on the horizon. My colleagues and I hope that the findings and recommendations of the Nuclear Energy Futures Project will be of use to policy makers as they prepare for the important meetings which will be held later this year.

Louise Fréchette
Chair of the Nuclear Energy Futures Project
Distinguished Fellow,
The Centre for International Governance Innovation

Preface to the Final Report of the Nuclear Energy Futures Project: Parts 1 to 4

This report culminates three-and-a-half years' work on the Nuclear Energy Futures (NEF) project. The project was funded and supported by The Centre for International Governance Innovation (CIGI) and carried out in partnership with the Canadian Centre for Treaty Compliance (CCTC) at Carleton University, Ottawa.

The purported "nuclear renaissance" was the starting point of the Nuclear Energy Futures project, which was initiated in May 2006. The purpose of this project was three-fold:

- to investigate the likely size, shape and nature of the purported nuclear energy revival to 2030 – not to make a judgment on the merits of nuclear energy, but rather to predict its future;
- to consider the implications for global governance in the areas of nuclear safety, security and nonproliferation; and
- to make recommendations to policy makers in Canada and abroad on ways to strengthen global governance in these areas.

Numerous outputs have been generated over the course of the study, including the Survey of Emerging Nuclear Energy States (SENES) online document, the GNEP Watch newsletter and the Nuclear Energy Futures papers series. The final installment from the project comprises six outputs: the Overview, an Action Plan, and a four-part main report. A description of how the project was conducted is included in the Acknowledgements section at the front of the Overview.

Part 1, The Future of Nuclear Energy to 2030, provides a detailed look at the renewed interest in global nuclear energy for civilian purposes. Growing concerns about energy security and climate change, coupled with increasing demand for electricity worldwide, have prompted many countries to explore the viability of nuclear energy. Existing nuclear states are already building nuclear reactors while some non-nuclear states are actively studying the possibility of joining the nuclear grid. While key drivers are spurring existing and aspiring nuclear states to develop nuclear energy, economic and other constraints are likely to limit a "revival." Part 1 discusses the drivers and challenges in detail.

Parts 2 through 4 of the main report consider, respectively, issues of nuclear safety, security and non-proliferation arising from civilian nuclear energy growth and the global governance implications.

Introduction To Parts 2 To 4: Implications of the Nuclear Revival

The implications for global nuclear governance of the less-than-dramatic nuclear revival projected by this report are not as alarming as they would be if a full-bore nuclear renaissance were on the horizon. Nonetheless, they are sufficiently serious to warrant attention now, especially as many aspects of the nuclear regime are today ineffective or under serious threat. Indeed, the slow pace of nuclear energy expansion gives the international community breathing space to put in place the necessary reform of global governance arrangements.

Parts 2 to 4 of the report will consider the implications of the nuclear revival — in the form predicted in Part one — for global governance in the key areas, respectively, of safety, security and weapons nonproliferation. Each section will:

1. Assess the current status of each issue area, including the existing global governance arrangements and their strengths and weaknesses;
2. Characterize the impact of the revival on the existing arrangements; and
3. Make recommendations for adapting the system so that it effectively and efficiently manages such change.

For the purposes of this report, "global nuclear governance" refers to the web of international treaties, agreements, regulatory regimes, organizations and agencies, monitoring and verification mechanisms and supplementary arrangements at the international, regional, sub-regional and bilateral levels that help determine the way that nuclear energy, in both its peaceful and military applications, is governed. Governance at these levels is in turn dependent on national implementation arrangements which ensure that each country fulfills its obligations in the nuclear field. Such a broad conceptualization of governance is intended to emphasize that a holistic approach is necessary when contemplating the implications of a civilian nuclear energy revival. Global governance will axiomatically be a collaborative enterprise involving many players. It will also be perpetually a work in progress. The NEF project has published a *Guide to Global Nuclear Governance: Safety, Security and Nonproliferation* which provides background to all of the governance elements considered here (Alger, 2008).

Although for the purposes of clarity this report treats nuclear safety, nuclear security and nuclear nonproliferation separately, there is a strong relationship among them that is not always reflected in the ad hoc evolution of the global governance regime pertaining to each. Nor is it often reflected in policy or academic analysis. In particular the nonproliferation community on the one hand, and the safety and security communities on the other, tend to ignore each other. Helping overcome this intellectual "stove-piping" is one of the secondary goals of this project.

The extent of the overlap between safety, security and nonproliferation is, however, increasingly recognized. Common principles, for instance, are seen to apply to safety and security, such as the philosophy of "defence in depth." As Richard Meserve points out with respect to nuclear power reactors, "The massive structures of reinforced concrete and steel … serve both safety and security objectives" (Meserve, 2009: 107). A major breach of physical security, such as sabotage of a nuclear power plant, could pose serious safety risks. Meserve also notes that occasionally plant features and operational practices driven by safety considerations conflict with those that serve security purposes: "Access controls imposed for security reasons can inhibit safety, limiting access for emergency response or egress in the event of a fire or explosion" (Meserve, 2009: 107). Furthermore, safety and security measures designed to prevent unauthorized access to nuclear material can help prevent the acquisition of nuclear weapons by terrorists and other unauthorized entities. Again, nonproliferation measures, such as each country's State System of Accounting and Control (SSAC), designed to help verify non-diversion of nuclear material to weapons purposes, also serve to deter unauthorized activities such as illicit trafficking and help the state account for and thus protect its nuclear assets.

Fortunately there is growing official recognition of the close relationship among these three areas and a recognition that they have to be considered holistically if the global governance of all three is to be strengthened. The "3-Ss" concept — safeguards, safety and security — was adopted by the 2008 Independent Commission of Eminent Persons convened to make recommendations on the role of the IAEA to 2020 and beyond (IAEA, 2008d). It was later endorsed by the Group of 8 (G8) Summit in Hokkaido in 2008 as a means of raising awareness of the importance of integrating the three fields and strengthening "3-S" infrastructure through international cooperation and assistance (G8, 2008).

Part 4: Nuclear Nonproliferation

The link between civilian nuclear energy and nuclear weapons proliferation has been an abiding one since the dawn of the nuclear age. The earliest civilian nuclear energy programs were by-products of the first nuclear weapons programs. Yet there were concerns from the outset that the process could work in reverse. It was feared that states would seek to acquire civilian nuclear energy as a cover for a nuclear weapons program. From the earliest days the solution was seen to be some form of global governance to restrict access to nuclear materials and nuclear technology. The 1946 Acheson-Lilienthal Report, in addition to suggesting that the US give up its fledgling nuclear arsenal, envisaged a "comprehensive international nuclear control regime" in which an international agency would take control of all nuclear materials, ranging from natural uranium to plutonium, which would be devoted entirely to peaceful uses (Acheson and Lilienthal, 1946).

These proposals were unable to prevail over the opposition of the Soviet Union and the Americans' own hesitations about nuclear disarmament. President Dwight D. Eisenhower, in his 1953 Atoms for Peace speech, instead proposed a less ambitious but still lofty idea (Eisenhower, 1953). An international atomic energy agency under United Nations auspices would be put in charge of a certain quantity of nuclear material, provided by the most advanced nuclear states, in order to expedite and promote the peaceful uses of nuclear energy worldwide. While nuclear disarmament by the US and the Soviet Union was off the agenda, all countries would be given the chance to benefit from the wonders of the "peaceful atom," apparently in the somewhat naïve hope that they would thus not be tempted to acquire nuclear weapons. Such assistance would be subject to unspecified "special conditions," presumably the "safeguards" envisaged by Acheson-Lilienthal.

Hence the initial trade-off between the peaceful uses of nuclear energy and nuclear nonproliferation — with all of its complications and contradictions — was struck in the first decade after the dropping of nuclear weapons on Hiroshima and Nagasaki. Today that bargain has morphed into an international nonproliferation regime that has indeed prevented the spread of nuclear weapons to scores of states, but which has not prevented proliferation entirely. It has also not resolved the central contradiction: that some states have accorded themselves the right to retain nuclear weapons apparently in perpetuity, while all others are under legally binding obligation never to acquire them.

It is into this potent political and technological mix that the current renewed enthusiasm for nuclear electricity generation is injecting itself, raising fears of a wave of "nuclear hedging" — whereby states seek the peaceful nuclear fuel cycle so they can move quickly to nuclear weapons acquisition when required. The international regime is currently being challenged in this very manner by Iran, which is engaging in precisely the type of ambiguous, hedging behaviour that an unbridled nuclear energy revival could unleash.

In response, there are calls for further improvements in nuclear safeguards and a tightening of controls on so-called sensitive parts of the fuel cycle — uranium enrichment and the reprocessing of spent fuel to produce plutonium. Among such proposals are resurrected old ideas, such as fuel banks to provide assurances of nuclear fuel supply and multilateralization of the fuel cycle, that were first aired in the initial round of nuclear energy expansion in the 1970s and 1980s. More encouragingly, there is a new wave of support and proposals for moving towards nuclear disarmament ("getting to zero") that may help break the deadlock between states arguing for ever tighter nonproliferation controls and those resisting on the grounds that the nuclear weapon states need to move faster to disarm as part of the nonproliferation grand bargain (ICNND, 2009).

This part of the report considers the links between civilian nuclear energy and nuclear weapons, the past history and current state of the global nonproliferation regime; the likely impact that a nuclear energy revival will have on it and ways to strengthen it in advance.

The Link between Civilian Nuclear Energy and the Bomb

The spread of peaceful nuclear energy, critics argue, goes hand in hand with the proliferation of latent capacities for developing nuclear explosive devices.[1] Nuclear reactors and nuclear explosives both harness the energy produced by nuclear fission.[2] However, the speed at which they do so is completely different and marks the crucial difference between them: in a reactor the energy release is controlled and sustained over an extended period, whereas in a nuclear bomb the release occurs in fractions of a second. The speed of the chain reaction in a nuclear explosion creates special requirements for the firing mechanism, the grade of the uranium or plutonium used, and the density, physical surrounding and shape of the fissile material. On the other hand, controlling the flow of neutrons in a power reactor arguably requires more sophisticated technology than a basic nuclear weapon (Mozley, 1998: 23-25, 44-46).

Yet the technologies of the two enterprises are essentially different and require different scientific knowledge and technical expertise to successfully design, produce and operationalize. These differences are substantial barriers to a state looking to advance from designing, building and operating a nuclear reactor to designing, building and detonating a nuclear device. As Mark Fitzpatrick puts it: "Commentators with an incomplete understanding of what it takes to build nuclear weapons often assume that the acquisition of nuclear energy could be an easy stepping stone to nuclear weapons" (IISS, 2009).

The following section examines what a single power reactor, or at most a few, can potentially contribute to the latent nuclear weapons capabilities of an aspirant nuclear energy state.

Scientific and Technological Expertise and Training

The extent to which a nuclear energy neophyte will gain scientific expertise and experience from obtaining a nuclear power reactor depends on the existing capabilities of the country concerned and the manner in which the reactor is acquired. There is a vast difference, in terms of the expertise and experience to be gained, between a state designing and building a new reactor from scratch and buying one from a foreign supplier. If purchased on a turnkey basis, where everything is supplied by the foreign consortium, including construction and initial operating personnel, and the "keys" handed over on completion, there will be little to no local nuclear learning during construction. Even if the buyer takes over the running of the plant from the outset, this will only provide experience in operating a reactor, not necessarily in designing and building another one. Some newcomer states may even contract foreign companies to run nuclear reactors on their territory indefinitely, precluding any local nuclear learning (although national regulators would presumably need to become familiar with its operation). For instance, the United Arab Emirates (UAE) is not only purchasing reactors from a South Korean firm on a turnkey basis, but is contracting the firm to run the reactors over their projected lifespan of 60 years (Economist, 2010: 47).

Some countries, like India and South Korea, have learned how to build reactors by buying and eventually reverse-engineering them, but this is a long-term project without guarantee of success and will depend in part on access to commercial proprietary information. Collaborative construction projects between vendor and buyer will offer more opportunities for industrial learning by the purchasing state, but most new entrants will by definition not be in a position to contribute design or specialized construction expertise.

In short, acquiring a nuclear power reactor (or several) would certainly add to the country's nuclear expertise and experience, especially if it already had a foundation on which to build. But it is expensive, slow and not the most effective way to proceed to acquire a familiarity with nuclear science and technology and to gain the experience useful for a nuclear weapons program. What a civilian nuclear reactor can provide is more ethereal: a plausible cover for seeking a broad range of nuclear expertise, experience and technology without arousing suspicion of nuclear weapon intentions.

States seeking nuclear expertise for the first time, especially with an eventual nuclear weapons program in mind, are most likely to begin by sending their personnel abroad for education and training in such disciplines as physics and nuclear engineering, seeking assistance from other states and the International Atomic Energy Agency (IAEA),[3] establishing their own university programs in such disciplines and by setting up nuclear research centres equipped with research reactors. As George Perkovich notes, "There is a tendency to talk about dual-use technology, but dual-use scientists and technologists are even more important. Civil nuclear programs, with or without a nuclear power reactor, enable the training of dual-use talent" (Perkovich, 2002: 193).

There is considerable overlap between the basic scientific disciplines required for a nuclear energy program and a nuclear weapons program. Such disciplines include the following (see Appendix A for a comprehensive list and their specific relevance to the two types of programs):

- nuclear engineering
- chemical engineering
- metallurgical engineering
- mechanical engineering
- electrical engineering
- physics
- mathematics and computer science
- chemistry.

Examples of peaceful military crossover in nuclear engineering include fissile atom depletion and production calculations, criticality calculations and nuclear reactor design (US GAO, 1979). Some of the disciplinary overlap — particularly in chemical engineering — relates to sensitive fuel cycle technologies such a enrichment and reprocessing.

In some instances states may already have a head start in their capability to move to nuclear weapons development in the form of research reactors, many of which use highly enriched uranium (HEU). This may make the acquisition of a nuclear power reactor moot in terms of additional research and training opportunities. Successful operation of a research reactor indicates that a country already has a basis for further research into nuclear science and engineering beyond what it would acquire by obtaining one or two power reactors. Research reactors are common among states without nuclear power reactors (IAEA, 2009h).

India, Israel, North Korea, Pakistan and South Africa all used peaceful nuclear education, training and technical assistance, including in some cases research reactors, provided by advanced nuclear states to enhance their potential nuclear weapons capability. India received training and technology particularly from the US and Canada, including a research reactor used to produce the material for its 1974 nuclear test. France provided technology and equipment to Israel in the 1950s, enabling it to build a plutonium production reactor and eventually nuclear weapons. It did not bother with a peaceful nuclear power program, but diverted all of its resources to weapons development. North

Korea received assistance from the Soviet Union, including a research reactor which produced the plutonium for its nuclear test devices. South Africa received a research reactor and the HEU to fuel it from the US, an act viewed as the genesis of its nuclear weapons program.[4] In fact, every case of successful nuclear weapons development since the Nuclear Non-proliferation Treaty (NPT) came into effect in 1970 occurred under the guise of a peaceful nuclear program with the assistance of nuclear supplier states. The "near misses" of Argentina, Brazil, Iraq and Libya exhibited the same characteristics, as does the current case of Iran.

Requests for assistance were mostly justified by these states on the basis of a general interest in the peaceful uses of nuclear energy, not on the basis of their power generation needs. Only Argentina, Brazil, India and South Africa went on to generate nuclear electricity. The acquisition of education, training and research reactors was the critical step, not the construction of a reactor for power generation. Among all of the proliferant states, only Pakistan's nuclear program began with the acquisition of a nuclear power reactor that was purportedly for generating electricity.

Access to Fissile Material

States seeking to acquire a nuclear power reactor for the purposes of obtaining access to fissile material for a bomb are also likely to be frustrated, especially when such facilities are under safeguards, although there are some scenarios in which this may be possible. While there has never been an instance of a state diverting uranium or plutonium from a civilian nuclear power plant for use in a nuclear device (India and North Korea diverted plutonium from research reactors), this does not mean that it is impossible (Gilinsky et al., 2004).

Uranium

In terms of the fuel, neither the low enriched uranium feedstock for a light water reactor (LWR) nor the natural uranium used for a heavy water reactor of the CANDU

The Case of Pakistan

From its beginnings in 1953, Pakistan's nuclear program appeared devoted exclusively to peaceful uses. It began with a small, 137 MW CANDU unit, the Karachi Nuclear Power Plant (KANUPP), sold to Pakistan by Canadian General Electric on a turnkey basis (Bratt, 2006: 101). Canada retained control over design and construction and there was minimal transfer of nuclear technological capability to Pakistan at that time. In addition, the reactor was under bilateral safeguards from the outset and under additional trilateral safeguards with the IAEA after 1969 (Bratt, 2006: 102). Like all CANDUs, the reactor operated with natural uranium and (like all nuclear reactors) produced plutonium in its spent fuel. Pakistan attempted to purchase a reprocessing plant from France, but was ultimately refused and thus had no way of retrieving the plutonium from the spent fuel.

The IAEA was able to verify through safeguards that no material was diverted from KANUPP, hence plutonium from the reactor was not available for Pakistan's 1998 nuclear weapon tests (which used HEU instead) (House of Commons, 1998). KANUPP appears to have contributed little to Pakistan's industrial learning, even in producing nuclear electricity. Duane Bratt records that when KANUPP became operational in 1972 the Pakistan Atomic Energy Commission expressed confidence that due to the "exhaustive training" of their nuclear scientists and engineers "the KANUPP operating team is fully capable of running the plant efficiently" (Bratt, 2006: 147-148). It has actually performed poorly, its average load factor since 1972 being only 27 percent and its contribution to Pakistan's electrical grid negligible (IAEA, 2009g). Unlike India, Pakistan did not seek to reproduce the CANDU either for plutonium production purposes or for nuclear electricity.

Nonetheless, the acquisition of KANUPP contributed to Pakistan obtaining a range of expertise, materials and infrastructure that collectively, as part of a much larger nuclear learning effort, it could use in moving towards a nuclear weapons program. Munir Ahmen Kahn, former leader of Pakistan's nuclear program, explained that:

> The Pakistani education system is so poor, I have no place from which to draw talented scientists and engineers to work in our nuclear establishment. We don't have a training system for the kind of cadres we need. But, if we can get France or somebody else to come and create a broad nuclear infrastructure, and build these plants and these laboratories, I will train hundreds of my people in ways that otherwise they would never be able to be trained. And with that training, and with the blueprints and the other things we'd get along the way, then we could set up separate plants that would not be under safeguards, that would not be built with direct foreign assistance, but I would now have the people who could do that. If I don't get the cooperation, I can't train the people to run a weapons program (Perkovich, 2002: 194).

The most important element of foreign assistance was not the KANUPP power plant itself, but the education of the first generation of Pakistani nuclear scientists abroad. It is estimated that 50 nuclear scientists and engineers from Pakistan were educated in Canada alone (Bratt, 2006: 201). J.G. Hadwen, Canadian ambassador to Pakistan from 1972 to 1974, noted that "of course Pakistani scientists and engineers were in many cases trained in Canada and Pakistan's experience in the operation of KANUPP formed the basis of whatever program the country decided to develop outside Karachi" (Bratt, 2006: 201).

Canada, suspecting that Pakistan was seeking to misuse technology it had supplied, and unable to persuade it to accept full-scope safeguards, ended nuclear cooperation with the country in 1974. Ultimately Pakistan failed in its plans to quickly produce a plutonium bomb and switched to the uranium enrichment route through the efforts of Abdul Qadeer (A.Q.) Khan, who gained his experience and centrifuge blueprints direct from the Uranium Enrichment Company (URENCO) enrichment plant in the Netherlands (Levy and Scott-Clark, 2007: 19).

type is suitable for a nuclear weapon. Ideally, uranium needs to be enriched to 90 percent or higher in U-235 to be considered weapons grade, compared with the 3 to 5 percent used in most light-water reactors. At low enrichment levels the amount of material needed for a device to reach criticality is so large that it could not realistically be detonated, particularly at enrichment levels below 20 percent (IPFM, 2007). Nuclear devices using material with somewhat lower enrichment levels have been built by advanced weapons laboratories, but the complexity and practicality of doing so drops dramatically with the enrichment level. A non-nuclear weapon state is unlikely to be able to accomplish such a difficult technical feat.

Diversion of low enriched uranium (LEU) fuel from a power reactor may offer advantages to a proliferant state by obviating several stages in producing HEU for a bomb. Using diverted LEU from a fresh LWR fuel load in a clandestine enrichment plant can reduce the needed plant capacity by a factor of five (Gilinsky, 2004: 9). This assumes that a neophyte nuclear energy state could also secretly build a small enrichment plant and successfully evade IAEA safeguards on its reactor and fuel. While on the face of it this is implausible, the proliferation by the A.Q. Khan network of designs for basic centrifuge technology to Iran, Libya and North Korea, along with clandestine manufacture of centrifuge parts in countries like Malaysia, argues against complacency.

Plutonium

Plutonium contained in the spent fuel resulting from the normal operation of nuclear power reactors is also far from ideal for building a first nuclear weapon. This is due to the occurrence of Pu-240, an isotope of plutonium that increases proportionately the longer the fuel is left in a reactor. Pu-240 has a high rate of spontaneous fission, which makes it impossible to use in a gun-assembly type weapon (of the type dropped on Hiroshima) as it will detonate prematurely. However, despite long-held beliefs to the contrary, it is theoretically possible to use it in a crude implosion device (of the type dropped on Nagasaki) that would yield at least one or two kilotons, a quite substantial explosion. The US National Academy of Sciences and US Department of Energy (DOE) reached this conclusion in the 1990s:

> Virtually any combination of plutonium isotopes … can be used to make a nuclear weapon. In short, reactor-grade plutonium is weapons-usable, whether by unsophisticated proliferators or by advanced nuclear weapons states (Feiveson, 2004: 436).

The Americans in fact successfully conducted a nuclear test in 1962 using reactor-grade plutonium in place of weapons-grade plutonium (DOE, 1994).

The more desirable isotope of plutonium for a reliable weapon is Pu-239, which unlike Pu-240, is least abundant when fuel is irradiated for the normal three fuel cycles lasting about 60 months. However, LWR reactor fuel does not need to be kept in the core for that length of time, but could be withdrawn before it is fully "irradiated." According to Gilinsky *et al.*, if the operator of a newly operating LWR unloaded its entire core after eight months or so the contained plutonium would be weapons-grade, with a Pu-239 content of about 90 percent (Gilinsky, 2002: 28). About 150 kilograms of plutonium (enough for about 30 nuclear bombs) would be produced per eight-month cycle. As he and his fellow authors put it, "The widely debated issue of the usability for weapons of plutonium from LWR fuel irradiated to its commercial limit has diverted attention from the capacity of an LWR to produce large quantities of near-weapons grade plutonium" (Gilinsky, 2002: 9). The idea that plutonium from LWRs is essentially unusable for nuclear weapons underpins the case for the alleged "proliferation resistance" of LWRs and consequently of the case for the irrelevance of a nuclear energy revival for nuclear proliferation.

An LWR under safeguards that was using larger than normal amounts of fuel would certainly come under suspicion that it was being used to produce plutonium and the IAEA is likely to detect the diversion. Moreover, the state would have to have some means of reprocessing the plutonium. However, combined with a clandestine "quick and dirty" reprocessing plant that some experts have claimed is technically feasible, the risk of such a diversion attempt is not zero. Gilinsky *et al.* claim that under the current safeguards regime there would be little chance of detecting the diversion and processing of the plutonium into metal and its fabrication for a weapon until it was too late (Gilinsky, 2002: 22). The International Panel on Fissile Materials (IPFM) agrees that such a "quick and dirty" plant could be built outside of safeguards, with minimal, rudimentary arrangements for worker radiation protection and radioactive waste management, in a year or less (IPFM, 2009: 106). Ultimately a state could of course abrogate its safeguards agreement and leave the NPT, turning its LEU openly into a plutonium production reactor, building a reprocessing plant or using one clandestinely constructed in advance.

Allegations are frequently made that natural uranium fuelled/heavy water moderated power reactors like the CANDU are more proliferation-prone than LWRs.[5] First, CANDU-type reactors are said to produce plutonium more "efficiently" and in larger volume per amount of fuel. Second, unlike the LWR, such a reactor does not need to be shut down to refuel (using, instead, so-called "on-load refueling"), thereby making it supposedly more difficult to apply safeguards to. Third, since such a reactor uses natural uranium, it does not require an enrichment facility to provide the fuel. As many countries have natural uranium deposits, this supposedly permits them to circumvent safeguards that would be imposed on imported enriched uranium as well as avoiding the expense of building their own enrichment plant. In 1977 a US study, the Ford-Mitre nuclear policy review, concluded that the CANDU was "more suitable for reliable weapons" than conventional LWRs (Keeny et al., 1977).

These claims are all contested, in particular by the designers of the CANDU.[6] First, while it is true that CANDU technology "produces the highest amount of plutonium per unit of power output of any commercial reactor" (MacKay, 1998), the difference is not stark: the percentage of Pu-239 in spent fuel at discharge is 68.4 percent, versus 57.2 percent for a Boiling Water Reactor and 55.7 percent for a Pressurized Water Reactor (Miller, 2004: 43). Because the CANDU uses a much greater mass of fuel, the plutonium is "dilute" in its spent fuel, typically 2.6 grams of fissile plutonium per initial kilogram of uranium (Whitlock, 2000). Second, despite "on-load refueling," the IAEA has never reported any difficulty in safeguarding CANDU reactors, although they do require extra resources. Safeguarding small numbers of fuel elements in each partial reload is in any case arguably easier than safeguarding bulk refueling. Modern means of continuous remote monitoring helps ensure verifiability in either case. Third, the use of natural uranium can be seen as a proliferation benefit rather than a drawback, since a potential proliferant cannot use a CANDU nuclear electricity program to justify acquiring an enrichment capability (although the new Advanced CANDU Reactor will use "slightly enriched uranium" which renders this argument moot). Moreover, most countries do not have their own heavy water production facilities for CANDU-type reactors, so they are reliant on imports that could be cut off if proliferation concerns arose. In short, as Bratt argues, "There is no consensus that the CANDU is a greater threat to non-proliferation than the LWR" (Bratt, 2006: 46).

Plutonium from any type of reactor thus poses a certain diversion risk. But a state bent on acquiring a nuclear weapon is more likely to attempt to build a clandestine dedicated plutonium production reactor to circumvent safeguards, as Syria is suspected of attempting to do, rather than attempt diversion from a power reactor under safeguards, which runs a high risk of being discovered. A benefit of a safeguarded peaceful nuclear energy program is that it may provide the industrial learning for a state to go on to build and operate a plutonium production reactor.

Familiarity with Handling Radioactive Material

Another benefit of a civilian nuclear program is learning how to handle radioactive material. The longer the material stays in a reactor, the greater the concentration of highly radioactive fission products and transuranic elements (Keeny et al., 1977: 246). The radioactivity of the material is several magnitudes higher than that of material produced in a dedicated plutonium production or research reactor and thus requires special handling in removing and deposition of the spent fuel in interim or long-term storage. All of the techniques involved in handling radioactive material from a dedicated plutonium production reactor can thus be learned by operating a power reactor, at least up until the reprocessing stage (Mozley, 1998: 56-63). However, diverting the plutonium from a civilian nuclear reactor and removing it from the fuel rods requires additional sophisticated techniques and technologies that are not derived from operating a power reactor. Even the high-capacity French commercial reprocessing plant reportedly had difficulty cutting up fuel rods to gain access to the plutonium (Miller, 2004: 49, fn 14).

Commercial reactor spent fuel is in fact considered to be so highly radioactive as to be "self-protecting," deterring access to the plutonium by terrorists and unsophisticated states. Since the uranium enrichment path to a nuclear device requires little exposure by personnel to radiation, this might be the preferred option for a proliferant state.

Access to "Sensitive" Technologies

The biggest barrier to a neophyte nuclear energy state seeking to use either uranium or plutonium from a power reactor for a nuclear weapon — besides the already formidable one of nuclear safeguards — is the difficulty of obtaining the necessary technology for enrichment and/or reprocessing.

Enrichment and reprocessing facilities are so far not widespread. The Nuclear Energy Agency (NEA) identifies 13 commercial enrichment facilities and five commercial reprocessing facilities worldwide (this excludes Iran's Natanz enrichment facility, which purports to be for peaceful purposes, but is suspected of being part of a weapons program, as well as India's research-oriented reprocessing facilities) (OECD/NEA, 2008: 57; Ramana, 2009). Germany, the Netherlands and the UK enrich uranium through the jointly owned company URENCO.

Commercial Sensitive Fuel Cycle Facilities, 2009

	Enrichment	Reprocessing
China	x	
France	x	x
Germany	x	
India		x
Iran	x	
Japan	x	
Netherlands	x	
Pakistan	x	
Russian Federation	x	x
United Kingdom	x	x
United States	x	

Source: Nuclear Energy Agency (2008: 57).

A succession of states have developed enrichment and reprocessing facilities — with greater or lesser outside assistance. India and South Africa exploited US and Canadian assistance to develop a reprocessing capability autonomously.[7] Although there was little direct transfer of sensitive fuel cycle technology designs or equipment, both states benefited from generous technical assistance and training, and there were only rudimentary safeguards, export controls or other constraints in place (Pilat, 2007). Until India's nuclear test in 1974, the advanced nuclear states were remarkably lax about restricting access to training and assistance in sensitive nuclear technology (US GAO, 1979). Pakistan, Israel and North Korea all had direct outside assistance in obtaining such technology.[8] Iraq pursued old calutron technology, information on which had been declassified. Brazil claims to have invented its own enrichment technology, although it is widely presumed to be based on URENCO designs provided by West Germany in the mid-1970s (Spector, 1988: 258). Iran benefited immensely from enrichment design information obtained through the A.Q. Khan network, while Libya had similar assistance but to less effect.

Open Acquisition of Sensitive Facilities

The vast majority of aspirant nuclear energy states will today not seek to obtain sensitive nuclear technology openly, at least not in the first couple of decades of commissioning their first nuclear reactor. Any state with only one or two reactors would immediately come under suspicion if it openly attempted to build an enrichment or reprocessing facility, even if it could obtain the necessary technology. It would be difficult for such a state to plausibly argue that it needed it, since it would be wildly uneconomic. (This has not stopped Iran from arguing, implausibly, for the need for 10 enrichment plants, even though it has no operational power reactor, and the only one being built, at Bushehr, will use imported Russian fuel.) Economies of scale suggest that any enrichment plant servicing less than about 10 1GW reactors would be uneconomic (Feiveson et al., 2008: 11). It has also been estimated that 75-100 percent of demand for enrichment services to 2030 will be satisfied by existing capacity, while demand for reprocessing services will be completely catered for by the existing over-capacity that is likely to persist into the future (ICNN, 2009: 139). France, Russia and the UK, which have the greatest commercial reprocessing capacities, have had declining numbers of customers for years.

Obtaining a nuclear power reactor does not impart any particular capability to move on to developing so-called sensitive technologies, either for the front (enrichment) or back (reprocessing) ends of the nuclear fuel cycle, so the capability would have to be acquired from abroad or indigenously developed. Emerging nuclear energy states are today unlikely to openly gain access to the technology. Transfers of sensitive technology are now tightly controlled and the controls are likely to get even tighter. The G8 countries currently have in place an informal moratorium on transfers of sensitive technologies, but this is likely to be replaced in the Nuclear Suppliers Group (NSG) by a criteria-based approach that would permit only the most nonproliferation-compliant states to qualify (see below for further analysis). Even then, an importing state is likely to receive the technology in a "black box" — meaning it can use the technology, but not obtain access to how it works.

The larger issue is not that emerging states will seek sensitive technology in the near future, but that several of the existing nuclear energy states without such capabilities, but with ambitious plans for more nuclear reactors, may do so. Their motivations may include a perceived need for energy security or to prove their technological prowess, or simply to have access to the entire nuclear fuel cycle as an "inherent right." Some states may persist with such technology despite the fact that domestically it may be uneconomic (depending on how many reactors they have) and that, if they wish to enter the global commercial market, they will face significant barriers to entry. States with large deposits of uranium, for instance, such as Australia, Canada, Kazakhstan and South Africa, have reserved their right in principle to enrich such material to "add value." Argentina and Brazil are reportedly planning a joint enrichment plant.

It is therefore imperative that a solution be found that permits access to the benefits of sensitive technology without damaging the nonproliferation regime. If additional existing nuclear energy states start acquiring the full nuclear fuel cycle, it will be much more difficult to dissuade the newcomers from following suit.

Clandestine Development of Sensitive Technologies

Emerging nuclear energy states with a moderate industrial capacity may be able to develop sensitive technologies relatively independently, but today they would have to do so entirely clandestinely, drawing on their existing nuclear expertise, information in the open literature, blueprints that proliferated as a result of the A.Q. Khan network, illicit imports of materials and technology, and by engaging the services of knowledgeable foreign personnel. Direct education and training in sensitive fuel cycle technologies has declined since the 1960s as a result of proliferation concerns, although it is difficult for those providing the training to draw a sharp line between what is sensitive and what is not.[9] As noted above, tightening export controls on transfers of sensitive technology make any clandestine effort much more difficult than in the past, but the movement of expert foreign personnel is less easily restricted.

On the enrichment side, the proliferation of knowledge and even blueprints for basic gas centrifuge technology to several proliferant states and unknown other recipients may benefit future proliferators. The original URENCO centrifuge design, the one first built in Pakistan by A.Q. Khan (the P1 and P2), is the logical "starter" technology for countries that might have trouble making more sophisticated models (Miller, 2004). More machines are needed than for more advanced designs, but once the technology is mastered they can be mass produced. A report by the Nonproliferation Policy Education Center in 2004 claims that "building and operating small, covert reprocessing and enrichment facilities are now far easier than they were portrayed to be 25 years ago" (Gilinsky et al., 2004: 3). A key reason is the increasing availability of centrifuge technology which permits HEU to be made with "far less energy and in far less space than was required with older enrichment methods," notably gaseous diffusion. This also makes them harder to detect. While confidence in the IAEA's ability to detect illicit HEU production at declared plants has improved dramatically since 1995 with the introduction of sampling and analysis at plants, along with wide area environmental sampling, the detection of small undeclared plants is more difficult because of their smaller "footprint" and likely minute radioactive emissions (Miller, 2004: 38-39). The question then turns on how sophisticated a state needs to be to construct a small, hidden plant.

A developing country acquiring one or two reactors is unlikely to be able to construct and operate its own enrichment plant, clandestinely or not. Even a relatively advanced country like Iran, which has been covertly seeking a nuclear weapon option for the past 20 years, is having trouble maintaining the smooth operation of relatively basic models as well as in deploying advanced ones. Centrifuge technology is inherently difficult to master. As the IPFM notes, studies of national centrifuge development programs suggest it takes 10-20 years to develop the basic, first generation technology, although this is being reduced as key technologies for producing the precision components required are increasingly available worldwide and are being integrated into computer-controlled machine tools (IPFM, 2009: 105).

Laser-isotope separation (LIS), which also has low energy requirements and is even more efficient than centrifuge technology, making it faster and easier to hide, could pose a greater future proliferation risk. In 2006, General Electric and Hitachi acquired an Australian laser enrichment process, SILEX, and is planning to build a large enrichment plant based on this process in the US. As IPFM notes, if this succeeds other states may follow (IPFM, 2009: 105).

As for reprocessing, the standard technology (PUREX, for plutonium/uranium extraction) is well known and relatively simple (compared to enrichment). As Marvin Miller notes, although details about how PUREX technology is implemented in specific plants is sometimes closely held for proprietary and/or national security reasons, the basic technology was declassified for the First Atoms for Peace Conference in Geneva in 1955 (Miller, 2004: 44). Since then it has been described in detail in numerous reports and books and disseminated through training programs, including those sponsored by government agencies such as the former US Atomic Energy Commission. Even so, replicating this reprocessing technology unassisted is probably beyond the capability of all of the smaller developing states currently seeking nuclear energy for the first time. However, as Miller puts it, "The fundamental question that needs to be addressed is whether a country with a modest industrial base and a nuclear infrastructure sufficient to operate an LWR can build and operate a clandestine plant to reprocess diverted LWR fuel using the PUREX process" (Miller, 2004: 45).

US expert studies since the 1950s have reportedly demonstrated the feasibility of "quick and dirty," small, clandestine reprocessing plants specifically for separating plutonium for weapons purposes. A 1977 study at Oak Ridge National Laboratory by Floyd Cutler, one of the developers of the PUREX technology, produced a design for a minimal LWR spent fuel reprocessing plant that would operate for just several months. It would take 4-6 months to build and could produce about 5kg of plutonium, one bomb's worth, daily (Miller, 2004: 48-50.). The US General Accounting Office queried some of the assumptions of the study, but not the estimated construction time. In 1996, a Sandia National Laboratories team designed a minimal reprocessing plant that could be built in about six months, with an additional eight weeks needed to produce its first significant amount of plutonium (8kg). It suggested that six skilled and experienced people would be required, readily available from nuclear weapon states or, notably, states with nuclear power plants. Although expert opinion is by no means unanimous on the feasibility of these schemes — only American studies have been considered here — and there is continuing doubt as to how sophisticated a state would need to be to succeed in implementing them, they nonetheless should give pause. Such possibilities, however remote, indicate the need for continuous review of received wisdom about the proliferation resistance of all types of nuclear technology and of the adequacy of nuclear safeguards — especially given the likelihood of additional states acquiring nuclear energy programs.

In conclusion, a peaceful nuclear energy program can be part of a state's trajectory towards acquiring the wherewithal for a nuclear weapons program, but it is neither necessary nor sufficient. The main benefit to be derived from obtaining one or more power reactors, operating under nuclear safeguards, for nuclear weapons "hedging," is the acquisition of nuclear expertise, training, material and infrastructure that would be difficult, if not impossible, to camouflage in a secret program. Having a civilian nuclear energy program does not remove the significant obstacles to acquiring fissile material for a nuclear device, nor does it provide the capability to weaponize and deliver a nuclear bomb.[10] A civilian nuclear energy program may provide some opportunities for fissile material diversion, however unlikely, rendering the spread of peaceful nuclear energy not entirely risk-free from a proliferation standpoint.

Since a complete ban on the use of nuclear energy for peaceful purposes is totally impractical, the role of the global nonproliferation regime, notably safeguards, is two-fold: to make misuse of and diversion from the civilian fuel cycle more difficult, time-consuming and transparent; and to detect and expose at the earliest point possible the development of a clandestine weapons program. As in the case of the fight against global terrorism, the nonproliferation regime needs to keep ahead of the ingenuity of those who would misuse technology intended for peaceful purposes.

The Global Nuclear Nonproliferation Regime

The Nuclear Non-proliferation Treaty

The Nuclear Non-proliferation Treaty is the founding international legal instrument, apart from the IAEA Statute itself, of the nuclear nonproliferation regime. The treaty was negotiated in the 1960s in the then Eighteen-Nation Disarmament Committee (the predecessor of the current Conference on Disarmament). It was opened for signature in 1968 and entered into force in 1970. The treaty established in international law the underlying premises of Atoms for Peace. First, in return for assistance in the peaceful uses of nuclear technology, the non-nuclear weapon states (NNWS) would not seek to acquire nuclear weapons. Second, their compliance would be verified by the IAEA, through nuclear "safeguards," and be subject to consequences in case of non-compliance, ultimately through referral to the UN Security Council.

The NPT also prohibited the five designated existing nuclear weapon states (NWS) — China, France, the Soviet Union, the UK and the US — from assisting NNWS to acquire nuclear weapons and called in Article VI for "negotiations in good faith" by all NPT parties (but by implication especially the NWS) to achieve nuclear disarmament. Since it was drafted by the three major nuclear powers of the day, the US, the UK and the Soviet Union, all of which subsequently resisted major changes by the NNWS, the commitment to nuclear disarmament is the weakest part of the treaty.

Over the decades the NPT has proved its worth, helping avoid the world of 20-plus nuclear weapon states predicted in the 1960s, and gradually attracting parties to the point where it is today almost universal, albeit with three significant remaining "holdouts" — India, Israel and Pakistan — and one withdrawal, that of North Korea. In 1995, the treaty was extended indefinitely. Despite periodic warnings of its imminent demise it has endured, essentially because of the security benefits it confers on its members (although these seem to be under constant debate).

However, serious cases of non-compliance — Iraq, North Korea, Libya and Iran — have undermined confidence in the treaty. Just as insidious has been growing dissatisfaction with the NPT's arbitrary and apparently permanent concretization of two classes of states: those that had detonated a nuclear device before January 1, 1967 — which also happened to be the permanent members of the Security Council — and those which had not. Over the years the lack of progress towards complete nuclear disarmament (despite significant cuts in nuclear weapons since the Cold War ended), and the lack of accountability of the NWS in meeting their Article VI obligations, has increasingly put the NPT and the IAEA under strain. Attempts to constantly strengthen nuclear safeguards draw opposition not just because of concerns over costs, intrusiveness and commercial competitiveness, but also because the NNWS feel that the nuclear weapon states have not lived up to their side of the NPT's grand bargain and that the burdens of the treaty are being borne disproportionately. This view is shared not just by the radical nonaligned, but by all of the states which foreswore nuclear weapons on the basis that every state would do so.

But it is not just the disarmament obligations that are problematic. Unadvisedly, Article IV of the NPT purports to grant all parties the "inalienable right" to "develop research, production and use of nuclear energy for peaceful purposes without discrimination." But that right is not inalienable, even within the terms of the NPT itself, since it is subject to compliance with Articles I and II. These Articles ban the provision of assistance to the NNWS to help them acquire nuclear weapons and prohibits their acceptance of such assistance. Article IV also does not commit any particular state to share its own nuclear technology with any other. But these niceties tend to be ignored by the more radical developing states that rail against verification, export controls and the alleged stinginess of technical assistance in the peaceful uses of nuclear energy. Among the states that take this tack from within the regime are Cuba, Egypt and Iran, while India and Pakistan have long berated it from without. More moderate states like Algeria, Brazil and Malaysia also echo this line, as does the nonaligned group as a whole. Iran is currently seeking to take full advantage of its "inalienable right" in arguing that there should be no constraints on its uranium enrichment program.

Exacerbating the situation, the NPT contains a loophole: a state can acquire all of the elements of the nuclear fuel cycle — from uranium mining to enrichment and reprocessing — as long as it declares them and subjects them to safeguards. But on six months' notice it may withdraw from the treaty on national security grounds and move immediately to acquire nuclear weapons. Withdrawal from the treaty could, in such a case, be perfectly legal. North Korea's abrupt departure from the NPT in 1993 was a case in point (although some states dispute its legality). Proposals have been made in recent years to close this loophole to prevent states from violating the treaty and withdrawing without consequence.[11]

Five yearly NPT review conferences are typically the arena where these abiding controversies over compliance with and implementation of the NPT erupt. Some conferences are perceived to have advanced the cause of nonproliferation, such as the 2000 Review Conference, which produced the politically binding Thirteen Practical Steps agreed as being the most important to be taken on the road to nuclear disarmament (UN, 2000). The administration of former President George W. Bush renounced US commitment to the document, as well as taking measures, such as withdrawal from the 1972 Anti-Ballistic Missile Treaty and refusal to support the 1999 Comprehensive Nuclear Test Ban Treaty (CTBT), that were regarded as backward steps. The most recent review conference, in 2005, ended in acrimony, without any final document. Not only the lack of progress in nuclear disarmament, but disputes about the Middle East and the Iranian and North Korean non-compliance cases played their part. Preparations are currently underway for the 2010 NPT Review Conference, with mixed expectations of success. Although President Barack Obama has signaled a new US commitment to nuclear disarmament and the NPT regime in general, this may be insufficient to balance the continuing stalemate over Iran and North Korea and enduring issues such as the Middle East nuclear weapon-free zone.

Nuclear Weapon-Free Zones

Among the most important of the additional legal instruments in the nonproliferation arena are the nuclear weapon-free zone (NWFZ) agreements that now cover a significant portion of the globe (de Jong and Froklage, 2009). They comprise the following:

- The 1967 Treaty of Tlatelolco, which created the world's first NWFZ, for Latin America and the Caribbean
- The 1986 Treaty of Rarotonga for the South Pacific
- The 1995 Treaty of Bangkok for Southeast Asia
- The 1995 Treaty of Pelindaba for Africa, and
- The 2005 Treaty of Tashkent for Central Asia.

In addition, Mongolia declared itself a nuclear weapon-free zone in 1992 (it entered into force in 2000). The 1950 Antarctic Treaty also forbids the deployment of nuclear weapons in the Antarctic. The 1967 Outer Space Treaty prohibits the stationing of nuclear weapons in outer space, on the moon or on other celestial bodies, while the 1971 Seabed Treaty prohibits the emplacement of weapons on the seabed.

While the nuclear weapon-free zones have some variation in their provisions, mostly relating to nuclear transit, nuclear dumping and nuclear security, they largely follow the same pattern. In terms of the peaceful uses of nuclear energy, all rely on IAEA safeguards to verify non-diversion to military purposes. All of them have separate compliance mechanisms for dealing with allegations of non-compliance, but all are notably weak from the perspective of governing institutions. While the Latin American zone has a small dedicated Secretariat and the African zone envisages establishing one, the rest rely on existing regional organizations. All of the zones have protocols open to accession by the nuclear weapon states, inviting them to provide assurances that they will respect the zone. While NWFZs do not substantially alter the obligations of non-nuclear weapon states party to the NPT, they do provide regional reinforcement of nonproliferation norms and compliance expectations.

The major regions not covered by nuclear weapon-free zones are Europe, East Asia, South Asia and the Middle East. Seventeen of the states identified by this project's Survey of Emerging Nuclear Energy States (SENES) are not included in such zones, either because zones do not exist in their region or because they have not yet joined. They are: Albania, Bahrain, Bangladesh, Belarus, Iran, Italy, Jordan, Kuwait, Morocco, Namibia, Oman, Poland, Qatar, Saudi Arabia, Syria, Turkey and the UAE. Morocco and Namibia have signed the Treaty of Pelindaba, but are not yet parties.

The International Atomic Energy Agency

The principal organizational embodiment of the nuclear nonproliferation regime is the International Atomic Energy Agency, which was established in 1957 as a direct outcome of Eisenhower's Atoms for Peace proposal. As a specialized Agency of the United Nations, the Agency is governed by its own, 35-member Board of Governors (BOG), elected on a global and regional basis by the General Conference of member states. Those elected always include the 12 "quasi-permanent" members considered the most advanced in nuclear energy when the Agency was formed.[12]

As an organizational instrument of global governance, the rise of the IAEA seems exemplary. Its membership has expanded from the 54 states that attended the First General Conference in 1958 to 151 members today. Its budget has increased from $3.5 million to $444 million (€315 million) in the same period, with an additional $158 million (€113 million) in extra-budgetary contributions for 2010 (IAEA, 2009f). The total number of support and professional staff has likewise grown from 424 to 2,326 (IAEA, 2009b; Fischer, 1997: 497-498). While in the IAEA's first three years of existence it applied safeguards solely to three tons of natural uranium supplied by Canada to Japan (Fischer, 1997: 82), by 2008 it had 237 safeguards agreements with 163 states, applicable to 1,131 facilities. In the same year it conducted 2,036 on-site inspections. Its Technical Cooperation (TC) program has grown from $514,000 in 1958 to $194 million (€139 million) for 2010. The IAEA is also regarded as one of the most efficient and well-managed UN agencies. The 2004 UN High-Level Panel on Threats, Challenges and Change declared that the IAEA "stands out as an extraordinary bargain" (UN, 2004: 18). In 2006, the US Office of Management and Budget gave it a virtually unprecedented rating of 100 percent in terms of value-for-money (US Office of Management and Budget, 2006).

The IAEA's Mandate

According to its Statute, the Agency's objective is to "seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world" (Article II). In doing so, "It shall ensure, so far as it is able, that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose." To this end the Agency was authorized to "establish and administer safeguards" (Article III.5), including for "special fissionable and other materials," notably plutonium and highly enriched uranium, both of which could be used to make nuclear weapons. Safeguards would involve not just nuclear accounting, but on-site inspections by international officials (Scheinman, 1987: 35). The Statute permits the Agency to "apply safeguards, at the request of the parties, to any bilateral or multilateral arrangements, or at the request of a State party, to any of that State's activities in the field of atomic energy" (Article III.A.5).

The original idea of a physical IAEA fuel "bank," from which the Agency would supply nuclear materials for peaceful purposes, did not eventuate at the time (although it has recently resurfaced). Instead, nuclear-capable states began to provide fuel and technology, including research and power reactors, direct to other states under bilateral arrangements that would, increasingly, be subject to IAEA safeguards. Meanwhile, the new Agency geared up to provide technical assistance in peaceful uses, which would also be under the "safeguards" that it set about inventing.

One of the legacies of the IAEA Statute that has troubling implications for the current revived interest in nuclear energy is the Agency's dual role of promoting and regulating nuclear energy. As national nuclear agencies such the US Atomic Energy Commission (1954-1974) discovered, such organizational schizophrenia can be vexing (Campbell, 1988: 69). In the IAEA case, its directors-general are obliged to be enthusiastic about the spread of nuclear power to any country that desires to have it, while also being harbingers of nuclear catastrophe if safety, security and safeguards are not taken into account and continually strengthened (ElBaradei, 2007).

The Agency's dual mandate has also manifested itself in continuous political and budgetary battles. From the outset, developing states have broadly seen the Agency's value primarily as a provider of technical assistance, while the developed states have focused more on its verification role in preventing the proliferation of nuclear weapons (although not always as enthusiastically as might be expected). As verification has intensified over the years, so have arguments about its intrusiveness, appropriateness and cost. Sensing that verification could not be avoided entirely, the developing states have adopted the tactic of linking increases in the verification budget to increases in the technical cooperation program.

Impact of the NPT

Negotiated more than a decade after the IAEA Statute, the NPT has been both a boon and a complication for the IAEA. In handing the Agency the task of verifying compliance with the nonproliferation obligations of state parties, it gave the organization its true raison d'être and the primacy in nuclear governance that it enjoys to this day. Yet the NPT has also crimped the potential of the Agency by exposing it to the enduring structural flaws of the nonproliferation regime.

One significant difficulty for the IAEA is that the NPT created disjointed governance of the nonproliferation regime. Verification of compliance by the NNWS was given to the IAEA, but non-compliance by the NWS with their disarmament obligations was left in institutional limbo (except for the five yearly NPT review conferences). There is no verification organization or even a secretariat for the

NPT as a whole. Hence, while the treaty led to the imposition through the IAEA of ever-increasing verification burdens on NNWS, including compliant states of no concern like Canada, the NWS were largely unburdened. Worries expressed during the NPT negotiations that the NNWS would be put at commercial and industrial disadvantage were met with "voluntary offers" by the NWS to put some of their facilities under safeguards (US ACDA, 1982: 85). In practice, the IAEA has had neither the resources nor inclination, given its other priorities, to implement such essentially token gestures. Yet although the Agency currently lacks the authority to verify compliance with the nuclear disarmament obligations of the nuclear weapon states, it is well placed to do so, if asked, in respect of safeguarding the large amounts of fissile materials that are likely to result from such a process.

Nuclear Safeguards

It is a miracle of global nuclear governance that despite the complications outlined above, IAEA nuclear safeguards have become increasingly authoritative, intrusive and significant in terms of the voluntary surrender of sovereign national prerogatives that they represent. Despite the annual battles over budgets and the outright opposition of some member states to any improvements, considerable strengthening has occurred over the years. There has in fact been continual bolstering of global governance in this area, through a combination of accretion of new parties to the NPT, creeping tightening of safeguards requirements by the Secretariat and the Board of Governors and periodic explosions of reform agreed by consensus in response to crises.

Early Safeguards

In the early years most IAEA safeguards resulted from transfers of bilateral safeguards arrangements to the Agency, notably those between the US and recipients of its Atoms for Peace largesse. Such so-called INFCIRC/26 safeguards, described as "technically amateurish" (Büchler, 1997: 48), applied only to the specific materials and facilities transferred, mostly small research reactors. After the Soviet Union became more favourably disposed to safeguards, a more elaborate and intrusive model was possible, based on document INFCIRC/66/Rev.2 (IAEA, 1968), drafted by the Secretariat and approved by the BOG in 1965. Some of these early agreements survive, despite the subsequent evolution of the safeguards regime, most notably those applied to select facilities in the three states that have never joined the NPT — India, Israel and Pakistan.[13]

Comprehensive or Full-Scope Safeguards

The real revolution came with the NPT, which imposed a multilateral obligation on the NNWS to declare and place all of their nuclear materials, facilities and activities (which by definition would all be for peaceful purposes) under IAEA safeguards — hence the terms "full-scope" or "comprehensive" safeguards. The NPT required the negotiation by each state party of a bilateral comprehensive safeguards agreement (CSA) with the Agency to govern the application of safeguards to that state. These were based on frameworks and models developed by the Agency, approved by the BOG in 1972 and encapsulated in document INFCIRC/153 (IAEA, 1972).

Such safeguards seek to provide reasonable assurance of the timely detection of a "significant quantity" of declared "special" nuclear material (notably enriched uranium and plutonium) being diverted from peaceful uses to nuclear weapons production.[14] Verification is accomplished though nuclear accountancy, on-site inspection by a standing IAEA inspectorate and technical means. New safeguards concepts introduced by INFCIRC/153 included: "subsidiary arrangements" that specify how safeguards are to be applied in each state; a focus on "strategic points" where verification might be most revealing; the use of instrumentation and non-human inspection techniques (today this increasingly involves remote monitoring using video cameras); recognition of surveillance and containment as important complements to material accountancy; and a requirement that each country establish a State System of Accountancy and Control (SSAC).

Such safeguards have themselves been quietly strengthened over the years by BOG fiat and Secretariat practice, to the applause of states that support safeguards and to the chagrin of those that wish to minimize them. The Indian nuclear test in 1974, although not a violation of an IAEA safeguards agreement, led to the establishment in 1975 of the 20-member Standing Advisory Group on Safeguards Implementation (SAGSI), which has subsequently recommended many technical improvements to safeguards. Despite grumblings about the cost and the perceived unfair safeguards burden on states with substantial peaceful nuclear industries like Canada, Germany and Japan, the legitimacy of the system was, until the early 1990s, increasingly accepted by Agency members and its efficacy taken for granted. The Secretariat was able to report annually to the Board that it had no indication that there had been diversion of nuclear materials from peaceful to military purposes by any state (although there have been subsequent revelations of relatively minor but still troubling violations by Egypt, Romania, Taiwan and South Korea).[15]

Strengthened Safeguards Post-Iraq

This complacency was shattered with the revelation after the 1990 Gulf War that Iraq had been clandestinely mounting a nuclear weapons program in parallel with its IAEA-inspected peaceful program. The IAEA's failure to detect Iraqi activities, located in some cases "just over the berm" from where inspectors regularly visited, brought ridicule from those who misunderstood the limitations of its mandate and despair on the part of safeguards experts who had for years feared this outcome. As former Australian ambassador to the IAEA, Michael Wilson, lamented: "in the enthusiasm to find an obvious and defenceless scapegoat, the Agency was perceived to be complacent and unobservant. The limitations on safeguards inspections, whose principles had been agreed by governments, were either disregarded or apparently not understood" (Wilson, 1997: 130).

The most fundamental problem was that the IAEA could only monitor and inspect materials and facilities formally declared to it by states. This provided would-be proliferators with the latitude to develop substantial undeclared nuclear capabilities undetected, either co-located with declared facilities or completely separate. A further difficulty was the reliance on nuclear accountancy as the principal tool for detecting non-compliance with safeguards and, in turn, dependence on safeguards themselves as the key tool in detecting non-compliance with the NPT. Political limitations placed on the design of nuclear safeguards in the early years had led to a presumption of compliance and a conservative safeguards culture that ultimately proved unable to detect serious violations. The Agency felt it could not use all of the powers it had acquired, including "special inspections"; it tended to ignore unofficial information or indicators of proliferation beyond diversion, notably weaponization activities (Acton and Newman, 2006) and nuclear smuggling; and it failed to take a holistic view of states' activities.

Arms controllers had argued for years about whether the IAEA could, within its mandate, use all of the verification tools possible to verify that a state party was not engaged in a nuclear weapons program, or whether it was restricted to simply verifying that there had been no diversion of peaceful nuclear materials to weapons purposes. In any event, until the 1990s the IAEA did not have the tools, even if it had had the inclination, to go beyond the latter. (To be fair, even states like the US that had such tools, such as satellite imagery and active intelligence services, had missed Iraq's illicit activities.)

It is true that the IAEA had always had the right to request a so-called special inspection (the equivalent of a "challenge" inspection in other disarmament regimes) where there was a strong suspicion of malfeasance. But political constraints, often combined with a lack of incriminating data as a credible basis for a challenge, meant that such inspections were never initiated. The Board, post-Iraq, reiterated its right to seek special inspections, but it soon found on its first attempt to launch one — in North Korea in 1993 — that it was peremptorily refused (IAEA, 2003a).

Following revelations of the Iraqi program, the IAEA managed to redeem itself in the eyes of many critics by the professional manner in which it verified the extent of Iraq's non-compliance and assisted it in destroying its nuclear infrastructure in accordance with UN Security Council demands.[16] The Agency scored another victory, in 1992, by being the first to detect North Korea's non-compliance with its new safeguards agreement by calculating that the country's declarations of its plutonium production were improbably low (IAEA, 2003a). However, it missed non-compliance by Libya that was not publicly revealed until December 2003 through the efforts of the UK and the US (Boureston and Feldman, 2004).

A direct consequence of the Iraq case was relatively quick agreement by the BOG on the so-called 93+2 program, under which the Secretariat was mandated to examine the legal, technical and financial aspects of strengthened safeguards and make recommendations to the Board. Pro-safeguards members, in league with Secretariat personnel who had long sought to strengthen their verification tools, were able to use the window of opportunity of Iraq's blatant violation to push reform through to an extent that was previously unthinkable. The result was a two-part program of strengthened safeguards.

Part One comprised measures that the Board concluded the Agency already had the legal authority to undertake and which could be implemented immediately. These included requesting additional information on facilities that formerly contained safeguarded nuclear materials, but which no longer did so; increased remote monitoring of nuclear material movements; expanded use of unannounced inspections; and environmental sampling at sites to which the Agency already had access. In addition, the Agency was able to expand its use of open source information, including satellite imagery (increasingly available commercially at cheap rates), as well as accepting intelligence information from member states. Part Two involved negotiating a supplement to states' comprehensive nuclear safeguards agreements that would provide legal authority for further safeguards measures.

The Additional Protocol

It took until May 1997 for the BOG to agree on the so-called Model Additional Protocol. By this stage, the shock of Iraq was wearing off and members were resuming their previous knee-jerk reactions to reform. Nonetheless, the Protocol provides for increased transparency by extending the obligations of states to declare, report and grant on-site access to the entire range of nuclear fuel cycle activities — from mining to the disposition of nuclear waste. The Protocol also requires states to report nuclear-related equipment production, nuclear-related imports and exports, nuclear fuel cycle-related research and development, and future plans for nuclear facilities. This enables the IAEA to develop a holistic view of states' nuclear activities, as opposed to one based solely on materials and facilities — quite a turnaround from the previous system. As former Director General ElBaradei noted, "Strengthened safeguards facilitate the Agency's new-found objective of providing credible assurance not only about declared nuclear material in a State but also about the absence of undeclared nuclear material and activities" (IAEA, 2002: 2).

A major challenge faced in implementing the Additional Protocol is that it is voluntary, making it likely that only states intent on complying will adopt one without pressure. The Agency has undertaken significant efforts to promote accession, including regional workshops, but progress has been slow (IAEA, 2008f). There have been accumulating calls for the Board to make the Protocol the safeguards "gold standard" and even make it compulsory, but there is also strong opposition to such a move. In practice, increasing numbers of states are adopting a Protocol, to the point where it is starting to become the norm.

Small Quantities Protocol

Some states continue to have a Small Quantities Protocol (SQP), which holds in abeyance comprehensive safeguards obligations, including declarations and inspections, while nuclear activities remain under a certain low threshold (IAEA, 1974). Controversy over SQPs arose when Saudi Arabia, a SENES state with nuclear energy ambitions, sought one.[17] In September 2005, the Board directed the Agency to begin renegotiating with SQP states to restore at least some of the IAEA's powers, based on a revised model agreement (IAEA, 2006). States with existing SQPs were invited to exchange letters with the IAEA to trigger implementation of the new model, while all future SQPs will be based on the new one. This would oblige states to submit a declaration of their nuclear holdings, however small, which in turn forces them to institute a State System of Accounting and Control. This should be especially useful in strengthening national measures to avoid theft and illicit trans-shipments of nuclear material (Lodding and Ribeiro, 2007: 1-4). But the initiative is, again, dependent on the goodwill of the states concerned and is proceeding slowly. Ideally, all states seeking nuclear energy should as soon as possible swap their SQP for an Additional Protocol.

Integrated Safeguards

In addition to strengthening safeguards, the Agency has also moved to rationalize the layers of safeguards imposed on states over the years, thereby increasing efficiency (and, it is hoped, effectiveness) by instituting the concept of Integrated Safeguards (Boureston and Feldman, 2007). This is partly a reward for punctilious compliance with all aspects of safeguards, including the Additional Protocol, as candidate states must undergo rigorous examination (and cross-examination) before qualifying. An unspoken benefit for the IAEA is that its verification resources can be devoted to other more productive purposes, allowing it to spend more time on state evaluation using information from all possible sources rather than activities in the field. By the end of 2009, "savings" of approximately 800 inspector days annually, or about 10 percent of the total, were being achieved (Muroya, 2009). In any one state, savings of 30-40 percent were possible (Muroya, 2009).

Current Participation in Safeguards

Despite the legally binding obligation of NPT state parties to have a comprehensive safeguards agreement in force, as of December 2009 there were 24 states that had not complied. These were mostly African and small island states. However, 14 of these states had at least signed a CSA and another two had had their draft agreements approved by the BOG. States cannot adopt an Additional Protocol until they have a CSA in place.

As of December 2009, 93 states had an Additional Protocol in force, 34 had signed one and another eight countries' agreements had been approved by the BOG (IAEA, 2003). Several states with significant nuclear activities have not yet concluded an Additional Protocol, including Iran and North Korea. Iran, which applied its Additional Protocol on a "provisional basis" from December

2003, suspended its cooperation with the Agency under the agreement in 2005.

In terms of the nuclear revival, it is particularly alarming that two states with significant existing civilian nuclear power programs and plans for expansion, Argentina and Brazil, have refused to conclude a Protocol, arguing that they are already well "safeguarded" as a result of their CSAs, their bilateral safeguards arrangement and verification Agency — the Argentine-Brazilian Agency for Accounting and Control (ABACC) — and their membership of the Latin American Nuclear Weapon-Free Zone. However, in rejecting the new gold standard in safeguards, they are setting a poor example to nuclear energy aspirants and calling into question the nonproliferation credentials that they have relatively newly acquired after giving up their nuclear weapon plans in the 1980s (Davis and Findlay, 2009: 8). Brazil was worryingly slow in agreeing to safeguards for its enrichment facility. It could especially strengthen its case for great power leadership and permanent membership of the UN Security Council, and remove continuing concerns about its nuclear-powered submarine program, if it were to adopt an Additional Protocol. This would be at little additional cost (although Brazilian reluctance is reportedly due to concerns that additional verification would reveal where it obtained its centrifuge technology from).

As for the SQP, currently 64 states still have old versions in force, 32 have the new version in force, five others are in process of converting old ones to new ones and two, Jamaica and Morocco, have simply rescinded them without replacement.

As of January 2010, according to IAEA sources, almost 50 states had qualified for Integrated Safeguards, including all EU member states (IAEA,2010).

Current State of the Safeguards System

The strengthened safeguards system is a great improvement on previous arrangements, increasing considerably the costs and risks for a potential proliferator and raising confidence in the ability of the Agency to achieve timely detection. It has also, to some extent, liberated the IAEA from its past timidity, both mandated and self-imposed, and emboldened it to examine the entire range of signals of a proliferator's intentions. The Agency is deliberately collecting and analyzing open source information; improving its remote sensing capabilities; and accepting intelligence information from member states obtained through so-called National Technical Means (NTM),[18] while recognizing its limitations. It is also seeking to overturn some of the mechanistic aspects of inspection and other practices that in the past tended to lead to institutional blindness.

In 2002-2003, revelations of Iran's clandestine uranium enrichment program reinforced the view that the old safeguards system, which had failed to detect almost 20 years of non-compliance by Iran, was grossly inadequate. Although Iran initially said it would act as if it had an Additional Protocol in place, it has failed to do so. Notably, the building of a second uranium enrichment facility near the city of Qom should, under strengthened safeguards, have been notified to the Agency in the planning stage, not after construction was well under way. Nonetheless, in the case of Iran the Agency has been able to flex its newly won verification muscles by investigating evidence of weaponization and the link between Iran's military and its alleged peaceful nuclear program, something it previously would have felt was beyond its remit. Even though Iran has not been entirely cooperative, the extra information requirements and increased Agency powers resulting from strengthened safeguards, such as complementary access, have proved potent in providing leads for the Agency to pursue through requests for further information and follow-up inspections. Environmental sampling has also proved illuminating, as has the provision of intelligence information by member states. While strengthened safeguards have helped reveal the extent of Iranian duplicity missed by the old system, they also provide increased reassurance that in the future such non-compliance cases will be detected earlier. The current stand-off with Iran is not a failure of the current safeguards system so much as a failure of the mechanisms for dealing with non-compliance once it is discovered. Both the Board of Governors and the UN Security Council are to be faulted for this (see the "Compliance" section below for further analysis).

Yet the strengthened safeguards system, including the Additional Protocol, still leaves the IAEA a long way from the essentially "anytime, anywhere" verification envisaged in its Statute.[19] The new provision for "complementary access" to sites near regularly inspected ones requires at least 24 hours' notice. If inspectors are already at the site in question, they must give two hours' advance notice. There is still a possibility that undeclared facilities could go undetected even with the Additional Protocol in force in a potential proliferant state. A demand for a special inspection remains an extraordinary, highly politicized option that the BOG has remained reluctant to use, even in a case like Syria. The Syrian government has refused to grant the Agency the necessary access or provide it with sufficient information to clarify whether it was building a nuclear reactor before Israel bombed the alleged site in October 2007. A state bent on non-compliance will take active measures to conceal its activities, including disinformation and delaying tactics of the type that both Syria and Iran have deployed.

This implies the need for further improvements to safeguards — an "Additional Protocol-plus" as it has been called by some. It also implies that the Agency cannot be expected by itself to furnish 100 percent reassurance, but that it must be assisted by regional organizations, technologically advanced member states (in the provision of sophisticated intelligence information, with of course the usual caveat about not revealing sources), research institutes (such as the Washington-based Institute for Science and International Security, which closely analyzes satellite imagery and other evidence) and non-governmental organizations (such as the London-based Verification Research, Training and Information Centre (VERTIC) which researches both the political and technical aspects of verification).

The Agency claims it is pursuing what it describes as "information driven" (IAEA, 2007b: 16) safeguards, supported by a modern "knowledge management system" (including a database that records the experiences of all safeguards inspectors). However, there remain concerns that the IAEA inspectorate's "culture" has still not entirely changed from one of examining a narrow range of information to one that considers each individual state's activities holistically. Further concerns have been expressed about the lack of transparency and openness within the Agency that permits vital information about state compliance to be too tightly held within certain offices, thereby defeating the purpose of the holistic approach (ICNND, 2009: 91-92). There is an optimal trade-off between confidentiality and transparency that many organizations find difficult to find and sustain. In this case, the Agency needs to be careful to preserve the confidentiality of information provided by states, in particular technical information that may assist a nuclear proliferator, and intelligence data derived from sensitive sources.

Other IAEA Nonproliferation-Related Activities

The discovery in 2002-2003 of a global illicit nuclear smuggling network operated by Pakistani nuclear program director A.Q. Khan gave the IAEA the impetus and licence to probe such activities, both in an attempt to unravel the A.Q. Khan case and to detect new ones. After working at the URENCO enrichment plant in the Netherlands for several years Khan had used the training he received and the blueprints he stole to spearhead an enrichment program in Pakistan, ultimately leading to its acquisition of nuclear weapons. Subsequently he set up an international smuggling network to provide Iran, Libya and North Korea with various degrees of illicit nuclear assistance, including blueprints for Iran's enrichment program (Hibbs, 2008: 381-391). The Libyan case in particular revealed a widespread international nuclear procurement network that traditional nuclear safeguards and other verification tools were unable to detect (although the Additional Protocol does help by providing information related to manufacturing of sensitive equipment, exports of specialized equipment and material, and nuclear-related imports).

In response, the IAEA established in 2004 an "elite investigative" group, the Nuclear Trade and Technology Analysis (TTA) Unit in the Department of Safeguards, tasked with centralizing all information available to the Agency in order to track known smuggling networks and endeavour to detect new ones. The unit monitors, with the help of some states and companies, refusals of suspicious import enquiries and orders, with the aim of detecting patterns and linkages. It also maintains the IAEA's institutional memory on covert nuclear-related procurement activities. The information gleaned by the unit may be used to support verification, including the preparation of state evaluations, a core safeguards activity.

However, the TTA Unit needs greater cooperation from IAEA member states and companies and greater financial and personnel support, including additional expert analysts, if it is to realize its full potential. As in the case of the related Illicit Nuclear Trafficking Database (see PArt 3 of this report), the unit is probably receiving information on only a fraction of the cases that are actually occurring. In 2006 the Agency launched an outreach program to states, seeking nuclear-trade-related information from them on a bilateral voluntary basis. Although by the end of 2007 some 20 states had been contacted, only several are providing information (Tarvainen, 2009: 63). Charles Ferguson argues that intelligence agencies, while protecting sources and methods, could and should share more information with the IAEA. He points out that "the CIA penetrated Khan's black market but kept the IAEA in the dark about this activity for years" (Ferguson, 2008). David Albright, in testimony before the US House of Representatives Subcommittee on Terrorism, Nonproliferation and Trade also contended that the work of the TTA Unit is not integrated into the IAEA's normal safeguards operation. Integration would, he claims, "dramatically increase the chances of detecting and thwarting illicit nuclear trade, while improving the ability of the IAEA to detect undeclared nuclear facilities and materials" (Albright, 2007).

In addition to the TTA Unit, the Agency's Safeguards Information Management directorate has two small units that have quasi-intelligence functions, one that analyzes open source information and another that assesses imagery. The former head of the directorate has called for a more professional, targeted IAEA "intelligence" capability, but many member states would be wary of such a venture (Grossman, 2009).

As described in the nuclear security section of this report, the Agency has also greatly expanded its assistance to states in preventing nuclear smuggling networks under a series of action plans which provide, inter alia, capacity building, security reviews and models for national implementation legislation as now required under UN Security Council Resolution 1540.

Current Institutional State of the IAEA

Despite the IAEA's importance to international security, this apparently prized Agency has been unable to secure the necessary material and financial support that it warrants.[20] Many states, even those with strong nonproliferation policies, show a surprising degree of parsimoniousness towards the organization when it comes to budgetary and other backing. An external management review by a consultancy company conducted in 2002 concluded that, despite its efficient management of resources, the IAEA was showing "signs of system stress" and could not sustain its achievements or respond to increasing demands without concomitant increases in resources.[21] Given the Agency's critical role in nuclear safety, security and nonproliferation worldwide, this is intolerable.

Finances

The IAEA was unable to avoid the zero real growth budgeting imposed on all UN agencies from the mid-1980s onwards. Although this may initially have helped make the Agency "leaner and meaner," in more recent years it began to seriously threaten its effectiveness. Since 1985 the IAEA has been dependent on extra-budgetary contributions, including from a non-governmental organization, the Nuclear Threat Initiative (NTI), to keep pace with growing demands for safeguards. Even the Agency's nuclear security program established in 2002 after 9/11, which should be a quintessential core function, is 90 percent funded from extra-budgetary resources (IAEA, 2008d: 29). With the support of the Bush administration, the Agency did gain a one-off increase of 10 percent in 2003, but this was phased in over 2004-2007 (IAEA, 2003b: 2).

In the final years of Director General ElBaradei's tenure (which ended in December 2009), there was a sense of financial crisis at the IAEA. In June 2007, he decried the Board's refusal to approve a requested increase of 4.6 percent in the annual budget, warning that the Agency's "safeguards function" was being "eroded over time" (Borger, 2007). In June 2008, he reportedly told the BOG that the proposed 2008 budget did not "by any stretch of the imagination meet our basic, essential requirements," adding that "our ability to carry out our essential functions is being chipped away" (Kerr, 2007).

The financial difficulties the Agency faces are partly an outcome of success: as the number of states has increased since the end of the Cold War, notably resulting from the break-up of the Soviet Union and Yugoslavia, and as more have acquired Comprehensive Safeguards Agreements and Additional Protocols, so has the verification task increased proportionately, despite later savings through Integrated Safeguards. The Agency has also been involved in unanticipated verification exercises in South Africa, Iraq, North Korea, Libya and Iran. In addition, the Agency is cooperating with the US and Russia in repatriating HEU from research facilities in vulnerable locations around the world as part of the Cooperative Threat Reduction (CTR) programs and the Global Partnership Against the Spread of Weapons and Materials of Mass Destruction (GPP). In the future, the Agency may be involved in verifying North Korea's compliance with its nuclear disarmament pledges and verification in Iran may intensify as part of a future deal. The application of safeguards to multiple Indian nuclear facilities following the 2005 US/India nuclear accord will incur significant costs, estimated in the order of €1.2 million for the first year for each new facility (IAEA, 2008e). The Agency's increased role in nuclear safety since Chernobyl and nuclear security since 9/11 have placed further strain on its budget. Demand for its Technical Cooperation programs has been constantly increasing, even without a nuclear energy revival.

In 2009, with the strong support of the Obama administration, steps were taken in the right budgetary direction for 2010. In September 2009, the IAEA General Conference, unusually, approved the precise amounts requested by the Secretariat: almost €315.5 million for the regular operations budget and €102,200 for the capital budget (IAEA, 2009f: viii and IAEA, 2009e: 1). This is an increase of €19.2 million or 6.5 percent for 2009, well above the current inflation rate. It does not include the Nuclear Security Fund (€19.9 million), the voluntary component of the Technical Cooperation program (€53 million) or other extra-budgetary programs (€40.5 million) (IAEA, 2009f). By comparison, the Commission of Eminent Persons in 2008 called for increases of about €50 million annually in real terms for the regular budget over several years, although it also called for a "detailed review of the budgetary situation and additional workloads of the Agency" (IAEA, 2003b).

Infrastructure and Technology

Gross under-investment arising from decades of budgetary constraints has had a deleterious impact on the Agency's facilities and equipment, which now require urgent modernization. In June 2007, Director General ElBaradei noted that the organization was forced to use an unreliable 28-year old instrument for environmental sampling and that there had been no general implementation of wide-area environmental sampling due to the projected cost (Borger, 2007).

Most noticeable of the infrastructure deficits is the poor state of the Safeguards Analytical Laboratory (SAL) at Seibersdorf outside Vienna, which analyses sensitive samples from nuclear facilities and other sites. Currently, the Agency is forced to use external national laboratories for backup analysis, which, as ElBaradei told the BOG, "puts into question the whole independence of the Agency's verification system" (IAEA, 2008a: 27). Using external laboratories in Western countries permits countries like Iran, for instance, to dispute the veracity of sample analysis. Most scandalously, the IAEA operation at Seibersdorf fails to meet the safety and security standards that the Agency encourages its member states to implement. Built in the 1970s, the facility requires, according to the Agency, approximately €50 million to "prevent a potential failure in the area, which could put the credibility of IAEA safeguards at risk" (IAEA, 2008a: 27). ElBaradei presented a report to the Board in October 2007 outlining the specific critical requirements for modernizing the SAL at an estimated cost of €39.2 million through 2008-2010 (IAEA, 2007c).

Keeping up with the latest advances in technology is crucial to the Agency's nonproliferation mandate since it is in a sense engaged in a "technology race" with potential proliferators that will be seeking the latest technology to advance their aims. Hence the Agency is investing in methods for detecting uranium hexaflouride gas (UF_6), which is used in centrifuges, as well as improved environmental sampling to detect minute radioactive particles. In addition, there is a long-term intention to replace human inspectors, where possible and appropriate, with remote monitoring technology. In addition, the Agency's plans to adopt a modern "knowledge management system" cannot be fulfilled without investment in both technology and personnel.

In April 2009, the BOG decided to establish a Major Capital Investment Fund (MCIF) for capital investment and infrastructure renewal (such as the SAL). The €12.6 million required for 2010 is to be financed through the 2010 capital budget of just €102,200, anticipated extra-budgetary contributions (€6 million) and projected savings in operational costs (€6.5 million) (IAEA, 2009f, 50). The MCIF is expected to jump to more than €30 million in 2011 when major capital expenditure is expected to begin in earnest. However, neither the extra-budgetary contributions nor the operational cost savings are assured, handing the new Director General, Yukiya Amano, a major budgetary challenge in his first year in office. This outcome stands in stark contrast to the call by the Commission of Eminent Persons in 2008 for a one-time increase of €80 million for, inter alia, refurbishing the SAL and for adequately funding the Agency's Incident and Emergency Response Centre (IAEA, 2008d: 30).

Human Resources

The US Government Accountability Office has described "a looming human capital crisis caused by the large number of inspectors and safeguards management personnel expected to retire in the next 5 years" (US GAO, 2005). Like nuclear vendors, operators and regulatory agencies, the IAEA is suffering from generational change, with 20 percent of its inspectors due to retire in the next few years (Muroya, 2009) and its Secretariat generally facing bloc retirements. Due to its participation in the UN Common System, the Agency has a retirement age of 62 years for most staff and only 60 years for a quarter of them. Even in normal circumstances the Agency faces stiff competition from industry and national regulatory bodies that can offer more attractive salary and other benefits. Under current policy, for instance, the Secretariat can only offer three-year initial contracts (extendable to five or seven years, but only in limited cases for longer). This results in major losses of institutional memory and expertise. The general worldwide shortage of educated and experienced personnel in the nuclear field, as discussed in Part 1 of this report, will take some time to alleviate.

Informal Nonproliferation Arrangements

The NPT and IAEA, while the most important elements in the nonproliferation regime, are buttressed by several other mutually reinforcing treaties, organizations and arrangements, as well as informal "norms, rules and principles." Some of these predate the NPT, some have emerged to deal with perceived lacunae in the treaty, while others have arisen to deal with unexpected nonproliferation threats, such as the legacy of the former Soviet weapons programs. Other informal arrangements have arisen to avoid controversies or outright opposition that would arise if they were proposed through the formal channels of the IAEA such as the General Conference or BOG.

There is, for instance, the web of bilateral nuclear supply agreements between states that impose tougher conditions than the normal IAEA safeguards on exported materials and equipment. For example, uranium exporters like Australia and Canada have long imposed conditions of supply that prohibit retransfers of material to third countries and seek repatriation of materials in case of breach. The US has an elaborate system for controlling the export of nuclear and dual-use technology.

There are also two programs of activities developed specifically to deal with the legacy of the Soviet Union's former nuclear weapons program, the various US CTR activities and the GPP. These are vital in helping secure and dispose of nuclear weapons and materials; destroying former production facilities; and retraining former scientists from Soviet weapons of mass destruction (WMD) programs. They make a significant contribution to nuclear safety, security and nonproliferation from the standpoint of past activities. However, they are of limited relevance, so far, to the nuclear energy revival being examined in this report and will not be considered further.

The Zangger Committee and Nuclear Suppliers Group

Two informal bodies have been established by nuclear supplier states to collectively strengthen nuclear export controls. These groups attempt to embody, institutionally, the commitment of NPT parties, both NWS and NNWS, not to assist states to acquire nuclear weapons. Since the IAEA Board of Governors contains states against which such restrictions would be imposed, informal arrangements were a necessary strategy.

The Zangger Committee (named after its inaugural Swiss chairman), which began meeting in 1971, seeks agreement among its now 36 members on what nuclear material and equipment should be allowed to be exported to another NPT state party under IAEA safeguards. It produces lists of items that "trigger" the application of safeguards.

Much more controversial is the 46-member Nuclear Suppliers Group, established in 1974 after India's nuclear weapon test, which seeks to establish, by consensus, guidelines for nuclear exports and nuclear-related (dual-use) exports to any state, including non-NPT parties. Its self-selected membership is mostly Western, with the significant additions of Argentina, Brazil, China and Russia. Among the NSG's guidelines is agreement to export nuclear and dual-use items only to states which are NPT parties and which have concluded comprehensive safeguards agreements with the IAEA. The guidelines are implemented by each participating state in accordance with its own national laws and practices.

States that are nuclear technology importers have long chafed at the NSG restrictions, arguing that they breach the spirit if not the letter of their "inalienable right" to the peaceful uses of nuclear technology under Article IV of the NPT. The radical states among them accuse the NSG of seeking to hold back the development of poor countries by denying them the benefits of nuclear technology. Since the IAEA itself runs an extensive technical assistance program and the vast majority of states are simply unable to absorb advanced nuclear technology, this claim is more political than substantive. Such opposition means, however, that the NSG remains a political lightning rod that can never be integrated into the formal structures of the IAEA. NSG members have nonetheless attempted to engage with non-members. In 2002, they mandated the chair to continue the dialogue with countries such as Egypt, India, Indonesia, Iran, Malaysia, Mexico, Pakistan and Israel that "have developed nuclear programs and are potential nuclear suppliers" (CNS, 2009).

Controversially, the NSG agreed in 2009, after much dissension among its members, to exempt India from its existing rules, in order to facilitate finalization of the 2005 US-India Nuclear Agreement (Huntley and Sasikumar, 2006). Supporters of the exemption argue that it brings India partly into the nonproliferation regime by putting all of its civilian nuclear fuel cycle under IAEA safeguards. It also subjects India to political and normative pressures to induce it to adopt other nonproliferation and disarmament obligations. However, neither the US agreement nor the NSG exemption decision committed India to taking key nonproliferation steps such as signing and ratifying the CTBT or agreeing to a ban on the production of fissionable material for weapons purposes. Critics also contend that the deal grants legitimacy to yet another state possessing nuclear weapons, opens the door for demands from Pakistan and Israel for equal treatment, frees up India's limited domestic uranium resources for its weapons program and undermines the raison d'être of the NPT.

For several years the NSG has also sought to agree on how to strengthen measures to prevent the export of particularly sensitive elements of the fuel cycle, such as enrichment and reprocessing technology. The existing NSG guidelines simply seek "constraint" from members. At its meeting in June 2009, the NSG agreed to a criteria-based approach for the export of sensitive fuel cycle technology, but was unable to agree on a specific set of criteria. The criteria NSG members discussed included both "objective" criteria, such as having an Additional Protocol in effect, and "subjective" criteria, such as the effects on regional stability of introducing sensitive fuel cycle technology. Canada has objected to a US proposal that even if criteria are met, technology would only be transferred in "black box" mode, preventing the recipient from accessing vital information about the technology and replicating it. Brazil objects to the Additional Protocol being a condition of supply, while South Africa is loathe to see any further restrictions on fellow developing countries. India is already seeking to claim that it would be exempt from new restrictions on sensitive technologies under its newly won general exemption from NSG export controls.

The Group of 8 (G8) countries in 2004 adopted, at US urging, an informal moratorium on enrichment and reprocessing technology exports pending agreement in the NSG. This was extended each year until 2008 when it lapsed. At its July 2009 L'Aquila Summit in Italy, the G8 noted that the NSG had not yet reached consensus on the issue, but agreed, pending completion of the NSG's work, to implement the NSG's November 2008 "clean text" (publicly unavailable and still not agreed) on a "national basis in the next year" (G8, 2009). It is not clear whether the NSG will be able to reach consensus on this contentious issue in 2010.

Proliferation Security Initiative

The Proliferation Security Initiative (PSI) was initiated by the US in 2003 to prevent the shipment by air, sea or land of WMD-related materials and technologies and related delivery systems, including those pertaining to nuclear weapons. US officials consistently declare that the PSI is "an activity, not an organization" which "does not have a headquarters, an annual budget, or a secretariat" (Winner, 2005: 129). PSI is instead a voluntary, informal collaborative arrangement established through a "Statement of Interdiction Principles" by its 11 original members (Winner, 2005: 130). PSI now claims 95 participants (US Department of State, 2009b).

Legally the Initiative is predicated on the rights of flag states and transit countries to board and inspect vessels, and their ability under international law to delegate this authority to other states (Byers, 2004: 527). Prior to 2003, such activities had been conducted informally by the US and its closest partners.[22] Some states, particularly China, object to the PSI and its application to ships transiting the high seas, regarding it as a threat to the Law of the Sea. Unlike slavery or piracy, international transfers of WMD are not proscribed under international law; furthermore, interdiction of dual-use technologies is contentious, as such equipment has both civilian and military applications.

The 2003 interdiction of the German-owned ship *BBC China* with centrifuge components destined for Libya is often attributed to the PSI, but was instead part of a separate effort to disrupt the Khan network (Boese, 2005). Since then several individual searches have been conducted under the PSI rubric, but due to the necessary secrecy of such operations it is difficult to gauge their success. The PSI's most notable accomplishments are reciprocal ship boarding agreements concluded between PSI states and international training exercises.[23]

The Report of the International Commission on Nuclear Non-Proliferation and Disarmament recommends "bringing the PSI into the UN system and providing a budget for it," suggesting it could be "improved by eliminating double standards, increasing transparency, and establishing a neutral organization to assess intelligence, coordinate and fund activities, and make recommendations or decisions" (ICNND, 2009). Such a proposal, while appealing in its attempt to multilateralize a "coalition of the willing," is unlikely to gain traction. Many UN member states are overtly hostile to the regime as representing a derogation of state authority (however voluntary) and a threat to existing international maritime law.

Global Nuclear Energy Partnership

In 2006, President Bush sought to address the nonproliferation challenges posed by Iran and the A.Q. Khan nuclear smuggling network, and simultaneously tackle the problem of nuclear waste, by initiating the Global Nuclear Energy Partnership (GNEP).[24] Under GNEP, advanced nuclear energy states would supply non-nuclear-weapon states with third-generation nuclear reactors and nuclear fuel and take back the resulting spent fuel. In return such states would agree to the highest nonproliferation standards and to not engage in enrichment or reprocessing. The advanced nuclear states would retain their monopoly on such enrichment and reprocessing technologies, reprocessing spent fuel in new facilities using allegedly "proliferation-resistant" technologies yet to be developed.[25]

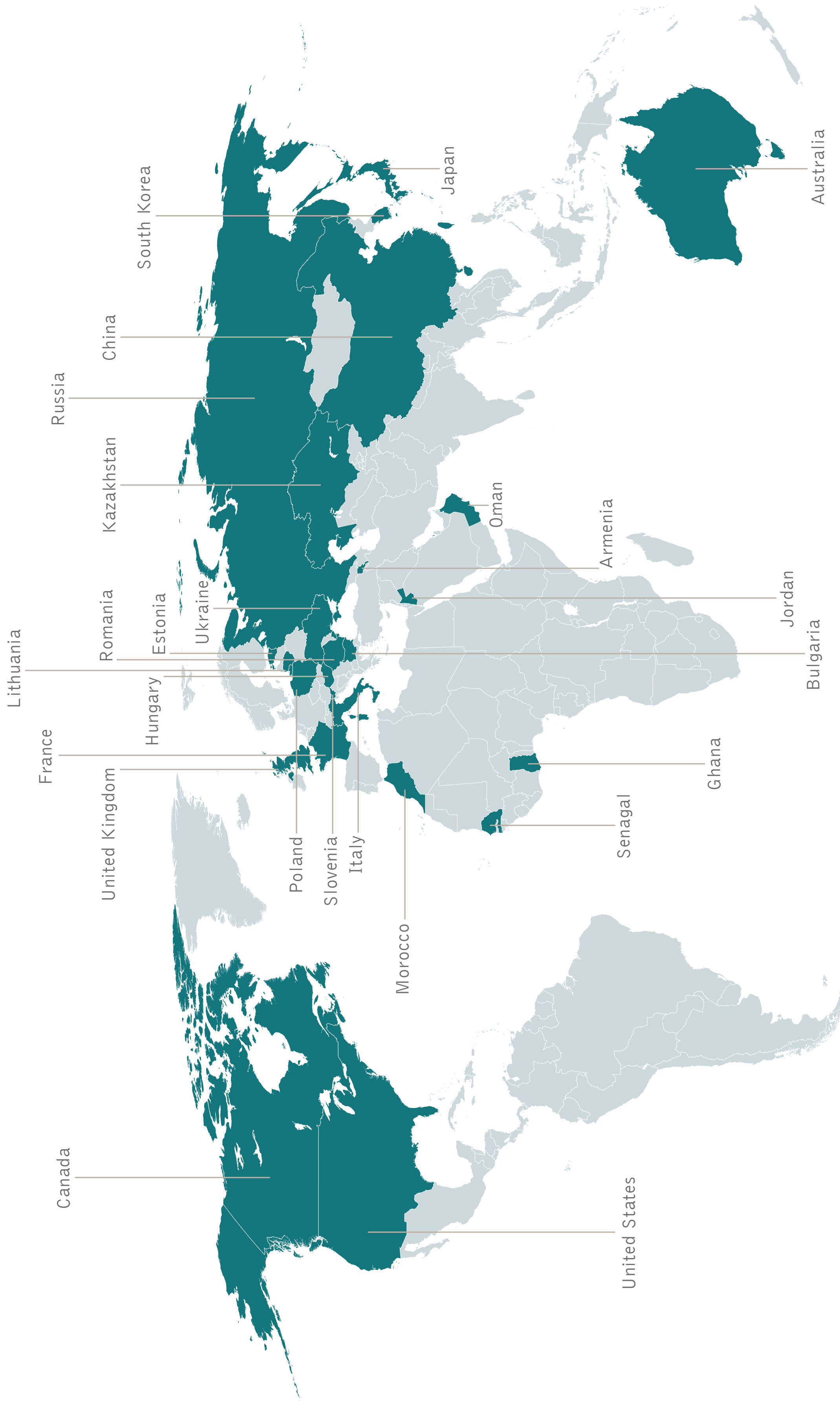
Domestically in the US, GNEP aimed to provide significantly increased funding to an existing research program on advanced reprocessing techniques (the Advanced Fuel Cycle Initiative or AFCI), as well as stimulating research into Generation IV reactor technology that would, it was hoped, propel the US back to the forefront of civilian nuclear energy development.

Internationally, the US convened a GNEP forum to seek states' agreement to the original GNEP principles, as well as establishing a series of consultations on a range of topics related to civilian nuclear energy and its fuel cycle. This proved controversial, as a number of US allies, including Australia, Canada and South Africa, objected to surrendering their right to such fuel cycle activities as enriching uranium, as well as being required to take back nuclear waste from overseas fuel sales. The original GNEP principles were modified accordingly. As of January 2010 GNEP had 25 members, including eight SENES states: Ghana, Italy, Jordan, Kazakhstan, Morocco, Oman, Poland and Senegal.

The Obama administration has continued to support the expansion of nuclear energy worldwide and encourage steps to limit enrichment and reprocessing, but is decidedly less enthusiastic than the Bush administration about early moves towards plutonium recycling domestically or funding expensive pilot plants. Obama's policy has been couched in the context of the President's call for a nuclear weapon-free world, with nuclear fuel banks and fuel assurances given great weight (Pomper, 2009: 11). Domestically, the Congress has eliminated funding for GNEP and cut AFCI funding to $145 million, with research focused on "proliferation resistant fuel cycles and waste reduction strategies" (US Congress, 2009). Energy Secretary Steven Chu has made it clear that he considers reprocessing a subject of long-term research rather than a near term domestic option (Horner, 2009).

Internationally, the Obama administration has not yet formally announced a new policy. In the meantime, GNEP gatherings are continuing. A ministerial meeting in Beijing in October 2009 agreed to review future directions, including the possibility of a name change to International Nuclear Energy Framework (ICNN, 2009: 142). Working groups have continued meeting on various subjects, including small and medium reactors and reliable fuel services.

GNEP Members, January 2010



Source: Miles Pomper, "US International Nuclear Energy Policy: Change and Continuity," Nuclear Energy Futures Papers No. 10, December 2009.

Next Generation Safeguards Initiative

A lower-key but complementary US activity to GNEP is the Next Generation Safeguards Initiative (NGSI) that has been underway in the US Department of Energy's national Nuclear Security Administration since 2008. It purports to be a "robust, multi-year program to develop the policies, concepts, technologies, expertise, and international safeguards infrastructure necessary to strengthen and sustain the international safeguards system as it evolves to meet new challenges over the next 25 years" (NNSA, 2009). NGSI seeks to build on existing partnerships with the IAEA, ABACC and leading countries in the safeguards field and to conduct outreach to states with "credible" plans to develop nuclear energy.

NGSI also replicates the GNEP model in convening international meetings of partners. An International Meeting of Next Generation Safeguards has been held in 2008 and 2009 with officials and experts from several states as well as the IAEA to identify key issues and views in the areas of technology, human capital and safeguards infrastructure. A first workshop in June 2009 in Vienna began the process of harmonizing various types of bilateral safeguards assistance to the IAEA. A second on human capital development and training resources for the next generation of safeguards professionals was held in September 2009 at the Joint Research Centre in Ispra, Italy.

NGSI has established a Safeguards Policy and Outreach Study Group to support safeguards development that has begun with studies to understand and document lessons learned about how the IAEA used its legal authorities in cases where undeclared nuclear activities were detected. The group has also begun an assessment of the IAEA's budget and future resource requirements for safeguards, as well as of options for increasing the transparency of the IAEA's State Level Approach. NGSI's Concepts and Approaches subprogram has completed studies on process monitoring; "Safeguards by Design"; safeguards approaches for enrichment and reprocessing plants; proliferation risk reduction assessments for reprocessing technologies; the "attractiveness" of materials for diversion; and the IAEA State Evaluation process. In 2009 a focus on the development of facility-specific safeguards approaches for gas centrifuge enrichment plants reportedly succeeded in engaging the IAEA and industry in this area. NGSI also commissioned a new study on the global tracking of uranium hexaflouride (UF_6) cylinders used to transport uranium to and from enrichment plants.

Specifically relevant to any nuclear energy revival, NGSI reportedly achieved "substantial progress" toward demonstrating and institutionalizing "Safeguards by Design," in which safeguards are incorporated into the design of new nuclear facilities at the earliest possible conceptual stage. NGSI has engaged industry on the issue and initiated a US National Laboratory project to draft technical requirements guidance for international safeguards suitable for use by facility designers.

On the technology front, the NGSI Safeguards Technology Development subprogram is focusing on developing advanced nuclear measurement technology, unattended and remote monitoring systems, data integration and authentication applications and field-portable detection tools to help inspectors verify the absence of undeclared nuclear materials and activities. The centrepiece is a multi-year project to assess 13 non-destructive analysis techniques for the direct quantification of plutonium in spent fuel. Ten new projects have been initiated to develop advanced tools and methods to detect undeclared production or processing of nuclear materials. NGSI is also working to "revitalize and expand" the "human capital base" for international safeguards in the US by working with US National Laboratories and universities.

Also of special relevance to the nuclear energy revival is the Nuclear Safeguards Infrastructure Development subprogram, which is working to help states that have credible plans for nuclear power to develop their safeguards infrastructure. This includes safeguards administrative authorities and frameworks, technical capacities and sustainable human resources. International training courses in the State Systems of Accounting and Control have been organized, including for states with Small Quantities Protocols. The US and Australia cooperated in a workshop in August 2009 on domestic safeguards regulations for national authorities in Thailand and Vietnam. In addition, NGSI held several regional workshops for states with an interest in civilian nuclear power to elaborate on the IAEA document *Milestones in the Development of National Nuclear Power Infrastructure*. These have been convened in Amman, Jordan, for Egypt, Jordan, Kuwait, Oman, Qatar, the UAE and Tunisia, and in Rabat, Morocco, for Algeria, Egypt, Jordan, Morocco and Tunisia (all of these are SENES states). In 2010, the program will be extended to new partners, specifically Armenia and Kazakhstan, and seek to expand cooperation with Middle East and Gulf Cooperation Council countries through both bilateral and multilateral activities. Other bilateral cooperation projects are continuing with Argentina, Brazil, China, Indonesia, Euratom, France and Japan.

The US is also engaging with Russia on safeguards and other nonproliferation issues. At the July 2009 US-Russia Summit in Moscow, Presidents Obama and Medvedev issued a joint statement calling for joint collaboration on international safeguards. This would be done through the US-Russia Bilateral Presidential Commission's Nuclear Energy and Nuclear Security Working Group. The co-chairs of the working group, Deputy Secretary of Energy Daniel Poneman and Rosatom Director General Sergei Kiriyenko, met in September 2009 in Washington, DC, and agreed on an action plan to advance nuclear security and civil nuclear energy cooperation.[26]

NGSI is a welcome, concrete contribution to strengthening nuclear safeguard that should be of great assistance to the IAEA and member states and one that is worthy of emulation by others with long safeguards experience such as Canada, Germany and Japan.

Implications of a Nuclear Energy Revival for Nuclear Proliferation

Successful aspiring states will, in all likelihood, only acquire one or two reactors in the timeframe being considered by this report. These will mostly be LWRs, with perhaps a few heavy-water reactors of the CANDU type. All of the SENES states will be reactor importers, although they have varying degrees of existing nuclear expertise and experience, ranging from Italy and Poland, with sophisticated industrial and technological backgrounds at one end of the scale, to completely inexperienced developing countries like Namibia and Senegal at the other. Just over half of SENES states have at least one research reactor, and a handful — Algeria, Egypt, Indonesia, Iran, Italy and Kazakhstan — have multiple units, suggesting a relatively advanced nuclear research program.

None of the states presently aspiring to nuclear energy for the first time, with the sole exception of Iran, is likely to have an advanced nuclear program with a complete nuclear fuel cycle by 2030. The vast majority of states are unlikely to be able to enrich their own uranium or even fabricate their own fuel, with the exception of perhaps Italy and Kazakhstan, and none is likely to be reprocessing plutonium on a sophisticated industrial scale.

SENES States' Operational Research Reactors

State	Number of reactors
Iran	5
Italy	4
Indonesia	3
Kazakhstan	3
Algeria	2
Egypt	2
Bangladesh	1
Ghana	1
Libya	1
Malaysia	1
Morocco	1

State	Number of reactors
Nigeria	1
Poland	1
Syria	1
Thailand	1
Turkey	1
Vietnam	1
Albania	0
Bahrain	0
Belarus	0
Jordan	0
Kenya	0

State	Number of reactors
Kuwait	0
Mongolia	0
Namibia	0
Oman	0
Philippines	0
Qatar	0
Saudi Arabia	0
Senegal	0
Tunisia	0
UAE	0
Venezuela	0

Source: IAEA (2009d)

Since all of the SENES states, (along with all other non-nuclear weapon states) are party to the NPT and all have comprehensive safeguards agreements, they will be required to apply nuclear safeguards to all of their power reactors and other peaceful nuclear activities. There is, in addition, likely to be strong pressure on such states, if they have not already done so, to have an Additional Protocol in place, making illicit diversion more difficult than in the past. Any examination of the proliferation implications of a nuclear energy revival must take these considerations into account.

Encouragingly, most SENES states either have signed an Additional Protocol or have one in force. However, key SENES states have not even signed one, most worryingly Egypt, Saudi Arabia, Syria and Venezuela. Oman and Qatar are also missing from the list. Unfortunately, eight SENES states still have the old version of the SQP in force and only Bahrain, Kenya and Qatar have replaced them with new ones. At least four SENES states — Bangladesh, Ghana, Indonesia and Poland — have qualified so far for Integrated Safeguards, signifying that their past safeguards record has been judged to be impeccable.

In addition, some SENES states are already tightly bound within additional mechanisms of the nonproliferation regime. Four SENES states are members of the NSG: Belarus, Italy, Kazakhstan and Turkey. Eighteen SENES states are participants in PSI: Albania, Bahrain, Belarus, Italy, Jordan, Kazakhstan, Kuwait, Libya, Mongolia, Morocco, Oman, Philippines, Poland, Qatar, Saudi Arabia, Tunisia, Turkey and the UAE.

In conclusion, all SENES states, with the exception of Iran, if they succeed in acquiring nuclear power reactors (this is in itself problematic as indicated in Part 1 of this report), will likely do so under nuclear safeguards. While those that succeed will acquire further general nuclear expertise and experience that may in the distant future be useful for a nuclear weapons program, they will certainly not acquire the beginnings of such a weapons program per se, nor will they obtain ready access to fissionable material suitable for a nuclear weapon program, much less a "breakout" capability. Some aspiring states such as the UAE are seeking to present themselves as nonproliferation models.

Adherence to Nuclear Safeguards by SENES States

State	Comprehensive Safeguards Agreement	Additional Protocol	Integrated Safeguards	Small Quantities Protocol	
				Old	New
Albania	In force				
Algeria	In force	Signed			
Bahrain	In force	In force			In force
Bangladesh	In force	In force	In force		
Belarus	In force	Signed			
Egypt	In force				
Ghana	In force	In force	In force		
Indonesia	In force	In force	In force		
Iran	In force	Signed			
Italy	In force	In force			
Jordan	In force	In force		In force	
Kazakhstan	In force	In force			
Kenya	In force	In force			In force
Kuwait	In force	In force		In force	
Libya	In force	In force			
Malaysia	In force	Signed			
Mongolia	In force	In force		In force	
Morocco	In force	Signed			
Namibia	In force	Signed		In force	
Nigeria	In force	In force			
Oman	In force			In force	
Philippines	In force	In force			
Poland	In force	In force	In force		
Qatar	In force				In force
Saudi Arabia	In force			In force	
Senegal	In force	Signed		In force	
Syria	In force				
Thailand	In force	Signed			
Tunisia	In force	Signed			
Turkey	In force	In force			
UAE	In force	In force		In force	
Venezuela	In force				
Vietnam	In force	Signed			

Legend

Unsigned	
Signed	
In force	

Sources: IAEA (2009c) and IAEA (2008b)

The UAE – Nonproliferation Angel?

The UAE is the most likely aspirant state — other than Iran — to actually succeed in acquiring a nuclear energy capacity soon. This is due to its oil wealth, the relationships it is steadily establishing with major nuclear suppliers and the exemplary behaviour it is exhibiting in fulfilling international nonproliferation expectations for new entrants. The UAE indeed sees itself as establishing a model for nonproliferation in the Middle East — a description repeated by senior US officials (GSN, 2009). It is stable, relatively well-governed (although not democratic), growing economically (despite the recent financial troubles of Dubai) and is not a security threat to its neighbours (although it is located in a highly volatile region with Iran a near neighbour). A union of seven emirates (Abu Dhabi, Dubai, Sharjah, Ajman, Umm al-Quwain, Ras al-Khaimah and Fujairah) without a strong national identity, the UAE's federal government has near-total control over the conduct of foreign affairs, although its constitution delegates authority over various domestic issues, including energy and resources, to the emirates (Khalifa, 1979: 40-41).

Justification for Nuclear Energy

A combination of rapidly increasing electricity demand, the high energy requirements of planned massive desalination plants and the desire to diversify its energy sources has led the UAE to pursue nuclear power. Although it has the world's sixth largest proven oil reserves and fifth largest proven natural gas reserves (CIA, 2009b), the UAE makes a strong economic case for why it would benefit from nuclear energy. Foreign Minister Shaikh Abdullah Bin Zayed Al Nahyan has declared that the UAE's rapid economic growth and a predicted shortage of natural gas "calls for diversifying the country's energy sources" (Gulf News, 2008c). The UAE has an existing electrical grid capacity of approximately 16,000 MW, but predicts that by 2020 peak demand will reach nearly 41,000 MW, a 156 percent increase in just over a decade (Gulf News, 2008a). Fresh water resources are extremely limited, resulting in plans for large-scale water desalination projects that require considerable amounts of energy, including a 9,000 MW desalination complex in Dubai (Windsor and Kessler, 2007: 124). By generating electricity using nuclear power, the UAE argues that it can export more oil and natural gas instead of using it for domestic consumption (WNN, 2008).

The UAE decision to invest in nuclear power also gains credibility because it was the result of a deliberative process that included the possibility of other energy alternatives. A government white paper examined several options, but concluded that nuclear power was the only one with the potential to meet rapidly increasing electricity demand. Even "aggressive" deployment of solar and wind could, it was estimated, only supply 6 to 7 percent of peak electricity demand by 2020 (Gulf News, 2008b).

The main criticism of nuclear energy — that its upfront costs are too high — is less of a problem for the UAE due to the country's wealth. The UAE's GDP per capita of $40,000[27] is the nineteenth highest in the world — above that of countries with advanced nuclear industries such as Canada, Japan and the UK (CIA, 2009a). The government's cost estimate for each nuclear power plant of $7 billion each indicates that it is fully aware of the costs of nuclear power plants and is willing to assume them (Gulf News, 2008a). The UAE is thus one of few aspiring nuclear energy states that has fully considered the costs and benefits of nuclear power and has decided to proceed with its plans based on that analysis.

Nonproliferation Disposition

The UAE has taken or is in the process of taking all of the necessary steps towards implementing nuclear power in such a way that avoids raising proliferation concerns. The UAE's interest in nuclear energy is so new that it only concluded a CSA with the IAEA in October 2003 (although it acceded to the NPT in 1995) (IAEA, 2009c). The IAEA Board of Governors approved an Additional Protocol for the UAE on March 3, 2009, and the UAE signed it on April 9, 2009 (IAEA, 2009c). Once it comes into force it will render the UAE's Small Quantities Protocol obsolete, but the UAE has in any case agreed to terminate its SQP in respect of nuclear cooperation agreements where it has been made a condition of supply (Blanchard and Kerr, 2009: 11-12). Although as of January 2010 the UAE still has some legislative and other steps to take before its legal obligations are complete, there is little doubt that it will agree to the highest safeguards standards currently practised.

Another highly lauded step the UAE took was to sign a groundbreaking nuclear cooperation agreement, a so-called 123 Agreement, with the US. This requires that the UAE have an Additional Protocol in force before any transfers of technology can occur (US-UAE, 2009: 12-14), and allows the US to terminate the agreement if the UAE pursues enrichment or reprocessing technology (US-UAE, 2009: 10). It also commits the US to negotiating equally strict agreements with other states in the region (or the UAE has to be offered the same less restrictive agreement) (US-UAE, 2009: 26-27). The US-UAE nuclear cooperation agreement thus not only requires that the UAE commit to the highest nonproliferation standards, but has some bearing on how other nuclear agreements — at least with the US for now — are constructed in the Middle East. Perhaps a greater contribution to nonproliferation is the example it sets for limiting the spread of enrichment and reprocessing technology to new states in a more subtle way than by adopting a universal ban (US Department of State, 2009e). Foreign Minister Shaikh Abdullah Bin Zayed Al Nahyan has also committed the country to maximum transparency, an unusual step in the Middle East: "The UAE will publish the programme's full details, in keeping with its approach of absolute transparency in dealing with the international community" (Gulf News, 2008c). Finally, the UAE is not only purchasing reactors from a South Korean firm on a turnkey basis, but is contracting the firm to run them over their projected lifespan of 60 years, meaning that local industrial learning, for good or ill, will be minimal (Economist, 2010: 47).

If other states choose to follow a similar path as the UAE has so far, its decision to pursue peaceful nuclear technology could be of net benefit to the nonproliferation regime rather than an increased risk to it.

This report focuses mostly on capabilities rather than proliferation intentions. The latter would require a finely grained analysis of each SENES state's strategic situation, political and economic aspirations and leadership. Nonetheless, even without considering intentions, there are some troubling aspects of certain SENES states' behaviour in the nonproliferation area. There are gaps in safeguards participation by some SENES states, some have been reluctant participants in strengthened safeguards and some have engaged in questionable activities in the past (notably Algeria and Egypt). The Middle East looms as a region where "nuclear hedging" against Iran might be a factor in states' nuclear energy aspirations, however long and arduous such a route to nuclear weapons might be. Additional states to those identified in SENES and other surveys, with different attitudes and strategic situations, may present themselves overnight as aspirant states. One or two states may engage in a crash program of civilian energy development that, despite all odds and despite being under safeguards, gives them a breakout capability. Isolated states with capricious leadership, such as SENES states like Belarus, Libya and Venezuela, may be tempted to do so.

In any event, as explained above, generating nuclear electricity does not offer the only path to nuclear weapons acquisition: a state may conclude that acquiring nuclear expertise through foreign assistance, education and training and a research reactor is a faster, less expensive path than a nuclear power program. Myanmar, the country currently of most long-term proliferation concern in Southeast Asia, is suspected of seeking to take this route, which could trigger a cascade of proliferation "hedging" by others with bigger civilian nuclear energy programs. Beyond 2030, especially in a situation where catastrophic global warming becomes more apparent, there may be a stampede to nuclear energy that overturns the pre-2030 trends presented in this report. All of this argues for continuing vigilance, avoidance of complacency about the current nonproliferation regime and efforts to continually improve it.

Implications of a Nuclear Energy Revival for the Nuclear Nonproliferation Regime

Implications for the IAEA

The nuclear energy revival of whatever size and shape presents both risks and opportunities for the IAEA and its safeguards regime. The opportunities include the potential to shape the revival in a way that did not occur in the early days of nuclear energy and in the first round of significant nuclear energy expansion in the 1970s and 1980s. The Agency is well positioned to provide expanded advisory services to help new entrants plan their programs from the ground up, to ensure that they have in place the best possible regulatory, safety and security regimes, are fully compliant with nuclear safeguards and have the necessary infrastructure and personnel (IAEA, 2007a). The ideal outcome would be for the Agency to be able to lever the new interest in peaceful uses of nuclear energy to convince states to put in place all of the prerequisites for a safe, secure and proliferation-resistant enterprise.

There is a risk, however, that without additional resources and commitment from member states the Agency will be overwhelmed. Already the number new of states calling on its advisory services in respect of civilian nuclear energy is rising, whether for nuclear electricity generation or other civilian purposes. Yury Sokolov, IAEA Deputy Director General of Nuclear Energy, estimated in July 2009 that over the coming two years the Agency is expected to assist 38 national and six regional nuclear programs, a "three-fold increase from the previous reported period" (IAEA, 2009a). Advisory services on safety and security will be especially stretched. Safeguards will need to be applied to increasing numbers of civilian nuclear power plants and associated fuel cycle facilities, even if the revival is confined to current users.

Finance

Former Director General ElBaradei recommended a doubling of the IAEA budget to around €700 million by 2020, a recommendation accepted by the 2008 Commission of Eminent Persons (IAEA, 2008d: 30-31). While it is impossible to accurately forecast the precise budgetary needs of the Agency as far in advance as 2030, particularly given the uncertainty of the extent of the nuclear revival as outlined in this report, the type of increase envisaged by ElBaradei, proportionately applied for another 10 years would appear reasonable considering the total budget would still be under €1 billion. Such increases should be accompanied by reform of the Agency's financial forecasting model involving, as the Commission suggested "a comprehensive approach to assessing its future resource requirements" (IAEA, 2008d: 31). In any event, zero budgetary growth should never again be imposed on an Agency that clearly faces rising demand in an area crucial to international peace and security.

In addition, all of the core statutory functions of the Agency, including in respect of safety, security and nonproliferation should be fully funded from assessed contributions. The Nuclear Security Fund should be included in this arrangement. The regular budget should include costs associated with providing advice and assistance to aspirant nuclear energy states on the requirements for and responsibilities involved in acquiring nuclear power reactors. The Technical Assistance program should continue to be based on negotiated targets, but be planned on a multi-year basis to ensure greater predictability (IAEA, 2008d: 31). Voluntary funding arrangements in the safeguards area should be reserved for unforeseen expenditures such as verifying North Korean disarmament or verifying excess stocks of weapons-grade fissionable materials in a nuclear disarmament process, although this should be supported by a contingency fund to avoid funding delays in urgent cases (IAEA, 2008d:31).

Personnel

To ensure that it can attract high quality personnel for both its Secretariat and inspectorate, the Agency should:

- Seek exemption from the UN Common System for salary purposes and adopt a flexible and transparent personnel system in order to be able to offer attractive terms and salaries to key recruits that are competitive with industry and national regulators.
- Seek collaborative arrangements with industry, universities and research centres to permit a two-way secondment of talented individuals.

Governments should be more willing to second experts to the Agency, not just in the technical cooperation area, but in the safeguards and regulatory areas dealing with safety and security.

Collaboration with Industry

One surprising lacuna in global governance identified throughout this report is the lack of close collaboration between the IAEA and industry. There seems to be mutual misapprehension, and, in some cases, distain on both sides in much the same way that industry and government often view each other. Many in the nuclear industry regard nonproliferation in particular as being solely the concern of governments. This applies also to nuclear security, but to a lesser degree to nuclear safety. Efforts must be made on all sides to end this situation by forging a true collaboration between all of the stakeholders likely to be affected by the revival in interest in civilian nuclear energy. The NEA seems to have developed a better relationship with industry than the IAEA, while informal arrangements like the Global Initiative to Combat Nuclear Terrorism are attempting to be more inclusive. Nuclear safety has its putative global network and the World Association of Nuclear Operators (WANO), while nuclear security has its World Institute of Nuclear Security (WINS).

The Case of Areva

The French nuclear company Areva seems to be an industry pioneer in explicitly getting involved in nonproliferation issues. In 2009, Anne Lauvergeon, its chief executive officer, became probably the first industry leader to address a session of the annual Nonproliferation Conference held by the Carnegie Endowment for International Peace, normally the preserve of nuclear nonproliferation experts. She was also a member of the Commission of Eminent Persons on the Future of the IAEA and has contributed an article entitled "The nuclear renaissance: an opportunity to enhance the culture of nonproliferation" to the fall 2009 special edition of *Daedelus: Journal of American Academy of Arts and Sciences* (Lauvergeon, 2009).

Areva asserts it is doing more than talking about nonproliferation: its "Value Charter" has nonproliferation at the top of its operating principles and the company claims it "does not, and will never, cooperate with any customer from a country that does not adhere to international nonproliferation standards or is not compliant with its nonproliferation obligations" (Lauvergeon: 94). Even if a country satisfies such criteria, Areva "reserves the right to assess the political stability and security situation of the country, and even the region, to consider possible risks associated with a given commercial transaction." The company reports that is has a special training and awareness program for all its employees in charge of export controls and that it is committed to exercising special care in considering the transfer of sensitive technologies (for instance by imposing non-transfer conditions on supplying such technology to Japan).

Clearly, Areva's unusual prominence in the nonproliferation arena makes good commercial sense and fits well with the French government's strong commitment to nuclear energy domestically and to French nuclear energy exports. Nonetheless, it should also serve to both set an example and help break the traditional "ice" between industry on the one hand and nonproliferation bureaucracies and the non-governmental nonproliferation community on the other. Yet the fact that the industry has a long way to go has been demonstrated by Ms. Lauvergeon herself. She added a caveat to her agreement to the consensus report of the IAEA Commission of Eminent Persons that included a denial of a "direct correlation between disarmament and deployment of the peaceful uses of nuclear energy" and a rejection of any IAEA role in nuclear disarmament or even mention of it in the Commission's report (IAEA, 2008c: ii).

As the International Commission on Nuclear Nonproliferation and Disarmament (ICNND) recommends "… the role of the world's nuclear industry in mitigating the proliferation risks of a growing civilian nuclear sector worldwide will need to grow, requiring more intense government-industry collaboration than has hitherto been the case" (ICNN, 2009: 129). A conference on the future of nuclear energy convened by the *Bulletin of the Atomic Scientists* in Chicago in September 2008 also warned that: "Given that the use of a nuclear weapon or an accidental explosion anywhere in the world might bring about a global renunciation of nuclear energy, it is in the interest of the global nuclear industry to be centrally involved in stemming weapons proliferation" (MacFarlane et al., 2008). Areva's principles and policies and the World Nuclear Association's inclusion of nonproliferation in its Charter of Ethics and Principles of Uranium Stewardship are useful beginnings. What would be even more useful would be a standing body of representatives of all reactor exporting companies and countries, along with the IAEA, to identify agreed harmonized principles for exporting reactors that takes into account the nonproliferation track record of potential purchasers, along with their safety and security records and intentions, and the regional security context in which they are located. A redirected GNEP could be used for this purpose. Ideally it would be linked more closely to the IAEA and NEA and become more truly multilateral, rather than being directed from Washington as a US initiative.

South Korea's successful bid to supply the UAE marks the first time that a developing country has exported nuclear reactors, and to a fellow developing country no less. This underlines the fact that the spread of civilian nuclear power technology is no longer a developed/developing country issue, but one that cuts across such divisions. While radical nonaligned countries will see cooperation between nuclear reactor exporters as collusion designed to deprive them once more of nuclear technology, this argument needs to be resisted. Although the NPT grants states the inalienable right to access the peaceful uses of nuclear energy, it does not legally oblige any particular company or country to export to any other. Nuclear reactor exports are combined commercial and political decisions that if made individually could damage the nonproliferation regime considerably by creating lowest-common denominator approaches; if done collaboratively they could strengthen the regime.

Implications for Nuclear Safeguards

Increased numbers of power reactors, additional nuclear trade and transport, and potentially moves by more states to acquire the full nuclear fuel cycle will require the fullest possible application of safeguards, increased IAEA safeguards capacity and increased spending. It will at the very least require that all existing and new nuclear energy states adopt and implement an Additional Protocol. But further improvements in safeguards will be required to provide additional assurances.

The most recent attempt by the Board of Governors to consider further improvements to safeguards ended in failure when its Advisory Committee on Safeguards and Verification folded in June 2007 after two unproductive years. Although the Secretariat proposed at least 18 improvements for consideration, the Committee was unable even to adopt a work plan.[28] With its membership open to all IAEA members, Iran was able to pursue a wrecking strategy. Even the US, which under the George W. Bush administration had proposed the establishment of the Committee, seemed unwilling to devote the necessary political and financial capital to make it succeed. Perpetual disputes among committee members over the relative political and financial attention devoted by the Agency to nuclear safeguards, assistance in the peaceful uses of nuclear energy and nuclear disarmament also contributed to the paralysis. Perhaps under the Obama administration the US would stand a better chance of pursuing safeguards reform, including by resurrecting the Committee. The US NGSI program is making an invaluable contribution and may provide feedstock for a new US initiative.

As previously mentioned, one idea for further improving safeguards is to reinforce the Additional Protocol itself. Elements that could be incorporated in an "Additional Protocol Plus" are the following:

- Confirmation of the Agency's right and obligation to have access to sites and information related to the manufacturing of nuclear material production technologies, such as centrifuge manufacturing plants (IAEA, 2008d: 18);
- Confirmation of the Agency's right to seek evidence of weaponization activities as a prime facie violation of a nuclear safeguards agreement and of the NPT itself;[29] since some of the activities and materials involved may be "dual use" and therefore ambiguous in a weapons context, the Agency's mandate needs to be clarified in this respect;

- Confirmation of the Agency's right to interview individuals who may have knowledge of illicit activities (arguably already provided for in the IAEA Statute);
- Establishment of a requirement that states report denials of export requests relating to nuclear materials and technologies to the Agency's Trade and Technology Analysis Unit; and
- Shortening of the prior notification periods for on-site inspections.

These proposals would require the approval of the Board in appropriate form, some by amending the technical annexes to the Additional Protocol as provided for "on the recommendation of technical experts" (ICNND, 2009: 85).

On the technical side of safeguards, the IAEA should continue to investigate whether the use of sophisticated remote on-site monitoring can lessen reliance on human on-site inspectors without damaging verifiability. As demonstrated in the Iraq and Iran cases, there is often no substitute for human monitoring and verification skills, so the power of technological solutions should not be exaggerated.[30] The Agency should also take seriously the concerns of some experts that lengthening rather than shortening the periods between inspections, for example of spent fuel pools, which, as a result of Integrated Safeguards and/or due to lack of resources, may run the risk of missing diversion (Miller, 2004: 53).

Industry involvement in ensuring that new generation reactors are safeguards-friendly is essential, along with ensuring that design elements for safety, security and safeguards are integrated and do not work at cross-purposes. "Safeguards by design" is much more cost-effective and efficient than retro-fitting safeguards after construction. For example, the installation of cabling for remote monitoring is extraordinarily expensive, but can be cheaper if designed in advance. The Multinational Design Evaluation Program (MDEP) mentioned in Part 2 of this report could be engaged in this effort in collaboration with the IAEA.

A nuclear revival that sees an expansion in the number of "sensitive" fuel cycle facilities (although many observers believe this should be avoided if possible) may also awaken a sleeper issue that has long bothered the sharpest critics of safeguards: the fact that the current system cannot provide sufficient assurance of non-diversion of fissionable material from bulk-handling facilities, such as those involved in uranium enrichment, plutonium reprocessing and fuel fabrication. These facilities handle such large volumes of nuclear material that significant amounts, in terms of the quantities required for an illicit nuclear device, will be unaccounted for, lodged in pipes or other equipment, or subject to accounting and measurement errors. The system is also currently unable to verify rapid adaptation of enrichment and reprocessing plants from declared peaceful purposes to production of weapons-useable materials. Moreover, some critics claim that the IAEA's 30-year old criteria, suggested by the nuclear weapon states, for how much nuclear material is needed to make a nuclear weapon ("significant quantity") and how much time is required to convert such materials into a bomb ("conversion time") need significant revision downwards (Sokolski, 2007).

If a nuclear energy revival permits increasing numbers of non-nuclear-weapon states to acquire such facilities, the safeguards system risks losing credibility. Proposals for fuel banks, regional or multilateral enrichment facilities, and the phasing out of the use of plutonium for civilian purposes are widely deemed to be appropriate means for dealing with the proliferation implications of these developments, but all of these imply more powerful IAEA safeguards tools beyond even today's strengthened system. In the meantime, it would be useful for the IAEA to frankly tell its member states where it is unable to achieve verifiability. This will not only help relieve the Agency of the perennial burden of overblown expectations, but should catalyze radical new improvements in areas where they are feasible.

Faced with such challenges, the future evolution of nuclear safeguards lies in the realization by the international community that this form of verification is a security bargain that deserves openness, hard-headed scrutiny, commitment, finances and resources commensurate with its significance for international security.

Non-Compliance with Safeguards

Related to the efficacy of safeguards is the question of what to do about non-compliance when it is discovered. It is essential that the Board of Governors, and, if necessary, the IAEA membership as a whole, clarify the meaning of safeguards "non-compliance" with a view to declaring zero tolerance of any breach, regardless of intent. There is an argument that both South Korea and Egypt should have been found in non-compliance for their breaches, discovered in 2004 and 2005, respectively, as should Syria for failing to cooperate fully with the IAEA in its investigation of the alleged nuclear reactor construction site destroyed by Israel. Even when the Security Council sanctioned Iran in November 2003, it did not use the word "non-compliance," although Libya was deemed "non-compliant" in 2004.[31]

The BOG should instruct the Safeguards Department of the Secretariat that in future it should treat "non-compliance" as a technical term, to be decided on the facts, and presented automatically to the Board in those terms for consideration as to the action to be taken. The Board may or may not decide to confirm such a finding, but at the very least it would permit the Board to declare factually that the Director General has recommended a finding of non-compliance based on a technical judgement by the Secretariat. This may help remove at least some of the politicization that has characterized Board behaviour in recent years and head off accusations or imputations of bias on the part of the Director General and/or the Secretariat (made by Iran, Israel and the US over the Iran case and by the US in the Iraq case).

The Board should also formally confirm that non-cooperation by a state with the IAEA represents non-compliance: the Board should make it clear that it is the state's responsibility to prove its compliance to the Agency rather than the other way around, as has traditionally been the case.

More broadly, an attempt should be made to remove the current ambiguity about whether a violation of a safeguards agreement is a violation of the NPT. There has hitherto been an almost surreal supposition that the IAEA was not concerned with attempts by states to acquire nuclear weapons per se, but only with attempts to divert fissionable material to such a purpose. Since there is no other verification body but the IAEA, it has never been clear who else was charged with considering and investigating evidence of weaponization activities. This ambiguity should be removed by BOG fiat — over the likely objections of Iran and others. This should also be a matter for consideration by the 2010 NPT Review Conference.

More broadly still, there have been proposals for dealing with withdrawal from the NPT by a state that is in non-compliance with its safeguards obligations and by extension the NPT. The first idea is for the UN Security Council to declare that such withdrawal would be a threat to international peace and security, requiring the necessary severe response. A second is a declaration by the NPT parties that a state withdrawing from the NPT is not entitled to use nuclear materials, equipment and technology it obtained while a party to the treaty and must return these forthwith. (The ICNND has proposed a protocol to CSAs extending safeguards in perpetuity, as in the case of the IAEA-Albania Safeguards Agreement (ICNND, 2009: 89).) A third proposal is for states to make it a condition of supply that in the event of withdrawal from the NPT safeguards should continue with respect to nuclear material and equipment provided, as well as on any material produced by using it. All of these ideas have merit, although a non-compliant state withdrawing from the NPT will already have crossed such a normative and legal barrier that it is unlikely to be swayed by such legal niceties, perhaps with the exception of the Security Council actually taking enforcement action under Chapter VII of the UN Charter to restore international peace and security.

Preventing the Further Spread of Sensitive Fuel Cycle Technologies

The spread of sensitive enrichment and reprocessing technology to new states — whether aspirant or existing nuclear energy states or those without any interest in nuclear power generation — is the single greatest threat to the nonproliferation regime. Because such facilities are dual-use and have peaceful applications permitted by Article IV of the NPT, states that meet their safeguards and nonproliferation commitments have the right to acquire them for peaceful purposes: so preventing their further spread is challenging. The difficulties in stopping Iran from enriching uranium despite Security Council resolutions ordering it to do so illustrate the problem. One urgent objective of the nonproliferation regime in the future is to find a way of preventing scenarios such as the Iranian one arising in the context of a nuclear energy revival. The proliferation risks associated with sensitive fuel cycle technologies are now so well known that nuclear suppliers have taken steps to limit their dissemination. Several approaches are possible, with varying prospects.

Export Controls and Technology Denial

One approach is technology export constraints, as currently practised by NSG members in accordance with its collective decisions or by individual suppliers through additional unilateral decisions. The extreme version of this is complete technology denial. As noted above, the NSG, encouraged by the G8, is working towards strict criteria for new enrichment or reprocessing states that should limit their emergence. Even without new agreed restrictions, supplier states are not likely to transfer the technology to new states in the near future. The most telling example of this is US refusal to allow Canada access to enrichment technology unless it is "black-boxed." Areva itself has purchased "black box" enrichment technology from URENCO for its future enrichment plants, including one it plans to build in the US (Acton, 2009: 53). However, technology denial is rightly perceived as politically unsustainable in the longer term due to the demands of those non-nuclear weapon states which perceive yet another case of discrimination by the nuclear "haves" against the nuclear "have-nots."

A second approach is the development of proliferation-resistant technologies that permit states to have the benefits of nuclear fuel recycling without the proliferation risks. A third approach is known as "multilateralization" or internationalization of the nuclear fuel cycle.

Proliferation-Resistant Technologies

Attempts have been made since the dawn of the nuclear age to design technical fixes for the proliferation problem, beginning with the idea of "denaturing" plutonium in the 1940s. Proliferation resistance involves establishing barriers, through technological means, to the misuse of civil nuclear energy programs to produce fissile material for nuclear weapons.

In the current context of a nuclear revival, companies designing Generation III and Generation III+ reactors are claiming that they are safer, more secure and more proliferation-resistant, although the details are still mostly unclear. But they are still mostly LWRs that use enriched uranium (as will the Advanced CANDU) and produce plutonium, so until at least 2030 the traditional nonproliferation concerns with such technology will persist (not least because current LWRs are having their lifetimes extended beyond 2030). The traditional technological solution here is the "once through" cycle with no reprocessing and ultimate deep geologic disposal of spent fuel.

Although the use of mixed oxide (MOX) fuel helps reduce stockpiles of spent fuel and plutonium, it still relies on plutonium being reprocessed, stored and transported and thus is a proliferation risk. Ideally the use of this "technological solution" should be phased out altogether and aspirant states should not be encouraged to engage in it. In the meantime, in countries that already have nuclear weapons fresh MOX should be protected like their nuclear weapon material. Such protection would be more difficult to ensure if MOX was routinely used in nations that do not have reprocessing plants or MOX fabrication facilities under IAEA safeguards (Garwin and Charpak, 2002: 318).

Similarly, currently proposed fast "burner" reactors, despite advantages in using uranium resources efficiently and reducing nuclear waste, do not offer proliferation resistance since they rely on weapons-grade plutonium for fuel and/or actually produce more of it. Thorium reactors depend on reprocessed U-233, which can itself be used for nuclear weapons, in addition to requiring enriched uranium or plutonium for their initial operating cycles. As Feiveson *et al*. put it: "It would be unwise to rush into a nuclear renaissance with the technologies that are the most developed now but which would not necessarily be the most suited to a large-scale expansion of nuclear power if other reactor technologies promise significant advantages" (Feiveson et al., 2008).

Many of the proposed technological solutions currently being mooted for additional proliferation resistance for Generation IV reactors and for the broader fuel cycle, notably as part of the Gen IV Forum and the IAEA's International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) (see Part 1 of this report) are still in the early developmental stage and most will not be available in the first round of a nuclear revival to 2030.[32] Such technologies include fast neutron reactors with an integrated core and no breeder "blanket" which ensures that plutonium will not be of weapons grade (although any plutonium is potentially weapons-useable as discussed). New reprocessing technologies promise that pure plutonium will not be separated out, but remain mixed with "self-protecting" highly radioactive actinides. Controversially, South Korea is developing "pyroprocessing," which it claims is proliferation-resistant, but which the US disputes. The DUPIC method of recycling pressurized water reactor (PWR) spent fuel in CANDU reactors, without separating plutonium, shows promise, but would be limited to states with both types of reactor (currently only South Korea, India and China) (ICNND, 2009: 128).

Even a cursory examination of these technologies indicates that, as the ICNND starkly concluded: "There is no magic bullet to eliminate all proliferation risk" and "No presently known nuclear fuel cycle is completely proliferation proof: proliferation resistance is a comparative term" (ICNND, 2009: 126). In the DUPIC case for instance, a state purchasing CANDUs to recycle PWR spent fuel could always switch to traditional fuel (Acton, 2009: 5). Fast "burners" can inevitably lead to interest in fast "breeder" reactors which are obviously more proliferation-prone (Acton, 2009: 52). Political and institutional barriers will always be necessary. Nonetheless, it is important that research and development continue, especially through multilateral mechanisms, as part of a longer-term effort to find technological solutions to complement the governance solutions that this report is focused on. As James Acton points out, there is nothing wrong with pursuing technological solutions, but "a failure to appreciate fully the political dimension of nonproliferation risks makes the concept of proliferation resistance at best irrelevant and at worst counterproductive" (Acton, 2009: 49).

Multilateralization of the Nuclear Fuel Cycle

The grab bag of proposals known somewhat misleadingly as multilateralization of the fuel cycle includes some that involve little multilateralization beyond providing assurances of reactor fuel supply so that states are not tempted to obtain their own enrichment capacities. The ultimate goal of true multilateralization would see all enrichment and reprocessing facilities for peaceful purposes being under international control and ownership, as well as under IAEA safeguards.

Although such ideas date back to the dawn of the nuclear age, and the original idea that the IAEA should have a physical fuel bank, they received a fillip in 2004 when then IAEA Director General ElBaradei convened an Expert Group on Multilateral Approaches to the Nuclear Fuel Cycle. A great number of proposals have been put forward since, some restricting themselves specifically to providing guaranteed nuclear fuel, while others veer towards multilateralizing parts of the fuel cycle.

Assurances of Supply, Including Fuel Banks

Several of the above proposals aim to discourage states from seeking enrichment technology simply by providing them with assurances of fuel supply in all circumstances except violation of safeguards and/or the NPT. Such assurances are meant to convince states that they will not be deprived of nuclear fuel for extraneous political reasons not related to nonproliferation. They are also designed to remove a pretext for states proceeding with enrichment and reprocessing when, in fact, they have weapons purposes in mind.

There are several difficulties with this approach, the main one being that they appear to be a "solution in search of a problem." It is the supplier states that have made all of the proposals, while the actual or potential importing countries are skeptical about them, claiming not to trust the supplier states to live up to their assurances and accusing them of wishing to preserve their technological superiority. A second argument made against such proposals, including by the companies that supply enriched uranium, is that the existing commercial market is sufficiently diversified to ensure supply. They point out that there has never been a case of a country having its supply cut off for political reasons. Even India, which was refused nuclear fuel for its CIRUS reactor after conducting its 1974 nuclear explosion, was able to receive it from France on the grounds of ensuring the "safety" of the reactor (Perkovich, 1999: 235).

Two of the proposals made for providing assurances of supply are relatively well advanced, one centred on the

Proposals for Assurances of Supply and/or Multilateralization of the Nuclear Fuel Cycle

US Proposal on a Reserve of Nuclear Fuel (2005): In September 2005, the US announced that it would commit 17 metric tons of HEU to be down-blended to LEU to act as a reliable supply of fuel for states that forego enrichment and reprocessing.

US Global Nuclear Energy Partnership (2006): As a part of GNEP, the US proposed that a consortium of countries ensure reliable access to fuel for countries that forego enrichment and reprocessing (Pomper, 2009).

World Nuclear Association Proposal (2006): In May 2006, the WNA Working Group on Security of the International Fuel Cycle proposed a three-stage assurances of supply arrangement:

a. Basic supply security provided by the existing world market;
b. Collective guarantees by enrichers supported by governmental and IAEA commitments; and
c. Government stocks of enriched uranium product (EUP) (WNA, 2006).

The proposal emphasizes that existing sources of supply are sufficient to ensure reliable supply for all states.

Concept for a Multilateral Mechanism for Reliable Access to Nuclear Fuel: The six enriched fuel supplier states — France, Germany, the Netherlands, Russia, the UK and the US — proposed two levels of assurance of supply. The first level, "basic assurances," commits suppliers to substitute for each other in cases of interruption of supply. The second level, "reserves," would be a virtual or physical supply of fuel set aside for use if basic assurances failed.

IAEA Standby Arrangements System: Japan proposed that an information system be established to compliment the six enriched fuel supplier states' proposal. The system would track national fuel cycle capacities throughout the entire fuel cycle so that other states always have a clear view of available supply.

Nuclear Fuel Assurance Proposal: This UK proposal, previously the Enrichment Bonds Proposal, suggests offering enrichment bonds that guarantee that national suppliers would not be prevented from supplying enrichment services, and to provide prior consent for export assurances.

Multilateral Enrichment Sanctuary Project: In May 2007, Germany proposed a multilateral uranium enrichment centre with extra-territorial status that would operate commercially under IAEA control. This proposal has since evolved into a Multilateral Enrichment Sanctuary Project (MESP), which would be supervised by the IAEA, but owned and operated by a multinational consortium.

Multilateralization of the Nuclear Fuel Cycle: Austria proposed a two-track system, the first involving increasing transparency beyond current IAEA safeguards, the second creating a nuclear fuel bank to act as a hub for all nuclear fuel transactions.

Nuclear Fuel Cycle non-paper: In June 2007, the European Union, in response to many of the above proposals, emphasized the importance of maintaining flexibility in considering approaches to the fuel cycle. The non-paper proposed proliferation resistance, assurance of supply, consistency with equal rights and obligations, and market neutrality as important criteria for any fuel cycle proposal.

International Nuclear Fuel Agency: In a draft paper released in 2009, Thomas Cochran and Christopher Paine proposed that an International Nuclear Fuel Agency (INFA), be established to certify design, construction and operation of all uranium enrichment facilities worldwide (Cochran and Paine, 2009: 2). All enrichment activities would be conducted inside long-term "Sovereign Secure Leased Areas" that INFA would lease from governments; enrichment facilities would still be under national or private ownership, but INFA would ensure that safeguards were maintained and would control entry and egress from the site as well as end use of the enriched fuel supplied.

Source: Adapted in large part from by Yury Yudin, *Multilateralization of the Nuclear Fuel Cycle: Assessing the Existing Proposals*, UNIDIR, Geneva 2009.

IAEA and one in Russia, although both require the approval of the IAEA Board of Governors before they can be realized. Both schemes have run into surprisingly strong opposition in the Board from the very states that they are designed to assist.

IAEA Nuclear Fuel Bank

The fuel bank initiative was proposed by the Nuclear Threat Initiative in September 2006. NTI committed $50 million to the IAEA to help it establish a stockpile of LEU to provide fuel assurances for nonproliferation-compliant states. A condition was that IAEA member states commit an additional $100 million, an amount raised by March 2009 with contributions from the EU, Kuwait, Norway, the UAE and the US (NTI, 2009). The Director General's proposal to formulate a plan for how the IAEA Fuel Bank would operate was, however, defeated in the BOG in June 2009 by developing states, which saw it as impinging on their Article IV rights under the NPT (NTI, 2009).

International Uranium Enrichment Centre

Russia has proposed devoting one of its existing nuclear facilities, located at Angarsk in Siberia, to providing international enrichment services on a "non-discriminatory" basis to facilitate assurances of supply. Currently, Russia owns 51 percent of the project, which has already been launched, while Kazakhstan, Armenia and the Ukraine own 10 percent each, leaving 19 percent still available (Loukianova, 2008). The Centre and its fuel will be under IAEA safeguards (Loukianova, 2008) and the IAEA would have a role in deciding which states should have access to the fuel supply and in what circumstances. It is the first concrete outcome of a proposal in January 2006 by Russian President Vladimir Putin for a Global Power Infrastructure that would offer all countries equal access to nuclear energy, while ensuring nonproliferation objectives were met. The Russian program includes establishing a guaranteed reserve of 120 tons of LEU in the form of uranium hexaflouride with enrichment levels of 2.0-4.9 percent U-235, amounting to two full fuel loads for a pressurized water reactor.

The recommendation that the Director General begin negotiations with Russia on its proposal were approved at the November 2009 BOG meeting, but with eight states voting against (Argentina, Brazil, Cuba, Egypt, Malaysia, Pakistan, South Africa and Venezuela), three (India, Kenya and Turkey) abstaining and one, Azerbaijan, not in attendance (Woods and MacLachlan, 2009). The new IAEA Director General Yukiya Amano and the Secretariat now have the "green light" to proceed but with less than overwhelming support. Informal talks have taken place with Russia for some time, so prolonged negotiations may not be necessary. However, with potential customers alienated from the proposal, it is not clear what its real future is.

Complete Multilateralization of the Fuel Cycle

The most radical solution to providing assurances of supply is the multilateralization of the entire nuclear fuel cycle. To prevent the unnecessary spread of enrichment and reprocessing technology many observers, including former IAEA Director General Mohamed ElBaradei, have proposed complete multilateralization (or internationalization) of the front and back ends of the nuclear fuel cycle. In 2003, he told the IAEA General Conference that the international community should consider:

> … the merits of limiting the use of weapons usable material (plutonium and high enriched uranium) in civilian nuclear programmes, by permitting it only under multilateral control. Similarly, we should also consider limiting the processing of such material — and the production of new material through

> reprocessing and enrichment — to international centres. These limitations would need to be accompanied by appropriate rules of transparency, control, and above all, assurance of supply. It is clear that strengthened control of weapons usable material is key to our efforts to strengthen non-proliferation and enhance security (ElBaradei, 2003).

Under such a regime, governments that currently have fuel cycle facilities would offer them up for multilateralization and all future plants would come under the same regime. The US National Academy of Sciences identifies five key motivations for wanting to do so:

1. To assure countries that they have reliable access to reactor fuel.
2. To provide countries with an opportunity to profit from enrichment or reprocessing.
3. To reduce the proliferation risk of individual plants due to shared ownership.
4. To pool resources to reduce economic burdens.
5. To create facilities that can receive high-risk materials (NAS, 2009: 10-11).

Views on the degree of internationalization needed are divided. Some argue that creating a few multilateral facilities to act as an incentive for states to forego indigenous enrichment and reprocessing is enough (NAS, 2009: 52). Questions have also been raised about the extent of multilateral ownership of facilities, as well as about the national, multinational or international staffing of facilities and their locations (NAS, 2009: 52). It is likely, however, that only a true multilateral regime, however radical an idea that may seem at present, will satisfy those states that are most concerned about discrimination and determined to preserve all of their Article IV rights. Such a regime would in any event have to be part of any serious move towards complete nuclear disarmament.

The Link between Nonproliferation and Nuclear Disarmament

While nuclear disarmament is not the central concern of this report, there is an obvious link between it and calls for strengthening global governance in the realm of nuclear nonproliferation. There is increasing recognition that the non-nuclear weapon states will not accept further restrictions on their peaceful nuclear activities without real movement on nuclear disarmament. Deepti Choubey, in a study for the Carnegie Endowment for International Peace, interviewed foreign ministry officials from 16 non-nuclear weapon states, including US allies both within and outside NATO. She concluded that "The stark reality is that nuclear weapon states are in arrears and have a significant debt to pay before key non-nuclear weapon states will consider additional nonproliferation commitments" (Choubey, 2008: 4).

This has huge implications for ensuring that a nuclear energy revival takes place in the context of strengthened global governance. Aspiring states are eager for assistance and advice from the IAEA in considering the option of nuclear energy and in implementing a decision to proceed. But they will be loathe to have new nonproliferation constraints and conditions imposed on them that existing nuclear energy states were not subject to when they began, or in the case of the nuclear weapon states and safeguards, are still not subject to more than 40 years after the NPT was negotiated. This dispute may not just occur in the nonproliferation area, but may spill over into attempts to impose additional conditions with regard to nuclear safety and security that existing nuclear energy states did not have to face. There is a danger that the nuclear energy revival could further exacerbate relations between the developed and developing countries.

The steps towards nuclear disarmament that the non-nuclear weapon states have long demanded is by now well known and encapsulated in several United Nations documents as well as the reports of various commissions and panels. Among these are the Final Document of the First United Nations Special Session on Disarmament (UNSSOD 1) in 1978 (UN, 1978); the 1996 Canberra Commission on the Elimination of Nuclear Weapons (Canberra Commission, 1996); the Thirteen Practical Steps agreed at the 2000 NPT Review Conference;[33] the 2006 Weapons of Mass Destruction Commission (WMD Commission, 2006); and most recently, the Independent Commission on Nuclear Nonproliferation and Disarmament (ICNND), which released its report in December 2009. Among the steps they have in common are:

- Deep cuts in the nuclear weapon arsenals of Russia and the United States, including tactical nuclear weapons;
- Follow-on cuts in the arsenals of the other "official" nuclear weapon states, China, France and the UK, and ultimately those of the "unofficial" nuclear weapon states, India, Israel and Pakistan (assuming that North Korea will sooner rather than later implement its existing agreement to disarm);
- De-alerting of the strategic nuclear weapon systems of Russia and the US;
- Changes in nuclear doctrine by all states with nuclear weapons, including no-first use declarations; the provision of negative security assurances and an end to extended deterrence postures; along with a "sole purpose" declaration that reserves the role of nuclear weapons to the deterrence of use by others;
- Entry into force of the 1996 Comprehensive Nuclear Test Ban Treaty (CTBT); and
- Negotiation and implementation of a Fissile Material Cut-Off Treaty (FMCT) or a Fissile Material Treaty (FMT) that also deals with existing stockpiles of weapons materials.

Commendably, the ICNND report for the first time seeks to link stages in the nuclear disarmament process not just to nonproliferation steps in general, but to "progressive implementation of measures to reduce the proliferation risks associated with the expansion of civil nuclear energy" (ICNND, 2009: 186). It also admirably seeks to establish linkages between disarmament measures and strengthening of the regimes for nuclear safety and security. Measures specifically mentioned include the entry into force of the 2005 Amendment to the Convention on the Physical Protection of Nuclear Material, movement towards greater multilateralization of the nuclear fuel cycle, government industry cooperation on proliferation-resistant technologies; and promotion of awareness worldwide of the importance of safeguards, security and safety and "assistance to countries in developing relevant measures."

Given this report's consideration of the future of nuclear energy to 2030, the most pertinent part of the ICNND's recommendations is its Medium Term Agenda to 2025, by which time a "minimization point" for nuclear disarmament is achieved, characterized by (ICNND, 2009: 186):

- no more than 2,000 nuclear warheads (less than 10 per cent of today's arsenals);
- agreed doctrine: every nuclear-armed state committed to no first-use; and
- credible force postures: verifiable deployments and alert status reflecting that doctrine.

This would be accompanied by non-nuclear measures designed to strengthen international security, building support for a comprehensive Nuclear Weapons Convention, the CTBT in force, an FMCT in force and all surplus nuclear weapons materials under safeguards.

It is beyond the remit of this report to consider the practicability of the recommendations of this latest attempt to lay out a path towards nuclear disarmament. The achievement of the ICNND's Medium Term Agenda to 2025 would naturally be supportive of and entirely consistent with this report's recommendations regarding nuclear safety, security and nonproliferation.

CONCLUSIONS

The advantage that a state would gain from acquiring nuclear energy as a cover for a nuclear weapons program is difficult to calibrate precisely and easy to exaggerate. Essentially a state with no previous exposure to nuclear science and technology (increasingly rare these days) that acquires and operates a once-through nuclear power reactor (run on imported low-enriched uranium and with storage or return of spent fuel) will gain only the beginnings of what it would need in order to learn how to build a nuclear device. This will include scientific and technological expertise, especially in the handling of nuclear materials, experienced personnel, infrastructure and a legitimate basis for research and experimentation. If the state buys a turnkey plant, which it only gradually assumes operating, the benefits will be much smaller. If, as is likely, it also operates a peaceful nuclear research program, including a research reactor, the benefits may be of varying significance. In any case, such a state, in order to proceed to a weapons program would need access to, or an understanding of how to obtain, enriched uranium or plutonium, as well as bomb design and construction. Ultimately testing, weaponization and means of delivering a weaponized device will be required.

The spread of power reactors globally, whether of the light-water variety or not, is not, however, without its proliferation and diversion risks. LEU for nuclear fuel can give a state a head-start in enrichment to weapons grade; weapons-grade plutonium can be obtained from LWRs if a certain batch of fuel is not irradiated for the normal period; and even non-weapons grade plutonium might be useful in a crude, low-yield but still destructive nuclear device. Combined with the possibility of small clandestine enrichment or reprocessing facilities, such diversion scenarios call into question claims that a nuclear revival has no implications whatsoever for weapons proliferation.

The main threat to nuclear nonproliferation from a nuclear revival comes not, however, from the spread of reactor technology per se, but the possibility that increasing numbers of non-nuclear weapon states, encouraged by the lure of energy self-sufficiency and security, will seek a complete nuclear fuel cycle — from uranium mining to the enrichment of uranium and the reprocessing of spent fuel. This will give them access to weapons-grade material, in addition to a hedge that may be realized at any time by perfectly legitimately withdrawing on three months' notice from the NPT and seeking nuclear weapons. An additional threat emerges from the possibility of terrorists stealing fissionable material from a civilian nuclear facility or from shipments in storage or in transit.

The current nuclear nonproliferation regime currently faces serious challenges, notably from Iran and North Korea and by revelations of extensive nuclear smuggling that might be continuing or replicated in future. Concessions made to India have not been helpful. The discontent of non-nuclear weapon states with perceived inequities in the regime again runs the risk of being reflected in the 2010 NPT Review Conferences and thereafter. Such challenges to the regime will only be made worse by a careless nuclear energy revival that mirrors the original spread of "peaceful" nuclear technology. Fortunately the IAEA's nuclear safeguards regime has been strengthened considerably in recent years and several other multilateral initiatives have been taken to bolster the regime. Nonetheless, global governance in this area demands more resources, more creative approaches and greater commitment to universalizing nonproliferation agreements and arrangements. This will not be possible until the existing nuclear weapon states and major nuclear energy states are prepared to forego options that they ask others to forego, namely the right to the full nuclear fuel cycle and the retention of nuclear weapons in perpetuity.

Recommendations

Safeguards

- The Additional Protocol should be made the "gold standard" for nuclear safeguards, including becoming a condition of supply for all nuclear material and technology and a requirement for all states seeking nuclear energy for the first time; the IAEA should be supported and funded in its effort to achieve universality for the Additional Protocol, especially through regional outreach.
- Old versions of the Small Quantities Protocol should be quickly replaced by the new version; any state seeking nuclear power plants should immediately convert to an Additional Protocol.
- The US, Canada and other safeguards supporters should initiate an immediate move to further strengthen IAEA safeguards through an Additional Protocol-plus process; this should draw on the work of the US Next Generation Safeguards Initiative, the proposals prepared by the Secretariat for the former Advisory Committee on Safeguards and Verification and ideas reviewed in this report.
- While Integrated Safeguards is a useful program and should be pursued both as a reward for excellent safeguards behaviour, to relieve unnecessary burdens on states and to direct resources where most needed, care should be taken that verifiability is not endangered; the same applies to increased use of unattended remote sensing technology in place of human inspectors.
- The IAEA Board of Governors should be prepared to request special inspections in cases of suspected violation of safeguards or in cases of serious noncooperation with the Agency in providing additional information or access.
- The IAEA Board of Governors should confirm the authority of the Agency to monitor weaponization research and development (R&D) and actual weaponization activities.

IAEA Budget and Infrastructure

- This report endorses the recommendation of the Commission of Eminent Persons on the Future of the Agency to 20/20 that the IAEA budget be doubled by 2020 to cope, inter alia, with the increasing demands for nuclear safeguards and safety and security programs as a result of the increased use of nuclear energy; significant budgetary increases should be made thereafter to 2030.
- The IAEA should undertake a crash program to upgrade its Seibersdorf facilities to incorporate the latest technology and supportive infrastructure and to bring it up to the highest safety and security standards; the Major Capital Investment Fund needs to be boosted with the $50 million one-off injection of funds as recommended by former Director General ElBaradei.
- The IAEA should take steps to expand and renew its personnel resources, including considering proposals made in this report such as seeking exemption, where appropriate, from constraining UN system rules.
- More states should commit to support the IAEA's Trade and Technology Analysis Unit in its efforts to track nuclear smuggling networks, both with

information on declined export applications and other intelligence.

- This report endorses the suggestion of the ICNND on the need for "greater transparency in the IAEA's internal processes, how judgements are reached and decisions taken in the safeguards area especially and … a new approach to information sharing, in which states and the Agency work together as partners" (ICNND, 2009: 91-92).
- This report endorses the work of the Next Generation Safeguards Initiative in seeking ways to produce future generations of safeguards personnel both nationally and internationally, and to provide cutting edge technology and techniques for nuclear safeguards; the initiative's goals should be supported by other safeguards supporters like Canada, which could establish their own national versions of the initiative as well as participating in it internationally.

Nuclear Fuel Cycle

- Efforts should continue to establish an IAEA Fuel Bank, while recognizing that this is only a first step and one that will only be used in extreme circumstances, towards creating assurances of supply.
- The existing nuclear energy states need to realize that the only way that sensitive fuel cycle technology can be prevented from contributing to further nuclear proliferation is through the implementation of a non-discriminatory institutional framework involving multilateral ownership and operation of all enrichment, reprocessing and possibly other fuel cycle facilities: the US, Russia, the other nuclear weapon states and other major nuclear energy supplier states should commit to and begin implementing such a strategy.[34]
- Although not used in nuclear power reactors, in the interests of nonproliferation, all highly enriched uranium should be removed from all civilian use; this includes converting all research and isotope-production reactors to low enriched uranium as soon as possible and returning HEU to its country of origin.

Involvement of Nuclear Reactor Vendor Companies and States and Other Stakeholders

- The new Director General should ensure that the IAEA Secretariat works more closely with industry, research institutes and non-governmental organizations to ensure that it takes advantage of the capacities and perspectives of all of them.
- The nuclear industry, especially reactor vendors, should take nuclear nonproliferation more seriously than they have to date and cease denying that it is a problem strictly for governments and the IAEA; it is in industry's commercial interest to become involved more closely with the IAEA and other international institutions on nonproliferation issues, as a proliferation incident arising from a badly managed reactor sale would damage the revival as much as a safety or security incident; the WNA should lead the way in cooperation with progressive companies like Areva, in encouraging industry engagement, inter alia with the IAEA, WINS, the successor to GNEP and in the new forum proposed below.
- An international forum should be convened or an existing one adapted that brings together all states and companies involved in the sale of nuclear power reactors in order to harmonize the conditions under which such sales take place; the proposed successor to GNEP internationally is one option providing it is broadened to include reactor vendor companies.
- Criteria for reactor sales should include full compliance with and implementation of IAEA safeguards and an Additional Protocol; accession to all key conventions on safety and security; and full compliance with UN Security Council Resolution 1540. In addition, conditions relating to stability of national gov-

ernance, levels of corruption and regional security should also be considered, as well as voluntary renunciation of sensitive nuclear technologies.

Nuclear Disarmament

- Few of the measures proposed above to strengthen global nuclear governance in the peaceful uses of nuclear energy in the period to 2030 will be acceptable to enough states unless more substantive, early progress is made towards fulfilling Article VI of the NPT, and ultimately in achieving global, verified nuclear disarmament.
- This report endorses the recommendations of the ICNND for the 2010 NPT Review Conference and for getting to a nuclear disarmament "minimization point" by 2025 in preparation for the challenge of achieving complete nuclear disarmament.

Appendix A – Scientific Disciplines Relevant to Peaceful Programs and Nuclear Weapons

Discipline	Peaceful Uses	Weapons Uses
Nuclear Engineering	Design of nuclear reactors	Dedicated reactors*
	Shielding of nuclear reactors and all other types of radiation sources – health physics	Shielding of dedicated reactors and reprocessing plants
	Calculations of radiation doses from radiation facilities during normal operation and under accident conditions	Same
	Calculation of fuel burnup and fissile atom production	Same, particularly plutonium production rate
	Criticality calculations – fuel pools, reprocessing plants, etc.	Same
	Reactor siting and licensing	Developing and running weapons design codes
	Isotope applications	N/A
Chemical Engineering	Design of plants, especially gaseous diffusion, for enriching uranium	Same
	Design of reprocessing plants	Same
	Design of plants for production of heavy water, graphite	Same
	Design of chemical systems required in nuclear power plants	N/A
	Waste disposal systems	N/A
Metallurgical Engineering	Obtaining uranium metal from uranium ore	Same
	Preparation of uranium metal from uranium hexafluoride (from enrichment plants)	Same
	Fuel element manufacture	Same
	Materials for reactors: stainless steels, boron carbide, control rod materials, graphite	Same
		Reduction and purification of plutonium
		Fabrication of plutonium parts of weapons
Mechanical Engineering	Design of reactor structures	Same, dedicated reactors
	Heat transfer calculations for reactors	Same, dedicated reactors
	Design of steam generators, pressurizers, pumps, heaters, condenser, piping	Design of structural components of weapons
	Centrifuges for isotope separation	Same
	Mechanical design of fuel handling equipment, fuel casks, etc.	Same
	Heating ventilating, air conditioning	N/A
Electrical Engineering	Reactor instrumentation and control systems	Same, dedicated reactors
	Electric generation and distribution systems for nuclear power plants	Ignition systems for weapons
	Instrumentation and control of reprocessing plants, isotope enrichment plants	Same
Physics	Measurement of fundamental nuclear data for reactor design	Fundamental design calculations of weapons — the amount and distribution of uranium or plutonium, the explosive configuration, the location of the igniters, the weapon yield, and effects of weapon detonation
	Fundamentals of isotope separation, lasers, centrifuges, etc.	Same
Mathematics and Computer Science	Codes for reactor design and operation	Assist in calculations used in weapons design — developing the necessary codes
	Shielding design, radiation dose code	N/A
	Statistical analysis of reactor components, accident probabilities	N/A
Chemistry	Design, operation of chemical systems in nuclear power plants	Same, dedicated reactors
	Provide fundamental chemical data for design of reprocessing plant	Same

* a reactor specially designed to produce plutonium, typically to supply a weapons program.

Endnotes

1 The following section draws significantly from the work of Alger, 2009.

2 A fission reaction is induced by introducing neutrons into certain isotopes of uranium or plutonium atoms, thereby causing them to become unstable and split into lighter atoms. These lighter atoms do not equal the mass of the initial atom, and in the process this lost mass is converted into energy, as per Albert Einstein's famous $E=mc^2$ formula. Energy (E) is equal to the square of the product of mass (m) and the speed of light (a constant "c").

3 A US Congressional Office of Technology Assessment concluded in 1995 that "In general, assistance at the level and for the purposes provided by the IAEA makes little direct contribution to a nuclear weapon program. However, the skills and expertise that might be acquired by a state through such assistance could be relevant, both in terms of basic knowledge in dealing with nuclear materials and nuclear technology, and also possibly in terms of extrapolating techniques a state first learns through IAEA technical assistance" (US OTA, 1995: 54).

4 For detailed historical accounts of nuclear assistance to India, Israel, North Korea, Pakistan and South Africa, see the *Nuclear Threat Initiative's* country profiles. Available at: http://www.nti.org/e_research/profiles/index.html.

5 Most recently by the ICNND; see ICNND, 2009: 126.

6 For an excellent account of the CANDU controversy, see Bratt, 2006: 46-47.

7 For more information on India's nuclear program, see Perkovich, 1999.

8 Pakistan had help from France in building the Chasma and Pinstech reprocessing plants, China is suspected of helping Pakistan with the Kahuta enrichment plant. France also assisted Israel to construct the Dimona reprocessing plant. North Korea received reprocessing technology from the Soviet Union in the 1960s, and is suspected of receiving designs and components for an enrichment plant supplied by Pakistan. For further details, see Kroenig (2009) and NTI (2009c).

9 During the 1960s and 1970s the US government allowed a few dozen foreign scientists to be involved in unclassified research relating to enrichment or reprocessing. A declassified 1979 report by the US Comptroller General noted that: "Department of Energy officials said that sensitive areas of nuclear technology have been examined and precautions have been taken, but it is difficult to draw a firm line between what is and is not sensitive; it is a matter of degree" (US GAO, 1979: i-vi).

10 For more information about the challenges of weaponization, see NTI (2009).

11 For example, see Goldschmidt, 2007 and 2009: 4.

12 Unsurprisingly, with the addition of Japan, this was practically identical to the self-appointed group of countries that had drafted the Statute — Australia, Belgium, Brazil, Canada, Czechoslovakia, France, India, Portugal, South Africa, the Soviet Union, the United Kingdom and the United States. For an account of the BOG's construction, see Fischer, 1997: 39-40.

13 In NPT state parties, they are "suspended," but would be reactivated automatically should NPT-based safeguards for some reason disappear.

14 The quantities are 8 kilograms of plutonium and uranium-233, 25 kilograms of uranium-235 enriched to 20 percent or more, 75 kilograms of uranium-235 enriched to less than 20 percent, 10 tonnes of natural uranium and 20 tonnes of natural uranium or thorium (IAEA, 1998: 53).

15 For Romania, see Mozley, 1998; for Egypt and South Korea, see US GAO 2005: 20. Taiwan was caught by the Americans in 1976 constructing a prototype plutonium reprocessing plant. Although Taiwan had been expelled from the IAEA in 1972 to make way for the People's Republic of China, the Agency continued to apply safeguards under two agreements, INFCIRC/133 and INFCIRC/158, which came into force on October 13, 1969, and December 6, 1971, respectively. Taiwan has since been treated as a "non-governmental" entity and the Agency applies the equivalent of both comprehensive safeguards and the Additional Protocol to Taiwan. See Quester, 1985; IAEA, 2009c; and IAEA, 2008c: 68.

16 It achieved this in close cooperation with the UN Special Commission (UNSCOM) and the UN Monitoring, Verification and Inspection Commission (UNMOVIC) established by the UN Security Council.

17 Some members of the IAEA BOG voiced concerns about the Saudi SQP on the grounds that it provided insufficient transparency (IISS, 2008: 42).

18 NTM is a euphemism for all sources of information available to an individual state for monitoring the behaviour of other states, including in respect of treaty compliance. For further details, see UNIDIR, 2003: 20-22.

19 Article XII.5 of the IAEA Statute gives the Agency the authority "To send into the territory of the recipient State or States inspectors, designated by the Agency after consultation with the State or States concerned, who shall have access at all times to all places and data and to any person who by reason of occupation deals with materials, equipment, or facilities which are required by this Statute to be safeguarded, as necessary to account for source and special fissionable materials supplied and fissionable products and to determine whether there is compliance with the undertaking against use in furtherance of any military purpose…"

20 For a series of papers analyzing the IAEA, see Sokolski, 2008.

21 "At what cost, success," MANNET (Management Network), Chambésy, Switzerland, October 14, 2002, cited in IAEA, 2008d: 29.

22 When the North Korean freighter *So San* was found carrying missile components to Yemen, efforts were made to formalize an interdiction regime. A similar boarding in 1993 of the Chinese freighter *Yinhe* failed to yield evidence of suspected chemical weapon precursors and instead hampered further cooperation. See Winner, 2005: 130-132.

23 The US has concluded nine such agreements, including with Liberia and Panama, the two largest registrars of ships in the world (US Department of State, 2009c).

24 This section draws considerably on Pomper, 2009 and a series of GNEP Watch reports published electronically by CIGI from October 2007 to December 2008 (see www.cigionline.org).

25 One of these is the chemical UREX+ method which, unlike the traditional PUREX process, does not result in pure plutonium, but keeps it mixed with other oxides, rendering it more proliferation resistant. The other major alternative is pyroprocessing, which uses an electrical current to draw plutonium, uranium, some rare-earth fission products and transuranic elements into separate areas from the longest-lived fission products but also does not result in pure plutonium.

26 The working group has put significant effort into implementing the action plan, including initiatives to secure and consolidate nuclear materials, remove weapons-usable material from third countries, combat illicit trafficking of nuclear materials, and strengthen the international safeguards system and export controls. The group has identified key focus areas for collaboration to promote the safe and peaceful use of nuclear energy, and is exploring opportunities to work bilaterally and with counterparts from other countries to consider a new fuel services framework (US Department of State, 2009a).

27 Based on purchasing power parity.

28 A Vienna-based diplomat told *Arms Control Today* that the committee, which held a total of six meetings, was ultimately unable to reach consensus on a list of 18 recommendations provided by the IAEA Secretariat. Many states (presumably all of them non-Western) perceived the committee's deliberations to be "political" rather than "technical" and argued that more priority should be given to nuclear weapon states' obligations to reduce their nuclear arsenals, rather than improving safeguards (Kerr, 2007).

29 The ICNND report has mentioned as examples the conversion of fissile material to metallic form and particular shapes; the development of explosive lenses, high-energy electrical components or high-flux neutron generators; implosion testing; and acquisition of certain non-nuclear materials such as beryllium, polonium, tritium and gallium (ICNND, 2009: 85).

30 For example, see Hart, 2002.

31 Undersecretary of State for Arms Control and International Security John Bolton told reporters that the United States should not "apply a double standard" to South Korea (Kerr, 2004).

32 For an examination of technological and other possibilities to 2050 and beyond, see Feiveson et al., 2008.

33 Adapted from a recommendation in Feiveson et al., 2008: 17.

Works Cited

Acheson, Dean, and David Lilienthal, Chairs (1946). A Report on the International Control of Atomic Energy, Committee on Atomic Energy, US Department of State. Washington, DC. March 16.

Acton, James M. (2009). "The myth of proliferation-resistant technology," *The Bulletin of the Atomic Scientists*. November/December. Pp. 49-59.

Acton, James and Carter Newman (2006). "IAEA verification of military research and development," *Verification Matters*. No. 5. Verification Research, Training and Information Centre (VERTIC), London, July 2006.

Albright, David (2007). "Nuclear Black Markets: Pakistan, A.Q. Khan, and the Rise of Proliferation Networks," Institute for Science and International Security (ISIS), Written Testimony before the House Committee on Foreign Affairs' Subcommittee on the Middle East and South Asia and the Subcommittee on Terrorism, Nonproliferation, and Trade, June 27. Available at: http://www.globalsecurity.org/wmd/library/congress/2007_h/070627-albright.htm.

Alger, Justin (2009). "From nuclear energy to the bomb: the proliferation potential of new nuclear energy programs," *Nuclear Energy Futures Paper*. No. 6, Waterloo: CIGI.

Büchler, Carlos L. (1997) "Safeguards: the beginnings," in International Atomic Energy Agency: Personal Reflections. Vienna: IAEA.

Blanchard, Christopher M., and Paul K. Kerr (2009). "The United Arab Emirates Nuclear Program and Proposed U.S. Nuclear Cooperation," Washington: Congressional Research Service.

Boese, Wade (2005). "Key U.S. Interdiction Initiative Claim Misrepresented," *Arms Control Today*. Vol. 35. July/August. Available at: http://www.armscontrol.org/act/2005_07-08/Interdiction_Misrepresented.

Borger, Julian (2007). "Nuclear watchdog might not cope in atomic crisis," *The Guardian*. June 22. Available at: http://www.guardian.co.uk/world/2007/jun/22/northkorea.

Boureston, Jack, and Yana Feldman (2007). "Integrated nuclear safeguards: development, implementation, future challenges," Compliance Chronicles, Canadian Centre for Treaty Compliance. No. 4. January.

___ (2004). "Verifying Libya's nuclear disarmament," *Verification Yearbook 2004*. VERTIC, London.

Bratt, Duane (2006). *The Politics of CANDU Exports, IPAC Series in Public Management and Governance*. Toronto: University of Toronto Press.

Byers, Michael (2004). "Policing the High Seas: The Proliferation Security Initiative," The American Journal of International Law. Vol. 98, No.3: 526-545.

Central Intelligence Agency (CIA) (2009a). "GDP – Per Capita (PPP)," *The World Factbook*. Available at: https://www.cia.gov/library/publications/the-world-factbook/rankorder/2004rank.html?countryName=%20United%20Arab%20Emirates&countryCode=ae&regionCode=me&rank=19#ae (accessed August 12, 2009).

___ (2009b). "United Arab Emirates," The World Factbook. Available at: https://www.cia.gov/library/publications/the-world-factbook/geos/ae.html (accessed August 12, 2009).

Convention on Nuclear Safety (CNS) (2009). "Nuclear Suppliers Group," Inventory of International Nonproliferation Organizations and Regimes. James Martin Centre for Nonproliferation Studies. June 15.

Available at: http://www.nti.org/e_research/official_docs/inventory/pdfs/nsg.pdf.

Campbell, John L. (1988). *Collapse of an Industry: Nuclear Power and the Contradictions of U.S. Policy*. Ithaca: Cornell University Press.

Canberra Commission (1996). "Report of the Canberra Commission on the Elimination of Nuclear Weapons," Department of Foreign Affairs and Trade, Australia. August. Available at: http://www.dfat.gov.au/cc/CCREPORT.PDF.

Choubey, Deepti (2008). "Are new nuclear bargains attainable?" Carnegie Endowment for International Peace. Washington, DC.

Cochran, Thomas B., and Christopher E. Paine (2009). "Proliferation Resistant Uranium Enrichment – Discussion Draft," Presented at the International Forum on Nuclear Proliferation and Nuclear Energy Amman, Jordan. June.

Davis, Paul, and Trevor Findlay (2009). "Giving Up the Bomb: Motivations and Incentives," *Research Papers, International Commission on Nuclear Non-proliferation and Disarmament*. Vol. 8.

Department Of Energy (DOE) (1994). "Additional Information Concerning Underground Nuclear Weapon Test of Reactor-Grade Plutonium," Press Release, US Department of Energy, Office of the Press Secretary, Washington DC, June. Available at: https://www.osti.gov/opennet/document/press/pc29.html.

de Jong, Derek, and Raymond Froklage (2009). "Regional Nuclear Weapon-Free Zones," *Compliance Briefing Paper*. Canadian Centre for Treaty Compliance.

Eisenhower, Dwight D. (1953). "Atoms for Peace," Speech Before the General Assembly of the United Nations on Peaceful Uses of Atomic Energy. December 8.

ElBaradei, Mohamed (2007). "Nuclear power and the global challenges of energy security," World Nuclear Association Annual Symposium. London. September 6.

___ (2003). "Statement to the Forty-seventh Regular Session of the IAEA General Conference 2003," September 15. Available at: http://www.iaea.org/NewsCenter/Statements/2003/ebsp2003n020.html.

Feiveson, Harold, Alexander Glaser, Marvin Miller and Lawrence Scheinman (2008). "Can Future Nuclear Power Be Made Proliferation Resistant?" Center for international and Security Studies, University of Maryland, July. Available at: http://www.cissm.umd.edu/papers/files/future_nuclear_power.pdf.

Feiveson, H.A. (2004). "Nuclear Proliferation and Diversion" in Cutler Cleveland, ed. *The Encyclopedia of Energy*. Elsevier, March.

Ferguson, Charles D. (2008). "Strengthening Nuclear Safeguards," *Issues in Science and Technology*. Vol. 24, No.3 (Spring). Available at: http://www.issues.org/24.3/ferguson.html.

Fischer, David (1997). *History of the International Atomic Energy Agency: The First Forty Years.* Vienna: International Atomic Energy Agency.

G8 (2009). "G8 L'Aquila Statement on Non-Proliferation," July 9. Available at: http://www.g7.utoronto.ca/summit/2009laquila/2009-nonproliferation.pdf.

Government Accountability Office (GAO) (2005). United States Government Accountability Office, Highlights of "Nuclear Proliferation: IAEA has strengthened its safeguards and nuclear security programs, but weaknesses need to be addressed," GAO-06-93. Washington DC, October.

___ (1979). "Difficulties in Determining if Nuclear Training of Foreigners Contributes to Weapons Proliferation," Report by the Comptroller General of The United States. United States General Accounting Office.

Global Security Newswire (GSN) (2009). "UAE Pact Could Become Basis for Future Nuclear Deals, Experts Say," February 3. Available at: www.globalsecuritynewswire.org/gsn/nw_20090203_8154.php.

Garwin, Richard L., and Georges Charpak (2002). *Megawatts and Megatons: The Future of Nuclear Power and Nuclear Weapons*. Chicago: University of Chicago Press.

Gilinsky, Victor, Marvin Miller and Harmon Hubbard. (2004). *A Fresh Examination of the Proliferation Dangers of Light Water Reactors*. The Nonproliferation Policy Education Center. October 22. Available at: http://www.npecweb.org/Essays/20041022-GilinskyEtAl-LWR.pdf.

Goldschmidt, Pierre (2009). "Concrete Steps to Improve the Nonproliferation Regime," *Carnegie Paper.* No. 100. April.

___ (2007). "Saving the NPT and the Nonproliferation Regime in an Era of Nuclear Renaissance," Testimony before the House Foreign Affairs Subcommittee on Terrorism, Nonproliferation and Trade. July 28.

Grossman, Elaine M. (2009). "Boost in IAEA intelligence capability looks unlikely in near term." *Global Security Newswire*. June 22.

Gulf News (2008a). "Nuclear matters," July 31. Available at: http://www.gulfnews.com/business/General/10233061.html.

___ (2008b). "UAE to set up Emirates Nuclear Energy Corporation," April 21. Available at: http://www.gulfnews.com/nation/Government/10207145.html.

___ (2008c). "UAE will be the first Gulf state to develop civilian nuclear power," March 24. Available at: http://www.gulfnews.com/nation/Government/10199888.html.

Hart, John (2002). "On-site inspections in theory and practice," *Verification Matters*. No. 4. Verification Research, Training and Information Centre (VERTIC). London.October.

Hibbs, Mark (2008). "Pakistan's Bomb: Mission Unstoppable," *Nonproliferation Review. Vol.* 15, No.2: 381-391.

Horner, Daniel. "Accord on New Rules Eludes Nuclear Suppliers," *Arms Control Today.* (July/August). Available at: http://www.armscontrol.org/node/3729.

House of Commons (1998). "Canada and the Nuclear Challenge: Reducing the Political Value of Nuclear Weapons in the Twenty-First Century," House of Commons Standing Committee on Foreign Affairs and International Trade, December.

Huntley, Wade, and Karthika Sasikumar, eds. (2006). *Nuclear Cooperation with India: New Challenges, New Opportunities*. Simons Centre for Disarmament and Non-Proliferation Research. Vancouver: University of British Columbia .

International Atomic Energy Agency (IAEA) (2010). "Agreement Reached on Integrated Safeguards in European Union," Press Release 2010/01. Available at: http://www.iaea.org/NewsCenter/PressReleases/2010/prn201001.html.

___ (2009a). "Finding a role for nuclear: IAEA helps developing countries assess readiness for nuclear power," IAEA staff report. July 21. Available at: http://www.iaea.org/News Center/News/2009/nuclearrole.html.

___ (2009b). "IAEA by the numbers," Vienna. Available at: http://www.iaea.org/About/by_the_numbers.html (accessed December 15, 2009).

___ (2009c). "Latest Status of Safeguards Agreements & Additional Protocols," Vienna. Available at: http://www.iaea.org/OurWork/SV/Safeguards/sir_table.pdf (accessed November 24, 2009).

___ (2009d). "Nuclear Research Reactors in the World." Available at http://www.iaea.org/worldatom/rrdb/

___ (2009e). "Regular Budget appropriations for 2010," IAEA document GC(53)/RES/6. September 18.

___ (2009f). "The Agency's Programme and Budget 2010–2011," IAEA document GC(53)/5. August.

___ (2009g). Power Reactor Information System (PRIS). Available at: http://www.iaea.org/programmes/a2/ (accessed December 29, 2009).

___ (2009h). Research Reactors in the World. Available at: http://www.iaea.org/worldatom/rrdb/ (accessed December 29, 2009).

___ (2008a). "20/20 Vision for the Future," Background report by the Director General for the Commission of Eminent Persons, IAEA document GOV/2008/22-GC(52)/INF/4.

___ (2008b). "Annual Report 2008," IAEA document GC(53)/7. Vienna.

___ (2008c). "Annual Report 2007," IAEA document GC(52)/9. Vienna.

___ (2008d). *Reinforcing the Global Nuclear Order for Peace and Prosperity: The Role of the IAEA to 2020 and Beyond*, Report prepared by an independent Commission at the request of the Director General of the IAEA, IAEA document GOV/2008/22-GC(52)/INF/4, Annex 1. Vienna.

___ (2008e). "An Agreement with the Government of India for the Application of Safeguards to Civilian Nuclear Facilities," Nuclear Verification: The Conclusion of Safeguards Agreements and Additional Protocols. IAEA document GOV/2008/30. July 9. Available at: http://www.isis-online.org/publications/southasia/India_IAEA_safeguards.pdf.

___ (2008f). "Plan of Action to Promote the Conclusion of Safeguards Agreements and Additional Protocols," Vienna. September. Available at: http://www.iaea.org/OurWork/SV/Safeguards/sg_actionplan.pdf.

___ (2007a). "Considerations to Launch a Nuclear Power Program." Vienna.

___ (2007b). "IAEA Safeguards: Staying Ahead of the Game." Vienna. September. Available at: http://www.iaea.org/Publications/Booklets/Safeguards3/safeguards0707.pdf.

___ (2007c). "Safeguards Analytical Laboratory: Sustaining Credible Safeguards," Report by the Director General. IAEA document GOV/2007/59. October 24.

___ (2006). "Revision of the Standardized Text of the 'Small Quantities Protocol.'" IAEA document GOV/INF/276/Mod.1. February 21.

___ (2003a). "Fact Sheet on DPRK Nuclear Safeguards," International Atomic Energy Agency. May. Available at: http://www.iaea.org/NewsCenter/Focus/IaeaDprk/fact_sheet_may2003.shtml.

___ (2003b). Report to the Board of Governors by the Co-Chairmen of the Informal Open-ended Working Group on the Programme and Budget for 2004-2005. IAEA document GC(47)INF/7, Attachment 1. July 16.

___ (2002). "Non-proliferation of nuclear weapons and nuclear security: IAEA safeguards agreements and additional protocols." Vienna. Available at: http://www.iaea.org/Publications/Booklets/nuke.pdf.

___ (1998). "The Evolution of Nuclear Safeguards," *International Nuclear Verification Series*. No. 2, Vienna.

___ (1974). "The Standard Text of Safeguards Agreements in connection with the Treaty on the Non-Proliferation of Nuclear Weapons," IAEA document GOV/INF/276. August 22.

___ (1972). "The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons (NPT)," IAEA document INFCIRC/153 (Corrected). June.

___ (1968). "The Agency's Safeguards System," IAEA document INFCIRC/66 Rev. 2. September 16.

International Commission on Nuclear Non-proliferation and Disarmament (ICNND) (2009). *Eliminating Nuclear Threats: A Practical Agenda for Global Policymakers*. Canberra/Tokyo. November.

International Institute for Strategic Studies (IISS) (2009). "Preventing nuclear dangers in Southeast Asia and Australasia," Press statement, International Institute of Strategic Studies, London, September 28.

___ (2008). "The Arabian Peninsula," *Nuclear Programmes in the Middle East: In the shadow of Iran.* May.

International Panel on Fissile Materials (IPFM) (2009). "A Path to Nuclear Disarmament," in *Global Fissile Material Report 2009*. October. Available at: http://www.fissilematerials.org/ipfm/site_down/gfmr09.pdf.

___ (2007). "Global Fissile Material Report 2007," October. Available at: http://www.fissilematerials.org/ipfm/site_down/gfmr07.pdf, 2007.

Keeny Jr., Spurgeon M., Chair, et al. (1977). *Nuclear Power Issues and Choices*, Report of the Nuclear Energy Policy Study Group, MITRE Corporation. Cambridge, MA: Ballinger Publishing Company.

Kerr, Paul (2007). "ElBaradei: IAEA budget problems dangerous," *Arms Control Today.* July/August. Available at: http://www.armscontrol.org/act/2007_07-08/IAEABudget.

___ (2004). "IAEA Probes Seoul's Nuclear Program," *Arms Control Today*. October. Available at: http://www.armscontrol.org/act/2004_10/IAEA_Seoul_Nuclear_Program.

Khalifa, Ali Mohammed (1979). *The United Arab Emirates: Unity in Fragmentation*, Boulder: Westview Press.

Kroenig, Matthew (2009). "Exporting the Bomb: Why States Provide Sensitive Nuclear Assistance," *American Political Science Review*. Vol. 103, No. 1.

Lauvergeon, Anne (2009). "The nuclear renaissance: an opportunity to enhance the culture of nonproliferation," *Daedalus*. Vol. 138, No.4. Fall.

Levy, Adrian, and Catherine Scott-Clark (2007). *Deception: Pakistan, the United States, and the Secret Trade in Nuclear Weapons*. New York: Walker & Company.

Lodding, Jan, and Bernado Ribeiro (2007). "Strengthening safeguards in states with limited nuclear activities," *Trust & Verify*. No. 123, Verification Research, Training and Information Centre (VERTIC). March.

Loukianova, Anya (2008). "Issue Brief: The International Uranium Enrichment Center at Angarsk: A Step Towards Assured Fuel Supply," Nuclear Threat Initiative. November. Available at http://www.nti.org/e_research/e3_93.html.

MacFarlane, Allison, James Asseltine and John Ahearne (2008). "The future of nuclear energy: policy recommendations," *The Bulletin of the Atomic Scientists.* December 11.

MacKay, Paul (1998). "Why Candus are bomb kits," *The Ottawa Citizen*. June 7. Available at: http://energy.probeinternational.org/nuclear-power/nuclear-proliferation/why-candus-are-bomb-kits.

Miller, Marvin (2004). "The feasibility of clandestine reprocessing of LWR spent fuel," Appendix 2, in Victor Gilinsky et al. *A Fresh Examination of the Proliferation Dangers of Light Water Reactors*.

Mozley, Robert F. (1998). *The Politics and Technology of Nuclear Proliferation*. Washington, DC: University of Washington Press.

Muroya, Nobuiho (2009). Director, Division of Operations C, Department of Safeguards, IAEA, to Wilton Park Conference 1008 on "Nuclear Non-Proliferation and the 2010 Review." December 14-18.

National Academy of Sciences (NAS), Russian Academy of Sciences (2009). *Internationalization of the Fuel Cycle: Goals, Strategies, and Challenges*. Washington DC: National Academies Press.

National Nuclear Security Administration (NNSA) (2009). "Next Generation Safeguards Initiative Annual Report for FY2009," Office of Nonproliferation and Security, US Department of Energy, Washington DC.

Nuclear Threat Initiative (NTI) (2009a). "IAEA Board Splits on Nuclear Fuel Bank Proposal," Global Security Newswire. June 19. Available at: http://gsn.nti.org/gsn/nw_20090619_5943.php.

___ (2009b). "NTI in Action: Creating an International Nuclear Fuel Bank," Nuclear Threat Initiative. Available at: http://www.nti.org/b_aboutnti/b7_fuel_bank.html.

___ (2009c). "North Korea Profile: Nuclear," *Country Profiles*, Nuclear Threat Initiative, December. Available at: http://www.nti.org/e_research/profiles/NK/index.html.

OECD/NEA (2008). *Nuclear Energy Outlook 2008*. Nuclear Energy Agency, OECD.

OTA (1995). *Nuclear Safeguards and the International Atomic Energy Agency*. Office of Technology Assessment (OTA), OTA-ISS-615, US Congress, Washington DC, April.

Perkovich, George (2002). "Nuclear Power in India, Pakistan and Iran" in Leventhal, Paul, Sharon Tanzer, Steven Dolley, eds. *Nuclear Power and the Spread of Nuclear Weapons*, Dulles: Brassey's.

___ (1999). *India's Nuclear Bomb: the Impact on Global Proliferation.* Berkeley: University of California Press.

Pilat, Joseph (2007). *Atoms for Peace: A Future after Fifty Years?* Washington, DC: Woodrow Wilson Center Press.

Pomper, Miles A. (2009). "US International Nuclear Energy Policy: Change and Continuity," *Nuclear Energy Futures Papers.* No. 10, December.

Quester, George H. (1985). "Taiwan" in Jozef Goldblat, *Non-Proliferation: the Why and Wherefore*, Stockholm International Peace Research Institute (SIPRI). London: Taylor & Francis. Pp. 227-234.

Ramana, M.V. (2009). "The Indian nuclear industry: status and prospects," *Nuclear Energy Futures Papers.* No. 9, Waterloo: CIGI. December. Available at http://www.cigionline.org/publications/2009/12/indian-nuclear-industry-status-and-prospects

Scheinman, Lawrence (1987). *The International Atomic Energy Agency and World Order, Resources for the Future*, Washington DC, 1987.

Sokolski, Henry D. (ed.) (2008). *Falling Behind: International Scrutiny of the Peaceful Atom, Strategic Studies Institute*. Carlisle, PA: US Army War College. February.

Spector, Leonard (1988). *The Undeclared Bomb.* Cambridge, MA: Ballinger Publishing Company.

Sreenivasan, T.P. (2008). "The IAEA's Other Job," *Wall Street Journal Asia.* June 24.

Tarvainen, Matti (2009). "Unfair trade: nuclear trade analysis may provide early indications of proliferation," *IAEA Bulletin.* Vol. 50, No.2: 61-63.

The Economist, (2010). "Atomic dawn: KEPCO wins a nuclear contract," January 2. Pp. 47.

United Nations (UN) (2004). Report of the Secretary-General's High-Level Panel on Threats, Challenges and Change, United Nations document A/59/565, New York, December 2.

___ (2000). "Final Document of the 2000 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons," UN document NPT/CONF.2000/28, New York.

___ (1978). "Resolution Adopted on the Report of the Ad Hoc Committee of the Tenth Special Session," UN document A/RES/S-10/2, June 30.

UNIDIR (2003). Coming to Terms with Security: A Handbook on Verification and Compliance, UNIDIR and VERTIC, Geneva: United Nations.

United States Arms Control and Disarmament Agency (US ACDA) (1982). *Arms Control and Disarmament Agreements: Texts and histories of negotiations*. Washington DC.

US Congress (2009). "Energy and Water Development Appropriations Bill, 2009," Report from the Committee on Appropriations, 110th Congress, 2nd Session, House of Representatives. Available at: http://thomas.loc.gov/cgi-bin/cpquery/T?&report=hr921&dbname=110.

US Department of State (2009a). "Joint Statement by the U.S.-Russia Bilateral Presidential Commission Coordinators on Commission Progress," Washington DC. December 31. Available at: http://moscow.usembassy.gov/st_123109.html.

___ (2009b). "Participants," *Proliferation Security Initiative*. Bureau of International Security and Nonproliferation, US Department of State, Washington, DC. May 27. Available at: http://www.state.gov/t/isn/c10390.htm.

___ (2009c). "Ship Boarding Agreements," *Proliferation Security Initiative*, Bureau of International Security and Nonproliferation, US Department of State, Washington, DC. May 27. Available at: http://www.state.gov/t/isn/c10390.htm.

___ (2009c). Private conversation with US Department of State official, Washington, DC. April.

US Office of Management and Budget (2006). "Contributions to the IAEA," The White House, Washington DC. Available at: http://www.whitehouse.gov/omb/expectmore/summary/10004639.2006.html.

US-UAE (2009). "Agreement for Cooperation Between the Government of the United Arab Emirates and the Government of the United States of America Concerning Peaceful Uses of Nuclear Energy." January 15. Available at: http://www.npec-web.org/us-uae/20090115-UsUae-Revised123Agreement.pdf.

Weapons of Mass Destruction (WMD) Commission (2006). *Weapons of Terror: Freeing the World of Nuclear, Biological and Chemical Arms*. Stockholm, Sweden. June 1.

World Nuclear Association (WNA) (2006). *Ensuring Security of Supply in the International Nuclear Fuel Cycle. WNA Report, 2006*. Available at: http://www.world-nuclear.org/reference/pdf/security.pdf.

World Nuclear News (WNN) (2008). "UAE launches nuclear policy to meet energy demand," July 14. Available at: http://www.world-nuclear-news.org/NP-UAE_launches_nuclear_policy_to_meet_energy_demand-1407086.html.

Whitlock, Jeremy J. (2000). "The Evolution of CANDU Fuel Cycles and Their Potential Contribution to World Peace," Atomic Energy of Canada Limited (AECL). April. Available at: http://www.nuclearfaq.ca/brat_fuel.htm.

Wilson, Michael (1997). "The challenge of Iraq" in David Fischer, *International Atomic Energy Agency: Personal Reflections.* Vienna: IAEA.

Windsor, Lindsay, and Carol Kessler (2007). "Technical and Political Assessment of Peaceful Nuclear Power Program Prospects in North Africa and the Middle East," Pacific Northwest Center for Global Security. September.

Winner, Andrew C. (2005). "The Proliferation Security Initiative: The New Face of Interdiction," *The Washington Quarterly*. Vol. 28, No.2 (Spring). Pp.129.

Woods, Randy, and Ann MacLachlan (2009). "Developing countries wary board-approved fuel bank proposal may limit options," *NuclearFuel*. December 14. Pp. 1, 10.

About the Author

Dr. Trevor Findlay is a CIGI senior fellow and holder of the William and Jeanie Barton Chair in International Affairs and a professor at the Norman Paterson School of International Affairs at Carleton University, Ottawa, where he is also director of the Canadian Centre for Treaty Compliance.

From 1998 to early 2005, Dr. Findlay was executive director of the Verification Research, Training and Information Centre in London, UK. As an Australian diplomat, Dr. Findlay was a member of the Australian delegation to the Conference on Disarmament, the UN General Assembly and the UN Disarmament Commission. He was a senior fellow and acting head of the Peace Research Centre at the Australian National University before establishing the program on peacekeeping and regional security at the Stockholm International Peace Research Institute in Sweden. He is the author of several books, including Nuclear Dynamite: The Peaceful Nuclear Explosions Fiasco (Brassey's Australia, 1990) and The Use of Force in UN Peace Operations (Oxford University Press, 2002). He holds a BA Honours in political science from the University of Melbourne and a master's degree and PhD in international relations from the Australian National University.

Nuclear Energy Futures Project Publications

GNEP Watch: Developments in the Global Nuclear Energy Partnership
Miles A. Pomper, *#1 - #11*
October 2007 - December 2008

The Economics of Nuclear Power: Current Debates and Issues for Future Consideration
David McLellan, *Nuclear Energy Futures Paper #1*
February 2008

A Guide to Global Nuclear Governance: Safety, Security and Nonproliferation
Justin Alger, *Nuclear Energy Futures Special Publication*
September 2008

The Global Nuclear Safety and Security Regimes
Aaron Shull, *Nuclear Energy Futures Paper #2*
November 2008

The Russian Nuclear Industry: Status and Prospects
Miles A. Pomper, *Nuclear Energy Futures Paper #3*
January 2009

The British Nuclear Industry: Status and Prospects
Ian Davis, *Nuclear Energy Futures Paper #4*
January 2009

Survey of Emerging Nuclear Energy States
Ray Froklage et al., *Nuclear Energy Futures web-based document*
May 2009

Uranium Enrichment in Canada
David Jackson and Kenneth Dormuth, *Nuclear Energy Futures Paper #5*
May 2009

From Nuclear Energy to the Bomb: The Proliferation Potential of New Nuclear Programs
Justin Alger, *Nuclear Energy Futures Paper #6*
September 2009

The US Nuclear Industry: Current Status and Prospects under the Obama Administration
Sharon Squassoni, *Nuclear Energy Futures Paper #7*
November 2009

The Canadian Nuclear Industry: Status and Prospects
John Cadham, *Nuclear Energy Futures Paper #8*
November 2009

The Indian Nuclear Industry: Status and Prospects
M. V. Ramana, *Nuclear Energy Futures Paper #9*
December 2009

US International Nuclear Energy Policy: Change and Continuity
Miles A. Pomper, *Nuclear Energy Futures Paper #10*
January 2010

Nigeria and Nuclear Energy: Plans and Prospects
Nathaniel Lowbeer-Lewis, *Nuclear Energy Futures Paper #11*
January 2010

The Future of Nuclear Energy to 2030 and Its Implications for Safety, Security and Nonproliferation
Trevor Findlay, *Nuclear Energy Futures Project Report*
February 2010
Overview
Part 1 – The Future of Nuclear Energy to 2030
Part 2 – Nuclear Safety
Part 3 – Nuclear Security
Part 4 – Nuclear Nonproliferation

Nuclear Energy and Global Governance to 2030: An Action Plan
Louise Fréchette (chair), Trevor Findlay (director),
Nuclear Energy Futures Project Report
February 2010

Acronyms and Abbreviations

ABACC	Argentine-Brazilian Agency for Accounting and Control
ABWR	Advanced Boiling Water Reactor
ACR	Advanced CANDU Reactor
ADB	Asian Development Bank
AECL	Atomic Energy of Canada Limited
AFCI	Advanced Fuel Cycle Initiative (GNEP)
AFCONE	African Commission on Nuclear Energy
AFNI	L'Agence France Nucléaire International (France)
AIP	Advance Information Package (OSART)
ALARA	as low as reasonably achievable
ANDRA	Agence nationale pour la gestion des déchets radioactifs/ National Agency for the Management of Radioactive Waste (France)
ANWFZ	African Nuclear Weapon-Free Zone Treaty
AP	Additional Protocol (IAEA)
ASE	AtomsTroyExport (Russia)
ASME	American Society of Mechanical Engineers
ASN	Nuclear Safety Authority (France)
AU	African Union
BADEA	Arab Bank for Economic Development in Africa
BMWG	Border Monitoring Working Group (IAEA)
BNFL	British Nuclear Fuels Limited
BOG	Board of Governors (IAEA)
BSS	Basic Safety Standards (IAEA)
BWR	boiling water reactor
CACNARE	Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency
CANDU	Canada Deuterium Uranium reactor
CBO	Congressional Budget Office (US)
CCGT	combined cycle gas turbine
CCPNM	Convention on the Physical Protection of Nuclear Material
CCS	carbon capture and storage
CD	Conference on Disarmament (UN)
CDM	clean development mechanism
CEA	Commissariat à l'Énergie Atomique/ Atomic Energy Commission (France)
CEC	Commission of the European Communities (now EC)
CENNA	Convention on Early Notification of a Nuclear Accident
CFDT	Confédération Français Démocratique du Travail/ French Democratic Confederation of Workers
CHP	combined heat and power
CIA	Central Intelligence Agency (US)
CIRUS	Canada India Research US reactor
CISAC	Committee on International Security and Arms Control
CNRA	Committee on Nuclear Regulatory Activities (OECD/NEA)
CNS	Convention on Nuclear Safety
CNSC	Canadian Nuclear Safety Commission (Canada)
COGEMA	Compagnie Général des Matièrere nucléaire/ General Company for Nuclear Materials (France)
CORDEL	Working Group on Cooperation in Reactor Design Evaluation and Licensing (WNA)
CSA	Comprehensive Safeguards Agreement (IAEA)
CSS	Commission on Safety Standards (IAEA)
CTBT	Comprehensive Nuclear Test Ban Treaty
CTR	Cooperative Threat Reduction
DBT	design basis threat
DOE	Department of Energy (US)
DTI	Department of Trade and Industry (UK)
DUPIC	direct use of spent PWR fuel in CANDU
EC	European Commission
EDF	Electricité de France
EIA	Energy Information Agency (DOE)
ENAC	Early Notification and Assistance Conventions
ENATOM	Emergency Notification and Assistance Technical Operations Manual
ENEN	European Nuclear Education Network
ENSREG	European Nuclear Safety Regulators Group
EPAct	US Energy Policy Act (2005)
EPR	Evolutionary Power Reactor (formerly European Power Reactor)
EPREV	Emergency Preparedness Review Teams (IAEA)
EPRI	Electric Power Research Institute
ERBD	European Bank for Reconstruction and Development (EC)
ERNM	Emergency Response Network Manual
EUP	enriched uranium product
Euratom	European Atomic Energy Community (EC)
FAO	Food and Agricultural Organization of the United Nations
FBR	fast breeder reactor
FMCT	Fissile Material Cut-Off Treaty
FMT	Fissile Material Treaty
FOAK	first-of-a-kind
FP&L	Florida Power and Light
G8	Group of Eight
GAO	Government Accountability Office (US)
GCC	Gulf Cooperation Council
GCR	gas-cooled reactors
GDF	Gaz de France
GDP	gross domestic product
GHG	greenhouse gases
GIF	Generation IV International Forum
GNEP	Global Nuclear Energy Partnership
GPP	Global Partnership Program (G8)
GTCC	gas turbine combined cycle
HEU	highly enriched uranium
IACRNA	Inter-Agency Committee on Response to Nuclear Accidents
IAEA	International Atomic Energy Agency
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ICJ	International Court of Justice
ICNND	International Commission on Nuclear Nonproliferation and Disarmament
ICRP	International Commission on Radiological Protection
ICSANT	International Convention for the Suppression of Acts of Nuclear Terrorism
IDB	Inter-American Development Bank
IEA	International Energy Agency (OECD)
IEC	Incident and Emergency Centre
ILO	International Labor Organization
IMO	International Maritime Organization
INES	International Nuclear and Radiological Event Scale
INF	irradiated nuclear fuel
INFA	International Nuclear Fuel Agency
INIR	Integrated Nuclear Infrastructure Review (IAEA)
INLEX	International Expert Group on Nuclear Liability
INMM	Institute of Nuclear Materials Management
INPO	Institute of Nuclear Power Operations (US)
INPRO	International Project on Innovative Nuclear Reactors and Fuel Cycles
INRA	International Nuclear Regulators Association
INSAG	International Nuclear Safety Group (IAEA)
INSServ	International Nuclear Security Advisory Service (IAEA)
INSSP	Integrated Nuclear Security Support Plan (IAEA)
INTERPOL	International Criminal Police Organization

IPCC	Intergovernmental Panel on Climate Change
IPFM	International Panel on Fissile Materials
IPPAS	International Physical Protection Advisory Service (IAEA)
IRRS	Integrated Regulatory Review Service
IRS	Incident Reporting System (IAEA/NEA)
IsDB	Islamic Development Bank
ISIS	Institute for Science and International Security
ISSAS	International SSAC Advisory Service (IAEA)
ISSC	International Seismic Safety Centre
ITDB	Illicit Trafficking Database (IAEA)
ITE	International Team of Experts (IAEA)
ITER	International Thermonuclear Experimental Reactor
JREMPIO	Joint Radiation Emergency Management Plan of the International Organizations
JSW	Japan Steel Works
KEPCO	Korea Electric Power Corporation
KINS	Korea Institute of Nuclear Safety
LEU	low enriched uranium
LIS	laser-isotope separation
LNG	Liquid Natural Gas
LWGR	light water-cooled graphite-moderated reactor
LWR	light water reactor
MCIF	Major Capital Investment Fund (IAEA)
MDEP	Multinational Design Evaluation Program
MESP	Multilateral Enrichment Sanctuary Project
MIT	Massachusetts Institute of Technology
MOI	Ministry of Industry (Vietnam)
MOST	Ministry of Science and Technology (Vietnam)
MOX	Mixed Oxide Fuel
NAS	National Academy of Sciences (US)
NASA	National Aeronautics and Space Administration (US)
NATO	North Atlantic Treaty Organization
NCACG	National Competent Authorities' Coordinating Group
NEA	Nuclear Energy Agency (OECD)
NEF	Nuclear Energy Futures
NEI	Nuclear Energy Institute
NEPIO	Nuclear Energy Programme Implementing Organization
NERC	North American Electric Reliability Corporation
NERS	Network of Regulators of Countries with Small Nuclear Programmes
NESA	Nuclear Energy System Assessment
NEWS	Nuclear Events Web-based System
NGO	non-governmental organization
NGSI	Next Generation Safeguards Initiative
NIA	Nuclear Industry Association (UK)
NIF	National Ignition Facility (US)
NII	Nuclear Installations Inspectorate (UK)
NJFF	Nuclear Power Joint Fact Finding (Keystone Center)
NNWS	non-nuclear weapon state (NPT)
NPT	Nuclear Nonproliferation Treaty
NRC	Nuclear Regulatory Commission (US)
NRU	National Research Universal reactor (Canada)
NSEL	Nuclear Security Equipment Laboratory (IAEA)
NSF	Nuclear Security Fund (IAEA)
NSG	Nuclear Suppliers Group
NSSG	Nuclear Safety and Security Group (IAEA)
NTI	Nuclear Threat Initiative
NTM	National Technical Means
NUSS	Nuclear Safety Standards (IAEA)
NWFZ	nuclear-weapon-free zone
NWMO	Nuclear Waste Management Organization (Canada)
NWPA	US Nuclear Waste Policy Act (1982)
NWS	nuclear weapon state (NPT)
O&M	operation and maintenance
OECD	Organisation for Economic Co-operation and Development
OEF	operating experience feedback
OER	Operating Experience Reports
OSART	Operational Safety Review Teams (IAEA)
PBMR	Pebble Bed Modular Reactor
PHWR	pressurized heavy water reactor
PIU	Performance and Innovation Unit (UK Cabinet Office)
POC	Point of Contact
PRA	Probabilistic Risk Assessment
PRIS	Power Reactor Information System
PROSPER	Peer Review of the effectiveness of the Operational Safety Performance Experience Review
PSI	Proliferation Security Initiative
PSR	Periodic Safety Review
PUREX	Plutonium Uranium Extraction
PWR	pressurized water reactor
RADWASS	Radioactive Waste Safety Standards (IAEA)
RANET	Response Assistance Network
RBMK	Reaktor Bolshoy Moshchnosti Kanalniy (High Power Channel-Type Reactor)
RDD	radiological dispersal device
REPLIE	Response Plan for Incidents and Emergencies (IAEA)
RWC	Radiological Weapons Convention
SAG	Senior Advisory Group (IAEA)
SAGSI	Standing Advisory Group on Safeguards Implementation (IAEA)
SAGSTRAM	Standing Advisory Group on the Safe Transport of Radioactive Materials (IAEA)
SAL	Safeguards Analytical Laboratory (IAEA)
SEDO	Safety Evaluation During Operation of Fuel Cycle Facilities (IAEA)
SENES	Survey of Emerging Nuclear Energy States
SILEX	separation of isotopes by laser excitation
SMR	small- and medium-sized reactor
SOARCA	State-of-the-Art Reactor Consequences Analysis
SOER	Significant Operating Experience Reports
SOLAS	International Convention for the Safety of Life at Sea
SQP	Small Quantities Protocol (IAEA)
SSAC	State System of Accounting and Control
STUK	Säteilyturvakeskus (Radiation and Nuclear Safety Authority, Finland)
SWU	separative work unit
TCP	Technical Cooperation Programme (IAEA)
TRC	Technical Review Committee (IAEA)
TTA	Nuclear Trade and Technology Analysis unit (IAEA)
TVO	Teollisuuden Voima Oyj (Finland)
UAE	United Arab Emirates
UNFCCC	United Nations Framework Convention on Climate Change
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
URENCO	Uranium Enrichment Company
USSPC	ultra-supercritical pulverized coal
VARANSAC	Vietnam Agency for Radiation Protection and Nuclear Safety Control
VERTIC	Verification Research, Training and Information Centre
VVER	Vodo-Vodyanoi Energetichesky Reactor (Russia)
WANO	World Association of Nuclear Operators
WENRA	Western European Nuclear Regulators Association
WGRNR	Working Group on Regulation of New Reactors (CNRA)
WHO	World Health Organization (UN)
WINS	World Institute of Nuclear Security
WMD	weapons of mass destruction
WMO	World Meteorological Organization
WNA	World Nuclear Association
WNTI	World Nuclear Transport Institute
WNU	World Nuclear University (WNA)

About CIGI

The Centre for International Governance Innovation is an independent, nonpartisan think tank that addresses international governance challenges. Led by a group of experienced practitioners and distinguished academics, CIGI supports research, forms networks, advances policy debate, builds capacity, and generates ideas for multilateral governance improvements. Conducting an active agenda of research, events, and publications, CIGI's interdisciplinary work includes collaboration with policy, business and academic communities around the world.

CIGI conducts in-depth research and engages experts and partners worldwide from its extensive networks to craft policy proposals and recommendations that promote change in international public policy. Current research interests focus on international economic and financial governance both for the long-term and in the wake of the 2008-2009 financial crisis; the role of the G20 and the newly emerging powers in the evolution of global diplomacy; Africa and climate change, and other issues related to food and human security.

CIGI was founded in 2002 by Jim Balsillie, co-CEO of RIM (Research In Motion) and collaborates with and gratefully acknowledges support from a number of strategic partners, in particular the Government of Canada and the Government of Ontario. CIGI gratefully acknowledges the contribution of the Government of Canada to its endowment fund. Support from the Government of Ontario includes a major financial contribution to the Nuclear Energy Futures project.

Le CIGI a été fondé en 2002 par Jim Balsillie, co-chef de la direction de RIM (Research In Motion). Il collabore avec de nombreux partenaires stratégiques et leur exprime toute sa reconnaissance pour leur soutien. Il remercie tout particulièrement le gouvernement du Canada pour sa contribution à son Fonds de dotation, de même que le gouvernement de l'Ontario, dont l'appui comprend une aide financière majeure au projet Perspectives de l'énergie nucléaire.

Publications Team

Senior Director for Publications: Max Brem
Publications Coordinator: Jessica Hanson
Media Designer: Steve Cross
Copyeditors: Matthew Bunch and Tammy McCausland

Media Contact

For media enquiries, please contact:
Mary-Lou Schagena
Communications Specialist
Tel: +1.519.885.2444 x238, mschagena@cigionline.org

The Centre for International Governance Innovation
Centre pour l'innovation dans la gouvernance internationale

57 Erb Street West

Waterloo, Ontario N2L 6C2, Canada

tel +1 519 885 2444   fax +1 519 885 5450

www.cigionline.org