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Multilateralization of the Nuclear Fuel Cycle

Helping to Fulfil the NPT Grand Bargain

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About the cover

Wide shot of the 2010 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) as Yukiya Amano (on screens), Director General of the International Atomic Energy Agency (IAEA), addresses the Conference.

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FOREWORD

The Treaty on the Non-Proliferation of Nuclear Weapons, marking this year the fortieth anniversary of its entry into force, envisions the end of all nuclear weapons.

The political and technical challenges on the path to nuclear disarmament are enormous. But even if a world without nuclear weapons were achieved, in light of the inherent dual-use nature of nuclear technology and the production of civilian fissile materials by sovereign states, how could one prevent the diversion of such materials for the purpose of rearmament? Would such a nuclear-weapon-free world be more stable and secure than the world we have today? What measures can the international community take now to allay proliferation concerns, while also enabling progress towards complete nuclear disarmament?

This study addresses the security risks to a world without nuclear weapons that could come from nuclear fuel-cycle technologies and what could be done to mitigate those risks. It examines what role multilateral fuel-cycle arrangements could play in ensuring that progress towards complete nuclear disarmament is not hindered by proliferation concerns, and in helping to fulfill the goals of the Treaty on the Non-Proliferation of Nuclear Weapons—non-proliferation, the peaceful use of nuclear energy and nuclear disarmament.

Our hope is that this study will help to illuminate the critical issues that will need to be addressed to create "the conditions for a world without nuclear weapons, in accordance with the goals of the Treaty on the Non-Proliferation of Nuclear Weapons … , in a way that promotes international stability, and based on the principle of undiminished security for all", as resolved in Security Council resolution 1887.

Theresa Hitchens
Director
UNIDIR

SUMMARY

The ongoing dissemination of nuclear knowledge and technology as well as the expected expansion of nuclear energy worldwide could lead to the further spread of sensitive nuclear technologies—enrichment of uranium, reprocessing of spent fuel and handling of plutonium. This would give states access to weapons-grade material, taking them a long way towards nuclear weapons even without violating the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), specifically without "diverting" special nuclear material and, therefore, without any possibility of being restrained by International Atomic Energy Agency (IAEA) safeguards designed to verify whether material has or has not been diverted.

The spread of sensitive fuel-cycle technologies, or "virtual" nuclear weapons capabilities, puts additional strain on the non-proliferation regime exacerbating intrinsic tensions between the three "pillars" of the NPT—non-proliferation, the peaceful use of nuclear energy, and disarmament. At the heart of the problem is the way in which nuclear technology is typically managed, namely the highly national control of nuclear activities. States could obtain materials that are directly usable in nuclear explosive devices—high-enriched uranium and separated plutonium—from their national fuel-cycle facilities relatively quickly.

Virtual nuclear weapons capabilities pose non-proliferation risks because, if the political decision is made, virtual capabilities can be converted into actual capabilities in a relatively short period of time. They also pose challenges to nuclear disarmament because a nuclear-weapon-free world with nationally controlled fuel cycles would be unstable and unverifiable.

True multilateralization of the nuclear fuel cycle could change the way in which nuclear technology is managed, thus removing the tensions between the three pillars of the NPT. It would provide all states with non-discriminatory access to "the benefits of peaceful applications of nuclear technology" while barring direct access to weapon-usable nuclear material.

In regard to disarmament and non-proliferation, multilaterally owned and operated fuel cycles present the following advantages:

- they would shift the control of weapon-usable nuclear materials from individual states to multilateral arrangements and ensure a greater degree of peer scrutiny from participants, making it more difficult and risky to cheat and providing less opportunity for diversion or theft of nuclear material;
- they would facilitate the application of IAEA safeguards by guaranteeing higher standards of transparency and cooperation;
- they would make the nuclear intentions of states more apparent; and
- they would enable participating states to take advantage of the political and financial benefits offered by sharing ownership, management and profits of fuel cycle activities.

The existing proposals for multilateral approaches to the nuclear fuel cycle can be categorized into two broad groups: supplemental instruments for the existing nuclear market, which seek to provide extra assurances of reactor fuel supply without touching issues of ownership of nuclear material and facilities; and multilateral mechanisms, which envisage various degrees of multilateral ownership and control.

Supplemental mechanisms, such as fuel banks and assurance of supply mechanisms, are important as they diminish the salience of "security of supply" as a motivation for developing national uranium enrichment capabilities. But they can hardly address other reasons that may underlie states' decisions to acquire sensitive fuel-cycle technologies, such as commercial interest in making profits from selling materials and services on the market, national prestige, and perhaps the desire to acquire a virtual nuclear weapons capability. No supplemental mechanism is designed to actually change the way in which nuclear technology is managed.

Since 1970 the original NPT bargain, which is a complex compromise among states parties over the three pillars of the treaty, has proved its worth in limiting the spread of nuclear weapons. The 2010 NPT Review Conference demonstrated states parties' recommitment to the NPT bargain and their common interest in ensuring that the non-proliferation regime does not unravel.

But the tensions between the three pillars of the NPT, in particular regarding further dissemination of sensitive nuclear technologies, might put additional strain on the non-proliferation regime and complicate the implementation of the action plan for nuclear disarmament, non-

proliferation and the promotion of the peaceful uses of nuclear energy agreed at the 2010 Review Conference.

To remove the existing tensions, a revamped bargain will be needed. It should be universal and be able to strengthen the non-proliferation regime, to remove the inequalities between the states parties in the current bargain, to promote nuclear disarmament and to offer a satisfactory way of managing sensitive nuclear technologies, which would not hamper the use of nuclear energy for electricity generation, medicine or agriculture but would curb virtual nuclear weapons capabilities.

Such a revamped bargain would rest on the following commitments:

- All states would reaffirm their non-proliferation commitments and place their civilian nuclear material and facilities under IAEA safeguards without discrimination.
- All states would agree to pursue sensitive nuclear fuel-cycle activities exclusively under multilateral control.
- All states would unequivocally undertake "to accomplish the total elimination of … nuclear arsenals leading to nuclear disarmament". States possessing nuclear weapons would take concrete and credible steps and make more proactive and substantive progress towards ultimately achieving global, verifiable nuclear disarmament. All states, nuclear and non-nuclear, would contribute to achieving nuclear disarmament by pursuing in good faith and eventually concluding complementary agreements on conventional arms control and missile defence.

CHAPTER 1

INTRODUCTION

The year 2010 marks the fortieth anniversary of the entry into force of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), the cornerstone of the nuclear non-proliferation regime and the most adhered to arms control treaty in the world. The NPT can be understood as a bargain between five states that have nuclear weapons and 184 states that do not have nuclear weapons.[1] It is a complex compromise, which rests on three fundamental issues, or "pillars"—non-proliferation, the peaceful use of nuclear energy and disarmament. States with nuclear weapons commit not to transfer them to any recipient whatsoever while states without nuclear weapons undertake not to acquire any. To compensate for the subsequent distinction between "haves" and "have-nots", the NPT grants all states parties the inalienable right "to develop research, production and use of nuclear energy for peaceful purposes". It also obligates all states to work in good faith towards nuclear disarmament.

This bargain, however, wove intrinsic tensions into the non-proliferation regime. The first tension lies between the pillars of non-proliferation and the peaceful use of nuclear energy. The primary purpose of the NPT is to prevent the spread of nuclear weapons beyond the five legitimized nuclear-weapon states. But the intentional ambiguity of the "inalienable right" to use nuclear energy for peaceful purposes[2] has enabled states to engage in all nuclear activities short of the insertion of nuclear components into a nuclear explosive device. As such, it could lead to increased proliferation involving "virtual" nuclear weapons states, which would be capable of producing plutonium or high-enriched uranium and would possess the knowledge, non-nuclear materials and components needed to make nuclear weapons, but refrain from assembling these weapons. These states would remain compliant with the NPT while maintaining the latent capability for the rapid acquisition of nuclear weapons.

The second tension lies between the pillars of disarmament and the peaceful use of nuclear energy. If a non-nuclear-weapon state decides to

pursue virtual nuclear weapon capabilities, that could be due, at least in part, to the historical reliance of the nuclear-weapon states on their nuclear weapons as fundamental national security assets. As a result, an increasing number of virtual nuclear weapon states may kindle fears among the nuclear weapon states of "break out", and thus decrease their willingness to take practical steps towards comprehensive nuclear disarmament.

Two features of nuclear energy underpin these tensions between the pillars of the NPT bargain:

- the dual-use nature of nuclear technology. Peaceful and military applications of nuclear energy cannot be clearly separated. There is a wide grey zone of "sensitive" nuclear technologies—uranium enrichment, plutonium separation, the manufacture of plutonium and mixed uranium/plutonium fuel—that can provide fissile material either for generating electricity or for explosive applications; and
- the predominantly national management and control of nuclear activities, which can provide states with readily available sources of weapon-usable materials—high-enriched uranium (HEU) and separated plutonium.

The international non-proliferation regime has faced growing disagreement, especially during the last two decades during which it was revealed that some NPT states parties conducted weapons-related activities under the guise of peaceful nuclear applications.[3] Attempts to further strengthen non-proliferation obligations have met with resistance from some non-nuclear-weapon states. Those states are unwilling to have additional restrictions imposed on them in the absence of tangible progress towards nuclear disarmament. Meanwhile, the political and military elites in the nuclear-weapon states continue generally to regard nuclear weapons as "the ultimate insurance" against the threats of a changing and unpredictable world.

Nevertheless, in recent years new momentum is building towards a world without nuclear weapons. After almost two decades of near stalemate in bilateral arms control negotiations, the Russian Federation and the United States of America signed in April 2010 a new treaty on further reduction and limitation of strategic offensive arms. At the 2010 NPT Review Conference many governments have voiced support for the idea of a world free of nuclear weapons.[4] For example, Brazilian Minister of

External Relations Celso Amorim emphasized that "Brazil is convinced that the best guarantee for non-proliferation is the total elimination of nuclear weapons"; [5] Japanese Prime Minister Yukio Hatoyama stressed that "Japan has a moral responsibility to act at the forefront of efforts toward the elimination of nuclear weapons";[6] US Secretary of State Hillary Clinton said that the United States is "a country committed to a vision of a world without nuclear weapons and to taking the concrete steps necessary that will help us get there";[7] Egyptian Minister for Foreign Affairs Ahmed Aboul-Gheit argued for "the need for creating a legal framework to eliminate nuclear weapons through the conclusion of an international legally binding convention to eliminate nuclear weapons in a specified timeframe";[8] and Minister of State at the Foreign Office of Germany Werner Hoyer noted that "our common aim must be a world without nuclear weapons".[9]

Paving the way for comprehensive nuclear disarmament will require establishing a highly effective international system to verify and guarantee that all fissile materials are under international safeguards, provide timely warning of any attempt to manufacture nuclear weapons, and address non-compliance meaningfully. But even the most effective verification techniques would not necessarily build complete trust on the part of states that small amounts of weapon-usable materials have not been diverted from bulk handling facilities such as uranium enrichment and spent fuel reprocessing facilities. Even if the world were free of nuclear weapons, nationally controlled fuel cycles would still enable states to remain on the edge of resuming the manufacture of nuclear weapons, thus creating dangerous instabilities that could imperil the reality of such a world.

Persistent suspicions that unverifiable virtual capabilities could be easily converted into actual nuclear weapons would undermine the prospects for comprehensive nuclear disarmament. States possessing nuclear weapons would most likely prefer to maintain their arsenals in the face of many states that could quickly produce weapon-usable nuclear material from their nationally-controlled fuel cycles and thus be able to manufacture their own nuclear weapons.

Technical measures alone are insufficient to mitigate the tensions in the nuclear non-proliferation regime. Institutional measures—such as multilateralization of the nuclear fuel cycle—could be used to manage and regulate access to sensitive materials, facilities and technologies. "Multilateralization" in this case refers to any approach to the governance

of nuclear fuel cycles that goes beyond purely national control. While multilateralization cannot alter the nature of nuclear technology, it could eventually transform the way in which nuclear technology is managed and controlled. True, or comprehensive, multilateralization would entail putting all sensitive fuel-cycle facilities under multilateral ownership and control as well as under International Atomic Energy Agency (IAEA) safeguards.

CHAPTER 2

NEW MOMENTUM FOR NUCLEAR DISARMAMENT

Sixty-five years after the first and only use of atomic bombs, nuclear weapons continue to be a key element of the national security policies of a few states. Almost 20 years after the end of the Cold War, there remain "approximately 23,360 nuclear weapons located at some 111 sites in 14 countries. Nearly one-half of these weapons are active or operationally deployed".[10]

Under the NPT, the five recognized nuclear-weapon states (China, France, Russia, the United Kingdom and the United States) agreed to pursue negotiations in good faith towards nuclear disarmament, but a perceived lack of progress has been a cause of dissatisfaction, frustration and disagreement among other NPT states parties. At every NPT Review Conference held since the end of the Cold War, non-nuclear-weapon states, in particular members of the Non-Aligned Movement (NAM), have harshly criticized the nuclear-weapon states.

Such criticism is not entirely unfounded. At the 2000 NPT Review Conference, the five nuclear-weapon states agreed on thirteen "practical steps for the systematic and progressive efforts" towards nuclear disarmament, including an "unequivocal undertaking … to accomplish the total elimination of their nuclear arsenals".[11] Those steps included achieving the early entry into force of the Comprehensive Nuclear-Test-Ban Treaty, starting negotiations of a treaty on fissile materials, establishing a subsidiary body on nuclear disarmament within the Conference on Disarmament, enhancing transparency regarding the nuclear-weapon capabilities of the nuclear-weapon states, further reducing non-strategic nuclear weapons, diminishing the role for nuclear weapons in security policies, and engaging all the nuclear-weapon states in a process leading to the total elimination of nuclear weapons. Little progress has been made on these steps to this day. After the United States withdrew from the Anti-Ballistic Missile Treaty in 2002, progress on some of these steps, namely on achieving "the early entry into force and full implementation of [the 1993 Treaty on Further

Reduction and Limitation of Strategic Offensive Arms]" while "preserving and strengthening the Treaty on the Limitation of Anti-Ballistic Missile Systems as a cornerstone of strategic stability and as a basis for further reductions of strategic offensive weapons",[12] became impossible. The recriminations arising from a perceived lack of progress on the 13 steps contributed to the failure of the 2005 NPT Review Conference.

And yet, support for global nuclear disarmament has been growing in recent years. In a joint statement made in 2009, Russian President Medvedev and US President Obama said: "We committed our two countries to achieving a nuclear free world, while recognizing that this long-term goal will require a new emphasis on arms control and conflict resolution measures, and their full implementation by all concerned nations".[13] The two heads of state "decided to move further along the path of reducing and limiting strategic offensive arms in accordance with U.S. and Russian [NPT] obligations" and to return to the negotiating table to "work out a new, comprehensive, legally binding agreement on reducing and limiting strategic offensive arms to replace the START Treaty [the Treaty on the Reduction and Limitation of Strategic Offensive Arms]".[14] On 8 April 2010, they signed the Treaty Between the United States of America and the Russian Federation on Measures for the Further Reduction and Limitation of Strategic Offensive Arms.

Although the new treaty brings rather modest reductions to the nuclear arsenals of both states, it manifests the determination of Russia and the United States—the two states hold over 90% of the world's nuclear weapons[15]—to uphold their commitments under the NPT. The new treaty also re-established an inspection regime that lapsed in December 2009 with the expiration of the 1991 START treaty. More importantly, it could provide a foundation for more significant reductions later.

Even more hopes for nuclear disarmament have been raised by President Obama's speech in Prague on 5 April 2009, in which he stated "clearly and with conviction [the United States'] commitment to seek the peace and security of a world without nuclear weapons" and outlined his vision of a world free of nuclear weapons.[16] He also pledged to reduce the US nuclear stockpile, and urged other governments to do the same.

In recent years a number of former statesmen from Australia, Belgium, France, Germany, Italy, the Netherlands, Norway, Poland, Russia, the

United Kingdom and the United States have called for credible actions leading to the elimination of nuclear weapons.[17] In June 2007, UK Secretary of State for Foreign and Commonwealth Affairs Margaret Beckett delivered a speech entitled "A World Free of Nuclear Weapons?" at the Carnegie International Nonproliferation Conference.[18] In April 2009, Japanese Foreign Minister Hirofumi Nakasone proposed 11 benchmarks for global nuclear disarmament.[19] In 2009 the International Commission on Nuclear Non-proliferation and Disarmament, established by the Australian and Japanese governments, presented an action plan aimed at the eventual elimination of nuclear weapons.[20] In April 2010 the InterAction Council of Former Heads of State and Government urged the 2010 NPT Review Conference to promote "a comprehensive nuclear treaty architecture aiming at the elimination of nuclear weapons".[21]

Today many governments and civil society groups support the idea of a world free of nuclear weapons. As United Nations Secretary-General Ban Ki-moon stated, "Momentum is building towards a nuclear-weapon-free world. People are waking up. They are beginning to understand: the alternatives to nuclear disarmament—arms races and deterrence—carry grave risks, and can never offer true security".[22]

But sustaining that momentum raises the question of what conditions should be met to make a world without nuclear weapons more secure than a world with them, because nuclear disarmament is part and parcel of the global security architecture. Many important questions remain unanswered, among them how nuclear disarmament could affect national, regional and global security, what the extent of disarmament would be—that is, which nuclear activities would be permissible and which would not—and how to carry out nuclear disarmament safely and securely.

Addressing the political and technical challenges on the path towards rendering nuclear weapons things of the past is no small task. Yet the effort has to start today with a rigorous examination of the conditions for making the goal of a world without nuclear weapons desirable, palatable and feasible.

As Shultz, Perry, Kissinger and Nunn emphasized, "Achieving the goal of a world free of nuclear weapons will also require effective measures to impede or counter any nuclear-related conduct that is potentially threatening to the security of any state or peoples".[23] This study seeks

to examine and address one specific aspect of the nuclear disarmament puzzle—the risks nuclear fuel-cycle technologies could pose to the viability of a world without nuclear weapons and what can be done to mitigate those risks.

CHAPTER 3

THE GRAND BARGAIN OF THE NPT

The NPT is a founding document of multilateral non-proliferation endeavours and the cornerstone of the international nuclear non-proliferation regime. When opened for signature in 1968 after three years of negotiation, the treaty was intended primarily to stop the spread of nuclear weapons beyond the five states that had "manufactured and exploded a nuclear weapon or other nuclear explosive device prior to 1 January 1967"—these being France, China, the Soviet Union (the obligations and rights now assumed by Russia), the United Kingdom and the United States.

No international arms control treaty is as widely adhered to as the NPT. Today, treaty membership stands at 189 states. Only four states remain outside of the NPT: India, Israel and Pakistan, which have not signed it, and the Democratic People's Republic of Korea, which acceded to the treaty in 1985 under pressure from the Soviet Union, never fully complied with its obligations, and announced withdrawal from the treaty in 2003—although the validity of the withdrawal is debated.

The entry into force of the NPT made the development of nuclear weapons by its non-nuclear-weapon states parties a violation of international law. The NPT has been remarkably successful in limiting, albeit not entirely preventing, the further spread of nuclear weapons. This success can be judged by what might have happened had the treaty not existed: the spread of nuclear weapons would probably have been uncontrollable. During the 1950s and 1960s many experts predicted a rapid increase in the number of states possessing nuclear weapons. At one point or another, Argentina, Brazil, Egypt, Germany, Iraq, Japan, Libya, Poland, Romania, South Africa, South Korea, Sweden and Switzerland had nuclear weapons-related programmes. The main achievement of the NPT is that it has been able to minimize the expansion of the nuclear club.

Only four states have developed nuclear weapons since 1970; all of them are non-NPT states. India conducted its first nuclear test in 1974 and Pakistan followed suit in 1998. Israel has never been confirmed to have conducted a nuclear test nor has it officially admitted to having nuclear weapons, but it has been estimated to possess the sixth-largest nuclear arsenal in the world.[24] The Democratic People's Republic of Korea is the only state to have signed the NPT as a non-nuclear-weapon state and subsequently withdrawn and developed nuclear weapons—it conducted its first nuclear test in 2006. These states are often referred to as nuclear-armed states to distinguish them from the five nuclear-weapon states recognized by the NPT.

The NPT legitimizes, at least temporarily, the nuclear arsenals of the five nuclear-weapon states and sets different rights and obligations for the two groups of its states parties—nuclear-weapons "haves" and "have-nots". The treaty is thus often described as a "grand bargain" between the nuclear-weapon states and the non-nuclear-weapon states. The bargain rests on a delicate balance between three fundamental issues, or "pillars", of the NPT—non-proliferation, the peaceful use of nuclear energy and disarmament—and represents a complex compromise reached after extensive debates between states. Certain weaknesses, ambiguities and contradictions inherent to that compromise laid the foundation for long-standing disagreements among states parties to the NPT.

PILLAR 1: NON-PROLIFERATION

Articles I, II and III of the NPT bind all states parties to commit to non-proliferation. Article I articulates the fundamental obligations of the nuclear-weapon states while article II articulates the fundamental obligations of the non-nuclear-weapon states.

Article I

> Each nuclear-weapon State Party to the Treaty undertakes not to transfer to any recipient whatsoever nuclear weapons or other nuclear explosive devices or control over such weapons or explosive devices directly, or indirectly; and not in any way to assist, encourage, or induce any non-nuclear-weapon State to *manufacture* or otherwise acquire nuclear weapons or other nuclear explosive devices, or control over such weapons or explosive devices.

Article II

> Each non-nuclear-weapon State Party to the Treaty undertakes not to receive the transfer from any transferor whatsoever of nuclear weapons or other nuclear explosive devices or of control over such weapons or explosive devices directly, or indirectly; not to *manufacture* or otherwise acquire nuclear weapons or other nuclear explosive devices; and not to seek or receive any assistance in the *manufacture* of nuclear weapons or other nuclear explosive devices. [emphasis added]

Prima facie, both articles are relatively unambiguous. Nuclear-weapon-states are not to transfer nuclear weapons to any organization, state or non-state actor and not to assist non-nuclear-weapon states in acquiring them in any way whatsoever. Non-nuclear-weapon states are not to acquire nuclear weapons in any way and not to receive any assistance to do so. Where the interpretation of the articles becomes clouded is in the word "manufacture". Does the NPT commitment not to manufacture nuclear weapons incorporate a prohibition on all, or some, related activities, such as research and development applicable to nuclear weapons design, production of weapon-usable materials, and fabrication of components? Or is it applicable only to the final assembly of a nuclear explosive device? The exact meaning and scope of "manufacture" remains undefined.

During the negotiations of the NPT, there were attempts to clarify what exactly was going to be prohibited by the treaty. Thus, in February 1966 Swedish ambassador Alva Myrdal argued before the Eighteen-Nation Disarmament Committee:

> We could, of course, all agree that it is important to block the road to nuclear-weapon development as early as possible. But we must be aware that what we are facing is a long ladder with many rungs, and the practical question is: on which of these is it reasonable and feasible to introduce the international blocking?
>
> …
>
> To prohibit just the final act of "manufacture" would seem to come late in these long chains of decisions. … Could a middle link be found on which the prohibitory regulation should most definitely be focused? ... Must not regulations about effective controls be linked with certain definitive and uncontestable steps, such as actual purchases of nuclear reactors, fuel elements and so on from abroad, and/or

> the establishment within a country of such installations as plutonium separation plants and the like?
>
> …
>
> Could we already at the preliminary stage of the negotiations at least get from the authors of the various proposals [for a non-proliferation treaty] succinct statements concerning exactly at what steps they want to place the international treaty obligations not to "proliferate"?[25]

However NPT negotiators were unable to come to an agreement on what constituted the term "manufacture" and where on this "long ladder with many rungs" such international blocking should be introduced.

The fifth preambular paragraph of the NPT emphasizes "the principle of safeguarding effectively the flow of source and special fissionable materials" in peaceful nuclear activities to verify the fulfilment of non-proliferation obligations. According to that principle, all non-nuclear-weapon states are required to comply with IAEA safeguards, as stipulated under article III of the Treaty.

Article III

> 1. Each non-nuclear-weapon State Party to the Treaty undertakes to accept safeguards, as set forth in an agreement to be negotiated and concluded with the International Atomic Energy Agency in accordance with the Statute of the International Atomic Energy Agency and the Agency's safeguards system, for *the exclusive purpose of verification of the fulfilment of its obligations* assumed under this Treaty with a view *to preventing diversion of nuclear energy* from peaceful uses to nuclear weapons or other nuclear explosive devices. Procedures for the safeguards required by this article shall be followed with respect to source or special fissionable material whether it is being produced, processed or used in any principal nuclear facility or is outside any such facility. The safeguards required by this article shall be applied on *all source or special fissionable material* in *all peaceful nuclear activities* within the territory of such State, under its jurisdiction, or carried out under its control anywhere.
>
> 2. Each State Party to the Treaty undertakes not to provide: (a) source or special fissionable material, or (b) equipment or material especially designed or prepared for the processing, use or production of special fissionable material, to any non-nuclear-weapon State for peaceful

> purposes, unless the source or special fissionable material shall be subject to the safeguards required by this article.
>
> … [emphasis added]

Article III.1 binds each non-nuclear-weapon state to conclude a comprehensive, or full-scope, safeguards agreement with the IAEA to place under safeguards *all* of its nuclear material in *all* of its nuclear activities—by accepting the obligations under article II, non-nuclear weapon states can only legitimately engage in peaceful nuclear activities.

As set forth in article III.1, the primary purpose of the IAEA safeguards system is to prevent "diversion of nuclear energy from peaceful uses to nuclear weapons or other nuclear explosive devices". The term "diversion" is typically used in relation to nuclear materials and means either removing these materials from safeguarded activities or failing to declare them for safeguards. Under the umbrella of "diversion of nuclear energy", the NPT gives a broader meaning to this term, including the misuse of nuclear technologies and processes. Moreover, the reference to "preventing diversion" in the language of the NPT emphasizes that IAEA safeguards should be geared not only to detecting past and ongoing misuse of materials and technologies but also to forestalling such illegal actions.

PILLAR 2: THE PEACEFUL USE OF NUCLEAR ENERGY

Prior to the mid-1967 joint US–Soviet draft, no publicly presented draft of the proposed non-proliferation treaty contained any legal provision on the parties' rights to use nuclear energy for peaceful purposes. Non-nuclear-weapon states, however, wished to obtain a fair return for giving up the ability to acquire nuclear weapons. At their urging such provisions were included into the final text of the NPT.

The sixth preambular paragraph of the NPT affirms "the principle that the benefits of peaceful applications of nuclear technology … should be available for peaceful purposes to all Parties to the Treaty, whether nuclear-weapon or non-nuclear-weapon States". Following this principle, article IV permits all states parties to engage in the peaceful use of nuclear energy.

Article IV

> 1. Nothing in this Treaty shall be interpreted as affecting the *inalienable right* of all the Parties to the Treaty to develop research, production and use of nuclear energy for peaceful purposes without discrimination and *in conformity with articles I and II* of this Treaty.
>
> 2. All the Parties to the Treaty undertake to facilitate, and have the *right to participate* in, the fullest possible exchange of equipment, materials and scientific and technological information for the peaceful uses of nuclear energy. Parties to the Treaty in a position to do so shall also cooperate in contributing alone or together with other States or international organizations to the further development of the applications of nuclear energy for peaceful purposes, especially in the territories of non-nuclear-weapon States Party to the Treaty, with due consideration for the needs of the developing areas of the world. [emphasis added]

Article IV.1 allows all states parties to engage in peaceful nuclear research and production. This entitlement is referred to as an "inalienable right", a phrasing that has sparked many controversies. Some governments have interpreted this article as implying a "sovereign" right to nuclear activities, in other words an absolute and unconditional right. Yet the NPT sets certain conditions on the exercise of that right. First, all signatories must pursue nuclear energy for peaceful purposes "in conformity with articles I and II" of the NPT. Second, they must place all such nuclear activities under IAEA safeguards.

There has not been any clarification on the scope of application of this inalienable right in the context of articles I and II where "manufacture" of nuclear weapons has been prohibited, nor has there been any clarification of the term "manufacture" itself.

The inalienable right of NPT states parties "to develop research, use, and production of nuclear energy for peaceful purposes" has been reaffirmed on numerous occasions. The final document of the 2000 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons stated:

> The Conference reaffirms that nothing in the Treaty shall be interpreted as affecting the inalienable right of all the parties to the Treaty to develop research, production and use of nuclear energy for peaceful

> purposes without discrimination and in conformity with articles I, II and III of the Treaty. The Conference recognizes that this right constitutes one of the fundamental objectives of the Treaty. In this connection, the Conference confirms that each country's choices and decisions in the field of peaceful uses of nuclear energy should be respected without jeopardizing its policies or international cooperation agreements and arrangements for peaceful uses of nuclear energy and its fuel-cycle policies.[26]

The final document of the 2010 NPT Review Conference, which was unanimously adopted on 28 May 2010, contains similar language.[27] By requiring to respect the NPT states parties' fuel-cycle choices and policies, the language further reaffirms their right to engage in dual-use nuclear activities.

Article IV.2 of the NPT calls on nuclear-weapon states, or other parties "in a position to do so", to assist non-nuclear-weapon states in exercising their right to pursue peaceful applications of nuclear energy. This article also requests "due consideration for the needs of the developing areas of the world" to address the concerns of some states that the NPT may undermine their prospects for economic development.

PILLAR 3: DISARMAMENT

Early drafts of treaties to prevent the proliferation of nuclear weapons, submitted by the United States[28] and the Soviet Union,[29] contained no language on nuclear disarmament. But non-nuclear-weapon states, and in particular non-aligned states, did not want to legitimize a world divided according to those that possessed nuclear weapons and those that did not, and insisted that non-proliferation should be accompanied by measures to stop the arms race and make progress towards nuclear disarmament.[30] Article VI of the NPT was the compromise.

Article VI

> *Each of the Parties* to the Treaty undertakes to *pursue negotiations in good faith* on effective measures relating to cessation of the nuclear arms race at an early date and to *nuclear disarmament*, and on a treaty on *general and complete disarmament* under strict and effective international control. [emphasis added]

A literal reading of article VI suggests that all states parties are obligated to pursue negotiations in good faith on effective measures relating to ending the nuclear arms race and to nuclear disarmament, including complete nuclear disarmament. Additionally, states parties are obliged to pursue negotiations on a treaty on general and complete disarmament.

The preamble of the NPT, however, suggests a slightly different reading. In the eighth preambular paragraph the signatories declare "their intention to achieve at the earliest possible date the cessation of the nuclear arms race and to undertake effective measures in the direction of nuclear disarmament". In the eleventh preambular paragraph the signatories affirm their desire:

> to further the easing of international tension and the strengthening of trust between States in order to facilitate the cessation of the manufacture of nuclear weapons, the liquidation of all their existing stockpiles, and the elimination from national arsenals of nuclear weapons and the means of their delivery pursuant to a Treaty on general and complete disarmament under strict and effective international control …

The language of these preambular paragraphs suggests that article VI does not require measures relating to complete nuclear disarmament except as linked to general and complete disarmament when preconditions, such as the easing of international tensions and strengthening of trust among states, are met. Nevertheless "effective measures in the direction of nuclear disarmament", but ostensibly short of complete nuclear disarmament, are to be pursued without reference to general and complete disarmament or any preconditions.

The history behind the negotiations of the NPT and the practice of state parties pursuant to article VI suggest that negotiators and signatories envisioned two alternative routes to complete nuclear disarmament—one to "nuclear disarmament" without linkages and preconditions, and the other to "general and complete disarmament" with linkages and preconditions.[31] Apparently this ambiguity in the treaty provisions pertaining to disarmament was intentionally drafted to satisfy or broker a compromise between both groups.

But that compromise has generated a string of controversies and disagreements. During the NPT review conferences, many non-nuclear-

weapon states have criticized the nuclear-weapon states for what the former perceived as slow progress in terms of nuclear disarmament, which, in the opinion of some, could even constitute non-compliance with Article VI obligations. Such frustration obstructed consensus at three of the eight review conferences. In their turn, the nuclear-weapon states have countered by stressing the value of their undertakings in the direction of nuclear disarmament while qualifying statements regarding the prohibition of nuclear weapons by referring to the above-mentioned linkages and preconditions. However, at the 2000 NPT Review Conference those states for the first time accepted an unequivocal commitment to eliminate nuclear weapons as part of the thirteen practical steps to implement article VI—an unprecedented and substantive disarmament plan of action agreed by NPT states parties. The final document of the conference states:

> 15. The Conference agrees on the following practical steps for the systematic and progressive efforts to implement article VI of the Treaty on the Non-Proliferation of Nuclear Weapons …
>
> …
>
> 6. An unequivocal undertaking by the nuclear-weapon States to accomplish the total elimination of their nuclear arsenals leading to nuclear disarmament, to which all States parties are committed under article VI.[32]

This is much stronger language than had been accepted, for example, at the 1995 NPT Review Conference, at which the nuclear-weapon states agreed to "reaffirm their commitment … to pursue in good faith negotiations on effective measures relating to nuclear disarmament".[33] The final document of the 2010 Review Conference contains practically the same language by noting "the reaffirmation by the nuclear-weapon States of their unequivocal undertaking to accomplish, in accordance with the principle of irreversibility, the total elimination of their nuclear arsenals leading to nuclear disarmament, to which all States parties are committed under article VI of the Treaty".[34]

In 1996 the International Court of Justice, the primary judicial organ of the United Nations, in response to a request made by the General Assembly in December 1994 released an advisory opinion on the legality of the threat or use of nuclear weapons. As part of this document, the Court produced a formulation of the disarmament obligation under article VI:

> The legal import of that obligation goes beyond that of a mere obligation of conduct; the obligation involved here is an obligation to achieve a precise result—nuclear disarmament in all its aspects—by adopting a particular course of conduct, namely, the pursuit of negotiations on the matter in good faith.[35]

The Court's opinion does not mention any preconditions, or "general and complete disarmament" as a route to complete nuclear disarmament. As a matter of fact, states are unlikely to agree to complete nuclear disarmament unless they have alternative mechanisms to protect their vital interests. One of the fundamental attributes of sovereignty is the right to defend oneself either through national resources or through some international arrangement. But large qualitative and quantitative disparities in non-nuclear offensive and defensive weapons systems between states can seriously hinder the process of nuclear disarmament. Nuclear powers with inferior conventional capabilities may decide to abstain from nuclear disarmament as they might see their nuclear arsenal as an "equalizer" against those disparities. Future negotiations for nuclear disarmament should at some stage include serious discussions about international arrangements to regulate conventional offensive and defensive military capabilities. However, *general and complete* disarmament, understood as reductions of armed forces and armaments by all states to levels required for maintaining internal order and protecting the personal security of citizens and for providing manpower for an international peace force, does not seem to be a necessary condition for achieving a nuclear-weapon-free world.

TENSIONS IN THE NPT REGIME

The nuclear non-proliferation regime has suffered from a number of tensions that are increasingly evident and consequential. Some of them have their roots in the negotiating history of the Treaty and the subsequent ambiguities and compromises in the Treaty. However, the principal tension comes from the very nature of nuclear technology.

The non-proliferation regime, with the NPT at its heart, is intended to halt the spread of nuclear weapons, and finally to eliminate them, while allowing and, as some hold, promoting peaceful applications of nuclear energy. But it is practically impossible to make a clear-cut distinction between civilian and military applications of nuclear energy—as Hannes

Alfvén, Swedish physicist and Nobel laureate, once observed, "Atoms for peace and atoms for war are Siamese twins".

The inherent dual use of nuclear energy

Both peaceful and military applications of nuclear energy depend essentially on the same key ingredient: fissile material. Such material can undergo fission to release significant amounts of energy, which can be harnessed to generate electricity or be used to produce tremendous explosive force. Common fissile materials include uranium-233, uranium-235 and plutonium-239.

Enriched uranium, in which the percentage concentration of uranium-235 has been increased through the process of enrichment, or isotope separation, is a critical component for both nuclear power generation and nuclear weaponry.[36] Two uranium enrichment processes—the gaseous diffusion process and the gas centrifuge process—are used today on an industrial scale. The most prevalent type of commercial power reactor—light water reactors—use uranium enriched to 3–5% uranium-235. The fissile uranium in nuclear weapons, called weapons-grade uranium, usually contains 90% or more of uranium-235. But, in theory, a nuclear explosive device could be built using enriched uranium with a uranium-235 fraction of 20% or even less.

Plutonium-239 and other isotopes of plutonium are formed in the process of nuclear-reactor operation as uranium-238 is converted into heavier isotopes through nuclear reactions. After irradiated nuclear fuel has been discharged from a nuclear reactor, reprocessing technologies can chemically separate out the plutonium. Separated plutonium can be used to fabricate fuel for different types of nuclear power reactors. It can also serve as the fissile component of a nuclear weapon.

Nearly all processes involved in the civilian nuclear energy industry are similar to those in the military nuclear industry: from uranium mining and milling to uranium conversion, from uranium enrichment to nuclear fuel fabrication, from fuel irradiation in nuclear reactors to spent fuel reprocessing and separation of plutonium. Nuclear energy and nuclear weapons production cycles use basically the same materials, technology and equipment. There are no technological barriers between the production of fissile materials for civilian use or for military use. Weapons-

grade uranium can be produced using the same enrichment equipment used to produce low-enriched uranium (LEU) for civilian power generation. Both civilian and military reprocessing plants use the same technology to separate plutonium from spent nuclear fuel.

The nuclear properties of weapons-grade plutonium—that is, the plutonium containing more than 93% plutonium-239[37]—make it preferable for the use in nuclear weapons. Although not all isotopic combinations of plutonium are equally convenient or efficient, virtually any combination "can be used for the manufacture of nuclear explosive devices without transmutation or further enrichment".[38] In fact, certain practical obstacles—such as greater heat emission, greater neutron emission and higher exposure to radiation—make nuclear explosive devices made from reactor-grade plutonium more difficult to design, fabricate and handle as compared to weapons-grade plutonium. It has been argued that manufacturing a nuclear explosive device from plutonium separated from spent fuel of civil nuclear plants, called reactor-grade plutonium, would be prohibitively complex.[39] However, Carson Mark, who headed the theoretical division of the Los Alamos National Laboratory for 27 years, emphasized that "the difficulties of developing an effective design of [a nuclear weapon of] the most straightforward type are not appreciably greater with reactor-grade plutonium than those that have to be met for the use of weapons-grade plutonium".[40]

All nuclear reactors produce some quantity of plutonium. The isotopic composition of that plutonium, and thus its potential for use in a weapon, depends mainly on how the reactor is operated. The lower the fuel "burn-up"—that is the shorter the duration of irradiation of nuclear fuel in the reactor—the higher is the percentage content of plutonium-239 (as stated above, the higher the proportion of plutonium-239, the more preferable the plutonium would be for weapons use). Commercial light water reactors can also be used for the production of weapons-grade plutonium, even if they are less suitable for this than reactors specifically designed for weapons programmes.

The nuclear power industry worldwide would be delighted if plutonium produced in nuclear power reactors were not a weapon-usable nuclear material. This would make the case for promoting plutonium recycling in power reactors much stronger and make the task of distinguishing between civil and military applications of nuclear energy more feasible. But this is

not the case. Reactor-grade plutonium is "weapons-usable, whether by unsophisticated proliferators or by advanced nuclear weapon states".[41]

Although they are very similar, nuclear energy and nuclear weapon production cycles are not identical. The nuclear energy production cycle does not comprise the manufacture of nuclear weapons, which includes designing a nuclear weapon, producing and testing high-explosives and non-nuclear components, producing nuclear components and assembling weapons.

In the 1960s, scientists at the Lawrence Radiation Laboratory (which later became the Lawrence Livermore National Laboratory) wanted to know if "nuclear innocents" could design a working nuclear device. In 1964, they launched an exercise called the Nth Country Experiment. They hired two young physicists, who held no security clearance and had no experience with nuclear weapons, secluded them in an office located in an old navy barracks and charged them with designing a nuclear explosive device with a militarily significant yield—without access to any classified information. The two scientists were supposed to represent an imaginary country with fewer resources than an industrialized nation, but which met certain minimum requirements, such as having "a good university library, some competent machinists to shape plutonium or uranium, and an explosives team".[42]

Seven months after they began, the physicists realized that it was so easy to make a gun-type weapon with high-enriched uranium (HEU) that it did not present any real challenge and thus would not help to build their reputations. Scientists of the Manhattan Project understood this well—they did not test the gun-type device prior to its use in the bomb dropped on Hiroshima because they had complete confidence that it would work as predicted. The two scientists of the experiment picked a plutonium design specifically because it would present a greater challenge. By April 1967, they had designed a working plutonium device that was "run through the computers and brains of the bomb designers",[43] which confirmed that it would function.

Designing a nuclear explosive device would be easier today than it was in the 1960s because the information revolution has facilitated the dissemination of knowledge, and computing tools have become much more powerful and affordable. The rapid growth in dual-use technology

applications and globalized trade make monitoring and controlling the production and testing of non-nuclear components more difficult. Thus, the greatest barrier to the manufacture of a nuclear explosive device is the acquisition of fissile material, mainly in the form of HEU or separated plutonium.

Sensitive nuclear technologies

The IAEA Board of Governors identified certain technologies in the civilian nuclear fuel cycle that could be used to produce material for nuclear weapons as "sensitive technological areas". They are uranium enrichment, reprocessing of spent fuel, production of heavy water, and handling of plutonium, including manufacture of plutonium and mixed uranium/plutonium fuel.[44] In 2005, an IAEA Expert Group on Multilateral Approaches to the Nuclear Fuel Cycle published a report identifying certain stages of the nuclear fuel cycle as sensitive, namely "the production of new fuel, the processing of weapon-usable material, and the disposal of spent fuel".[45]

Until recently weapon-usable material and fuel cycle facilities capable of producing such material were located predominantly, even if not exclusively, in the nuclear-weapon states and non-NPT states. But industrialized nuclear-weapon states no longer hold a monopoly on sensitive nuclear technologies as a result of the ongoing dissemination of knowledge and technology.

The need to meet growing energy demands and to find alternatives to fossil fuels has reinvigorated interest in nuclear power around the world. A growing number of non-nuclear-weapon states are considering nuclear energy as part of their energy mix, including the development of domestic fuel-cycle technologies. Article IV of the NPT guarantees "the inalienable right" of all states parties to develop research, production and use of nuclear energy for peaceful purposes, including sensitive fuel-cycle technologies, in compliance with articles I, II and III. Hence, these technologies must not be diverted from "peaceful uses to nuclear weapons or other nuclear explosive devices" and must therefore be effectively safeguarded by the IAEA.

But the acquisition of uranium enrichment and spent fuel reprocessing facilities could bring states much closer to nuclear weapons capability

without directly violating the NPT and without any possibility of being restrained by IAEA safeguards designed to verify whether that material has or has not been diverted. The capacity to build nuclear weapons, which the NPT actually does little to restrict, was spreading in the past and will spread in the future, possibly at an accelerated pace, as the number of states acquiring fuel cycle technologies increases.

As former IAEA Director General Mohamed ElBaradei acknowledged in his statement at an IAEA symposium on international safeguards:

> [W]e have seen an increase in the number of countries who want to go in for the nuclear fuel cycle: sensitive fuel cycle activities, enrichment and reprocessing, but mostly enrichment. … This creates many new challenges, both for the international community and for [the IAEA], because verifying enrichment facilities or reprocessing facilities is quite difficult and the so-called conversion time [the time required to convert fissile material to the metallic components of a nuclear explosive device] is very short. So we are dealing with what I call *"virtual nuclear weapon States"*.[46] [emphasis added]

The spread of the capacity to make nuclear weapons does not necessarily imply the spread of the desire to possess nuclear weapons. However, among the key factors that drive states to obtain sensitive know-how could be the desire to diversify security capacities and to enhance readiness in case the decision to develop nuclear deterrence is made.

In 1961 the UN General Assembly unanimously approved resolution 1665 (XVI), which was based on an Irish draft resolution and which can be regarded as the genesis of the NPT. The resolution called on states already having nuclear weapons to refrain "from *transmitting the information* necessary for their manufacture to States not possessing such weapons".[47] In 1965 the Soviet Union publicly presented its first draft of a non-proliferation treaty. Article I of the draft reads:

> …
>
> Parties to the Treaty possessing nuclear weapons undertake *not to provide assistance*—directly or indirectly, through third States or groups of States—to States not at present possessing nuclear weapons in the *manufacture*, *in preparation for the manufacture* or in the testing of such weapons and *not to transmit* to them *any kind of manufacturing, research or other information or documentation* which

> can be employed for purposes of the manufacture or use of nuclear weapons.[48]

Many non-nuclear-weapon participants in the NPT negotiations opposed the clause calling for a prohibition of transfer of dual-use knowledge and technology fearing that such prohibition would have negative repercussions on their economic development. By 1968, these states had successfully lobbied for full access to nuclear knowledge and technology that could be considered peaceful.

Tensions at the core of the NPT bargain

While that compromise apparently helped make the treaty a reality, it wove intrinsic tensions into the fabric of the non-proliferation regime. As mentioned earlier, the NPT rests on the pillars of non-proliferation, the peaceful use of nuclear energy and disarmament. Those pillars are often referred to as being equally important and mutually reinforcing. But can they be simultaneously pursued and promoted without undermining the spirit and purpose of the NPT?

The tension between non-proliferation and the peaceful use of nuclear energy is easily noticeable. The primary purpose of the NPT, which is first and foremost a non-proliferation treaty, is to halt the spread of nuclear weapons to additional states beyond the five that had tested them before 1 January 1967. But the ambiguity around the legal meaning and technical modalities of the inalienable right to the peaceful application of nuclear energy enables NPT states parties to engage in diverse nuclear activities short of the insertion of nuclear components into a nuclear explosive device. This situation could result in a new wave of proliferation involving what ElBaradei referred to as virtual nuclear weapons states.

Such states have developed the capability to produce plutonium or HEU and possess the knowledge and non-nuclear materials and components needed to manufacture nuclear weapons. But they stop short of assembling nuclear weapons. They would therefore remain technically compliant with the NPT while maintaining the latent capability for the rapid acquisition of nuclear weapons. Therefore, the spread of the latent capability for the rapid acquisition of nuclear weapons under one NPT pillar could come into collision with the commitment to forsake such weapons under another NPT pillar, which would weaken the non-proliferation regime as a whole.

The tension between the disarmament and peaceful use of nuclear energy pillars is more complicated. The NPT binds its states parties to commit to nuclear disarmament. And yet, nuclear weapons still are often perceived as a way to gain power, international prestige or deterrence against potential attack. Despite some progress towards nuclear disarmament in the post-Cold War years, the nuclear-weapon states have yet to develop a transparent and persistent approach to nuclear disarmament.

Many politicians in the states possessing nuclear weapons consider them as an important part of their security. As French President Nicolas Sarkozy recently said, "I could not—give up nuclear weapons, insofar as I wasn't sure that the world is—was a stable and safe place. … I will not give up that nuclear weapon because it underpins my country's security".[49] Such statements can spread and perpetuate the belief among non-nuclear-weapon states that they too might need nuclear weapons in the future to buttress their national security. As long as the nuclear powers position nuclear weapons at the bedrock of their security architecture, they cannot realistically expect the rest of the world to think or act differently. When a non-nuclear-weapon state decides to develop a "hedge" or "virtual" nuclear weapon programme, its decision may be determined, at least in part, by policies of those states legally in possession of nuclear weapons.

On the other hand, the nuclear-weapon states may be unwilling to take further steps towards the prohibition of nuclear weapons if many more states acquire the capability to produce plutonium or HEU. As George Perkovich and James Acton noted, "if no acceptable form of regulation can be established for the proliferation-sensitive activities that many states which today promote disarmament are seeking to conduct, the abolition of nuclear weapons may not prove possible".[50] Therefore, the expansion of virtual nuclear weapon capabilities could erode prospects for nuclear disarmament.

It is impossible to avoid the dual-use nature of nuclear technology, but finding a more effective approach to its management—which could guarantee that "the benefits of peaceful applications of nuclear technology" are available to all states without spreading virtual nuclear weapon capabilities around the globe—is an extremely difficult but not impossible task.

THE PEACEFUL USE OF NUCLEAR ENERGY AND COMPLETE NUCLEAR DISARMAMENT: THREE SCENARIOS

Moving to comprehensive nuclear disarmament would entail establishing mechanisms to make "break-out" or clandestine rearmament detectable, difficult and costly and provide guarantees for a stable and verifiable nuclear-weapon-free world. Making progress towards nuclear disarmament raises the question of how to minimize the likelihood of break-out.

Three scenarios can be imagined for the place of nuclear fuel-cycle technologies in a world without nuclear weapons:

- a world with neither nuclear weapons nor nuclear energy;
- a world without nuclear weapons but with nationally controlled fuel cycles under international scrutiny and safeguards; and
- a world without nuclear weapons but with internationalized fuel cycles.

The first two scenarios will be discussed presently; the third scenario will be addressed in the following chapter.

Scenario 1—a nuclear-energy-free world

The first scenario seems to be the most stable. No nuclear energy means no fuel cycle facilities, no production of fissile materials, no nuclear trade and so on. In such a world, any form of nuclear activity would be more easily detectable than in a world where dozens of states engage in diverse nuclear activities. The existing stocks of nuclear materials could be effectively safeguarded by employing methods and techniques already employed by the IAEA. Title for these materials could be transferred from states currently owning them to the IAEA or another international organization.

Although it provides the highest prospects for stability, the first scenario has the lowest feasibility. Today, nuclear power generation is an established part of the world's energy mix, providing about 15% of global electricity. As of January 2010, 438 nuclear power reactors were in operation in 30 countries with a total net electricity generating capacity of 372GWe[51] while 54 countries operated nuclear research reactors.[52] Fifty-five nuclear power

plants with a net electricity generating capacity of 52.5GWe are currently under construction in 14 countries.[53]

Thirteen states currently possess uranium enrichment technology. Apart from the five nuclear-weapon states (China, France, Russia, the United Kingdom and the United States), three non-nuclear-weapon states (Germany, Japan and the Netherlands) operate large-scale enrichment plants, while two others (Brazil and Iran) are building smaller enrichment plants. Two nuclear-armed states (India and Pakistan) operate small-scale military enrichment facilities, while one non-nuclear-weapon state (Argentina) has a pilot enrichment plant in operation.

Five states own and operate reprocessing facilities for commercial spent fuel from power reactors—France, India, Russia, the United Kingdom, and Japan, the only non-nuclear-weapon state to do so. China is finishing the construction of a pilot commercial reprocessing facility. All nuclear-armed states (the Democratic People's Republic of Korea, India, Israel and Pakistan) have reprocessing capacities for military purposes. Moreover, dozens of states have uranium mining, conversion and fuel production capabilities. In addition to generating electricity, nuclear energy is extensively used in industry, agriculture and medicine.

Today, after the more than two decades of virtual stand-still as a consequence of the Three Mile Island accident of 1978 and the Chernobyl accident of 1986, the world faces the prospect of a nuclear "renaissance"—a potential expansion in the use of nuclear energy worldwide. Energy supply is a key economic, security and environmental issue for our planet and many states consider the nuclear energy option as a vital part of their energy mix, providing energy in quantities needed to decrease dependence on fossil fuels.

With all this said, the first scenario of a nuclear-energy-free world, even if the most stable, does not seem to be realistic.

Scenario 2—No nuclear weapons but nationally controlled fuel cycles

The second scenario envisages a world without nuclear weapons but with nationally controlled fuel cycles under international scrutiny and safeguards. This would effectively mean that despite the absence of

nuclear weapons, a number of states would retain the capacity to build nuclear explosive devices, or at least the capacity to produce weapon-usable nuclear material, in a relatively short period of time.

Some experts have argued that allowing the former nuclear-weapon states to maintain the capability to manufacture nuclear weapons on short notice—that is, to maintain virtual nuclear arsenals—would strengthen the nuclear deterrent effect by substituting "factory deterrence", or "weaponless deterrence", for deterrence with actual nuclear weapons, thereby helping to make a world without nuclear weapons-in-being a reality.[54] Such logic, first of all, has been applied to states that would relinquish their nuclear arsenals. Their weapons-related facilities, activities and materials would be placed under international monitoring. Thus, any attempt by any state to use those facilities or materials would most likely be detected by other nuclear-capable states and lead them to reactivate their own nuclear-weapon programmes in response. Any state would know that if it began to rearm others would too. Attempts to break out of the system would thus be self-defeating.

However, there are at least two potential problems with the idea of stable weaponless deterrence. First, if states maintained the capacity to rebuild nuclear weapons quickly it would make it easier for a state to cheat while making it more difficult to detect and respond to cheating in a timely manner. Permitted nuclear activities would create a background against which it would be more difficult to detect illegal activities. Second, having states hovering on the edge of resuming manufacture of nuclear weapons could create dangerous instabilities in which states might be rushed to rearm by fears, misunderstandings or miscalculations.

This logic applies not only to former nuclear-weapon states but also to any virtual nuclear weapon state. In a world without nuclear weapons, the use of nationally controlled civilian nuclear facilities for military purposes could be more attractive than now, since there would be no legal, dedicated military facilities. Moreover, the advantages to be gained could be perceived to outweigh the costs. If one state breaks out and builds even a handful of nuclear explosive devices, it would gain an immediate superiority, even if a short-term one. Suspicions that some state may break out during a crisis would create instabilities that could eventually lead to the collapse of this nuclear-weapon-free regime. The short duration of the advantage would exacerbate the instability—a state might have

an incentive to use its nuclear weapons before adversaries have them to prevent nuclear reprisal. A world without nuclear weapons, yet in which states would still have the knowledge and capacity to remake them, could be more unstable than the world of today.

Can international scrutiny and safeguards prevent such break-out? Hypothetically a highly effective system of international safeguards could do so, but there are certain impediments to making such a system a reality. First of all, bulk-handling facilities are difficult to effectively safeguard against diversion of nuclear materials. According to the IAEA classification, a bulk-handling facility is "a facility where nuclear material is held, processed or used in bulk form",[55] such as plants for conversion, enrichment, fuel fabrication and spent-fuel reprocessing.

According to the document that details the safeguards obligations of states parties to the NPT, INFCIRC/153, a technical objective of IAEA safeguards is specified as "the *timely detection* of the diversion of *significant quantities* of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown and deterrence of such diversion by the risk of early detection".[56] A significant quantity is defined as "the approximate amount of nuclear material for which the possibility of manufacturing a nuclear explosive device cannot be excluded".[57] For HEU a significant quantity is judged to be 25kg of uranium-235, and for plutonium 8kg.

The IAEA inspection goal—"performance targets specified for IAEA verification activities at a given facility"[58]—consists of two components:

- a timeliness component—the frequency of verification activities that are necessary for the IAEA to draw the conclusion that there has been no diversion of one significant quantity or more of nuclear material at a facility during a given calendar year; and
- a quantity component—the scope of the inspection activities at a facility that are necessary for the IAEA to draw the conclusion that there has been no diversion of one significant quantity or more of nuclear material over a time between two consecutive physical inventory takings.

Detection time is one of the factors used to establish the timeliness component of the IAEA inspection goal. Detection time—"the maximum

time that may elapse between diversion of a given amount of nuclear material and detection of that diversion by IAEA safeguards activities"[59]—should correspond approximately to conversion time, defined as "the time required to convert different forms of nuclear material to the metallic components of a nuclear explosive device".[60] Conversion time is estimated to be 7 to 10 days for metallic plutonium and HEU; 1 to 3 weeks for pure non-irradiated compounds of these materials such as oxides or nitrates, or for mixtures; and 1 to 3 months for plutonium or HEU in irradiated fuel.[61]

INFCIRC/153 details the methods to be used to detect a diversion in a timely manner: "To this end the Agreement [between the IAEA and the state] should provide for the use of *materials accountancy* as a safeguards measure of fundamental importance, with *containment and surveillance* as important complementary measures".[62]

The nuclear facility operator prepares data on the material balance covering a specific period, showing that all nuclear material at this facility can be accounted for. The IAEA inspectors perform an independent check on the data prepared by the facility operator. Specifically, a value of "material unaccounted for" (MUF), which is the difference between the book inventory and the physical inventory,[63] is determined. If MUF is equal to zero and the IAEA inspectors have confirmed the data submitted by the operator, then it is possible to conclude that no diversion has occurred. A non-zero MUF indicates a problem (from accounting mistakes and measurement uncertainties to diversion) and warrants further investigation.

This method works well when nuclear material is held within fixed packages such as fuel assemblies or containers. In such cases, the terms of the MUF equation are known exactly and the material balance can be calculated with a high degree of certainty. But for bulk-handling facilities the situation is different because of the nature of processing. In such facilities different forms of nuclear materials are present (gases, solutions, powders, pellets) and some forms are converted into others. Moreover, the ingoing and outgoing quantities of nuclear materials, such as plutonium in reprocessing and uranium in enrichment plants, can be measured only with an unavoidable and rather high degree of uncertainty. During bulk-handling facility operations, a significant amount of material inevitably becomes stuck inside processing equipment, piping and filters. As a result, a non-zero MUF can be expected for bulk-handling facilities even in the

absence of diversion and material accountancy must use statistical methods to distinguish possible diversion from measurement uncertainty.

The facility operator's measurement uncertainties associated with each of the four terms of the MUF equation are combined with the material quantities to determine the uncertainty of material balance σ_{MUF}. But even if the percentage value of σ_{MUF} is small, at a facility that processes large quantities of nuclear material the absolute value of σ_{MUF} can be high in terms of significant quantities.

The IAEA defines the minimum loss of nuclear material that can be expected to be detected by material accountancy as "expected accountancy capability". It is derived by statistical analysis and is based on assumptions of a detection probability (the probability, currently set at 95%, if diversion of a given amount of nuclear material has occurred, that IAEA safeguards activities will lead to detection), a false-alarm rate (the probability, currently set at 5%, that statistical analysis of accountancy verification data would indicate a diversion of material when no diversion has occurred), and a certain value of measurement uncertainty expected for closing a material balance.[64]

In short, the expected accountancy capability reflects the inherent limitations of the expected performance of a system of safeguards measures resulting from the unavoidable uncertainty in essential measurements and the degree of detection utilized techniques can actually achieve.

Miller's 1990 paper demonstrated that for large bulk-handling facilities, such as the Rokkasho Reprocessing Plant in Japan with an annual throughput of 800t of heavy metal, the value of expected accountancy capability would be 236kg of plutonium, or about 30 significant quantities, if physical material balance inventories were performed on an annual basis.[65] The loss of plutonium at this plant would thus have to exceed this value before it could be detected by material accountancy with 95% certainty.

While the term "expected accountancy capability" does not appear in the 2001 edition of the IAEA Safeguards Glossary, the agency still uses the same values for expected measurement uncertainties, detection probability and false alarm probability. Even if accountancy capability has improved since the early 1990s, the IAEA's stated goal of detecting with confidence

diversion from a bulk-handling facility of a significant quantity or more of nuclear material on a timely basis is very difficult to achieve in practice.

The IAEA does not rely exclusively on material accountancy. In order to strengthen the international safeguards system, the agency uses other techniques such as containment and surveillance, environmental sampling, design information verification, unannounced inspections and so on. But as Pierre Goldschmidt, former IAEA Deputy Director General for Safeguards and Verification, admitted "there are still problems inherent in ensuring that, in 'bulk facilities', even small amounts of nuclear material—a few kilograms among tons—are not diverted without timely warning".[66]

Furthermore, some experts have criticized the significant quantity values currently used by the IAEA as erroneous and inflated. They have argued that these values should be lowered eight-fold to 1kg of plutonium and 3kg of uranium-235.[67] And yet, lowering the significant quantity values would make the task of "the timely detection of the diversion of significant quantities of nuclear materials from peaceful nuclear activities to the manufacture of nuclear weapons" even more difficult.

As for detection time, it would be preferable to detect a diversion well before the perpetrator could assemble a weapon from the diverted material, in order to give the international community enough time to organize and coordinate some form of political response. Thus, detection time for a given nuclear material should be shorter than the conversion time for that material. But as noted earlier, the estimated time required to convert some forms of nuclear material into components of a nuclear explosive device is extremely short, and does not allow time for much political manoeuvring.

Other factors limit the effectiveness of international safeguards. Currently, the IAEA's authority is mostly limited to verifying nuclear material. In November 2005, the IAEA Director General acknowledged that "both safeguards agreements and additional protocols are focused on nuclear material—and therefore, the Agency's legal authority to investigate possible parallel weaponization activity is limited, absent some nexus linking the activity to nuclear material".[68] While nuclear material is a necessary component of a nuclear weapon, weaponization activities not involving this material—for example, explosive experiments with test assemblies—can be detectable. An effective verification system, especially in a nuclear-

weapon-free world, must have the ability to identify any indication that a state may be undertaking activities that could signal the existence of a nuclear weapon programme.

The NPT does not have a built-in response mechanism for non-compliance. According to the IAEA statute, the agency's Board of Governors is to call upon the violator to remedy non-compliance with IAEA safeguards and should report non-compliance to the UN Security Council and General Assembly. The IAEA statute does not stipulate any specific deadlines for this reporting, so the Board could delay reporting. The UN Security Council may impose specific penalties, such as diplomatic and economic sanctions, but the violator could still choose to remain non-compliant. Moreover, any of the Security Council's five permanent members could use its veto power to delay or dilute sanctions.

National control of fuel cycle facilities would make it easier for a state, wishing to do so, to falsify material balance data, interfere with verification procedures or refuse to allow safeguards inspections.

Pursuing comprehensive nuclear disarmament in a world with nationally controlled fuel cycles will require a highly effective international system to confirm that all fissile materials are placed under international safeguards, provide timely warning of any attempt to build nuclear weapons, and successfully confront non-compliance. As the number of nuclear weapons nears zero, states would be likely to demand an increasing degree of confidence in the proper functioning of the international verification system. But the nature of processing impedes the ability of the most effective verification techniques possible to provide complete confidence that small amounts of weapon-usable material have not been diverted from bulk handling facilities.

PROLIFERATION-SENSITIVE NUCLEAR ACTIVITIES AND DISARMAMENT

When the NPT was negotiated in the 1960s, it was believed that some fuel cycle technologies, in particular uranium enrichment, were too forbiddingly complex to be mastered by the overwhelming majority of would-be proliferators. At that time, enrichment technology was

considered to be solely the domain of the nuclear powers and a few of their developed allies.

But in 1993, the US Office of Technological Assessment concluded:

> In the near term, low- and medium-level gas centrifuge technology may become increasingly attractive to potential proliferants, for reasons including the availability of information on early-model centrifuge design, the widespread use of and possible illicit access to know-how for more advanced centrifuge technology, and the relative ease both of hiding centrifuge facilities and using them to produce highly enriched uranium (HEU). The more advanced centrifuge technology, once obtained, could lead to small, efficient, and relatively inexpensive facilities that would be particularly difficult to detect remotely.[69]

This assessment was largely based on the success of Pakistan's uranium enrichment programme in the 1980s and the extent of Iraq's efforts, which came to light in the early 1990s. It was further reinforced when the scope of activities of the nuclear black-market operation set up by Pakistan's A.Q. Khan became public in 2004.

Centrifuge enrichment facilities are difficult to detect using satellite imagery, emissions or any other method of observation because their physical buildings are inconspicuous, they consume modest amounts of electricity and the atmospheric emissions from these facilities are nearly non-existent. By comparison, separation of plutonium from spent nuclear fuel is less technologically sophisticated than enrichment of uranium and could be mastered more easily, but spent fuel reprocessing facilities are usually large and produce distinct signatures, such as emissions of certain radionuclides, so these facilities are easier to detect.

In recent decades, states with a relatively limited scientific and industrial base—such as the Democratic People's Republic of Korea, Iran and Pakistan—have proven capable of mastering sensitive nuclear technologies. The nuclear programmes of those states have highlighted a worrisome trend. While those states have not established commercially competitive enrichment or reprocessing programme because of economic or technological constraints, they have been able to acquire some nuclear weapons capability, be it actual or virtual.

Meanwhile, the civilian nuclear industry looks poised for worldwide expansion. The anticipated increase in global energy demand and the increased awareness of the dangers and effects of global warming and climate change are encouraging an increase in the use of nuclear energy. This could result in further dissemination of uranium enrichment and spent fuel reprocessing technologies, thus corroding confidence in the existing non-proliferation regime. At the heart of that crisis in confidence could lay suspicions over the intentions of states developing domestic fuel cycle technologies. The following factors could arouse such suspicions:

- bulk-handling fuel cycle facilities are difficult to safeguard and can be difficult to detect; and
- a virtual nuclear weapons capability is more easily achieved than a commercially competitive fuel cycle capability.

Resulting pessimism about the stability of the non-proliferation regime would weaken the non-proliferation and the disarmament pillars of the NPT.

Currently, the process of nuclear disarmament is mainly focused on bilateral agreements between Russia and the United States, which together hold over 90% of the world's nuclear weapons. Even after the limits of the new Strategic Arms Reduction treaty are met, the two states will still possess far more nuclear weapons than any other state. But as the process of nuclear disarmament moves towards deeper cuts and low numbers of nuclear warheads, then not only remaining warheads would matter, but also capabilities, intentions and suspicions.

If deep suspicions persist between states and their virtual capabilities seem unverifiable and easily convertible into actual nuclear weapons capabilities, the possibility of comprehensive nuclear disarmament will decrease. States possessing nuclear weapons may view the retention of their nuclear arsenals as unavoidable if other states could quickly recover weapon-usable nuclear material from their nationally controlled fuel cycles and manufacture their own nuclear weapons. On the other hand, if states are able to build mutual trust that all parties will comply with international agreements and confidence that none could re-establish nuclear weapons capabilities before the international community could effectively respond, the prospects for complete nuclear disarmament would improve.

CHAPTER 4

MULTILATERAL FUEL CYCLES AND NUCLEAR DISARMAMENT

If technical measures such as IAEA safeguards are by themselves insufficient to compensate for the imperfections of the nuclear non-proliferation regime, then certain institutional mechanisms—such as multilateralization of the nuclear fuel cycle—could serve to address these imperfections by changing how sensitive materials, facilities and technologies are managed. Generally, multilateral arrangements aim to denationalize sensitive fuel-cycle activities by placing decisions on the operation of nuclear facilities, and on the disposition of their products, in the hands of a group of states or international organizations, rather than in the hands of individual states.

SCENARIO 3—A NUCLEAR-WEAPON-FREE WORLD WITH INTERNATIONALIZED FUEL CYCLES

The third scenario finds a world without nuclear weapons with multilaterally owned and operated fuel cycles under international safeguards. Of course, nationally and multilaterally owned nuclear fuel-making facilities could co-exist. But the risks associated with that situation would be similar to those of the second scenario discussed previously. The principal difference would be a situation where the existence of facilities under national control is abandoned altogether. Multilaterally owned and operated fuel cycles would have certain advantages over nationally controlled fuel cycles in making both break-out and clandestine rearmament more detectable, politically risky, lengthy and costly and in improving prospects for a stable and verifiable world with nuclear weapons.

First, multilaterally controlled fuel cycles would shift the control of weapon-usable nuclear materials away from individual states. There would be no sensitive fuel-cycle facilities under purely national control. Transferring this control could prevent states from recovering weapon-usable nuclear material from fuel-cycle facility operations quickly, or would, at least,

make such endeavours more complicated and riskier in political terms. All participants in a multilateral fuel-cycle facility, in which ownership, control or operation are shared among a number of states that can watch over each other, would be under a greater degree of peer scrutiny making it more difficult to cheat and providing less opportunity for diversion or theft of nuclear material.

Of course, multilateral arrangements must be part of an integrated regime that puts not only facilities but also the produced materials under controls. Not only sensitive fuel-cycle facilities, but also existing and future stocks of weapon-usable nuclear material should come under multilateral ownership and control. Multilateral control of nuclear materials and production capabilities would make rearmament more difficult.

Second, multilateral fuel cycles would provide the international community with additional assurances of the parties' commitment to their non-proliferation and disarmament obligations. Currently, the successful application of safeguards demands cooperation and transparency with the IAEA on the part of all states. Potentially an individual state can complicate the Agency's work by providing information that is not clear or complete, denying certain information, obstructing inspections, and so on. To do the same at a multilateral fuel-cycle facility would require the collusion of all participants. Multilateral oversight and the presence of multinational staff would increase the intensity of peer scrutiny and would make secret agreements among the partners difficult to achieve. Although it cannot resolve the technical difficulties related to safeguarding bulk-handling facilities, multilateralization of the nuclear fuel cycle could facilitate the application of IAEA safeguards by promoting high levels of transparency and cooperation between multilateral partners and the Agency.

Third, an international incident would most likely arise if a state took control of a multilateral fuel-cycle facility or of multilaterally owned nuclear material during storage or transportation. The possibility of seizure of the facility by the host state would always be present, but a considerable political barrier would inhibit such action, in that such action would most likely convince the international community of the state's intent to acquire nuclear weapons thus resulting in an immediate confrontation.

Experts from the Natural Resources Defense Council, a US non-governmental organization, have recently proposed the creation of a new

autonomous international agency under the aegis of the United Nations to license the construction and operation of all uranium enrichment enterprises worldwide.[70] According to this proposal, states would grant the agency exclusive extra-territorial rights to sites where uranium enrichment activities are conducted, similar in some respects to the rights of governments to maintain and secure their embassies in other countries. This would increase the potential costs should a host state contemplate removing the agency and taking over the site. Such an approach of internationally supervised extra-territorial sites could apply to all sensitive fuel-cycle facilities, thus introducing additional barriers to break-out.

Fourth, the nuclear intentions of states would become more apparent. Given widespread acceptance of complete multilateralization of the fuel cycle by the international community, an individual state's decision to establish a national enrichment or reprocessing programme would result in the marginalization of that state. Such decision would be seen as a signal that the state may intend to acquire nuclear weapons capabilities, thus emboldening the international community to take decisive action.

Fifth, multilateral fuel cycles would convert the current "two-tier" system of suppliers and non-suppliers into a truly multilateral fuel-cycle arrangement of equal rights and obligations by providing partner states with some vested interest and involvement in fuel cycle ownership, management, operations and a share of profits. The partners would get guaranteed access to "the benefits of peaceful applications of nuclear technology" at a lower cost compared to a purely domestic fuel cycle.

Those prospective benefits notwithstanding, multilateral fuel cycle arrangements could carry certain risks. It is very important to carefully design multilateral fuel-cycle arrangements so that they do not facilitate or stimulate the illicit transfer of sensitive nuclear technologies or expertise. This has already occurred at least once in the past, when A.Q. Khan illegally obtained detailed information about URENCO's centrifuge process while working for a Dutch subcontractor to the enrichment consortium.

The so-called "black box" approach—an arrangement in which the sensitive technology (for example centrifuge equipment for uranium enrichment) is supplied pre-fabricated, while the operators of the plant do not have access to any proprietary or proliferation-sensitive information pertaining to the manufacture of centrifuges—is technically feasible and

generally considered viable by supplier states. The latter already rely on this approach to protect proprietary information in facilities located in other countries or operated by other companies.

For example, Enrichment Technology Company Limited (ETC) is a joint venture owned in equal shares by URENCO and AREVA. It has exclusive oversight of and responsibility for the development and manufacture of ETC centrifuge enrichment technology. It became a separate company in 2003 after the restructuring of URENCO. ETC now supplies black box enrichment technology to URENCO and AREVA. ETC gives the companies the necessary information to enable them to operate the enrichment plants safely and economically, but it does not transfer proliferation-sensitive knowledge of how to design and build centrifuges or cascades. At the end of a facility's operating life, the operator will call on ETC to "de-classify" the facility before it is given permission by ETC to start decommissioning the plant.[71] Two uranium enrichment facilities that will feature black box technology supplied by ETC are now under construction in the United States and one in France. Russia has also supplied black box centrifuge plants to China.

EXISTING PROPOSALS FOR MULTILATERAL APPROACHES

Over the past few years, states, nuclear industry and international organizations have put forward a number of proposals regarding multilateral approaches to the nuclear fuel cycle and assurances of nuclear fuel supply.[72] The proposals differ considerably in their vision, scope, goals and implementation timelines. As an acknowledgement of current political realities, many of them entail virtually no multilateralization beyond seeking to provide extra assurances of reactor fuel supply to offer states attractive alternatives to acquiring their own enrichment capacities. These proposals are designed as "guarantees-in-depth" or supplemental instruments for the existing nuclear market. As such, they would only be triggered in the event of a disruption in normal commercial supplies caused by factors unrelated to technical or commercial considerations. The proposed supplemental instruments can be categorized into two groups: assurance of supply proposals and fuel bank proposals.

Assurance of supply proposals

- **World Nuclear Association Proposal** (May 2006). A World Nuclear Association Working Group on Security of the International Nuclear Fuel Cycle proposed a three-level mechanism to assure the supply of uranium enrichment services: basic supply security provided by the existing world nuclear market mechanisms, collective guarantees by enrichment companies supported by commitments from governments and the IAEA, and government stocks of enriched uranium product.[73] The second level would be triggered only in the event of a disruption of normal commercial supplies. If one enricher could not meet its contractual obligations due to political pressure from its government, then all enrichers party to the agreement would fill the gap from their own resources under terms specified between the IAEA and the enrichers. This guarantee would be given to all non-supplier states contracting to obtain enrichment services from any enricher party to the agreement. If that network then failed, the third tier of supply assurance, represented by stocks of enriched uranium product held by national governments, could be used as a last resort.

- **Six-Country Concept** (June 2006). The six enrichment-service supplier states—France, Germany, the Netherlands, Russia, the United Kingdom and the United States—proposed a modified version of the World Nuclear Association proposal that offers two levels of enrichment assurance beyond the normally operating market.[74] At the "basic assurances" level, suppliers of enriched uranium would agree to substitute for each other in the case of supply interruptions to customer states that have "chosen to obtain supplies on the international market and not to pursue sensitive fuel cycle activities". At the "reserves" level, participating governments could provide reserves of LEU that would be made available if the "basic assurances" were to fail. Rights regarding the use of these LEU reserves could formally be transferred to the IAEA to provide greater assurance of supply.

- **IAEA Standby Arrangements System** (September 2006). Japan proposed the establishment of an information system (database) as a compliment to the Six-Country Concept to help prevent interruptions in nuclear fuel supplies.[75] The system, to be administered by the IAEA, would disseminate information contributed voluntarily by IAEA member states on their national capacities for uranium ore,

uranium reserves, uranium conversion, uranium enrichment and fuel fabrication. Should disruption occur, the IAEA would then act as an intermediary between non-supplier states and states that could provide the required services or materials.

- **UK Nuclear Fuel Assurance Proposal** (September 2006). The United Kingdom proposed a so-called "bonding" principle that would—in the event that the IAEA determines that specified conditions have been met—guarantee that national enrichment providers would not be prevented from supplying enrichment services, and provide prior consent for export assurances.[76] A formal agreement between governments, to be overseen by the IAEA, would ensure that suppliers are not unduly withheld for non-commercial reasons from fulfilling their contractual obligations.

Fuel bank proposals

- **US Proposal on a Reserve of Nuclear Fuel** (September 2005). The United States announced that it would commit up to 17t of HEU deemed to be excess to national security needs to be down-blended to LEU to use as a reserve "to support assurances of reliable fuel supplies for states that forego enrichment and reprocessing".[77] The material would remain under US control and subject to obligations attached to US-origin nuclear material.

- **IAEA Nuclear Fuel Bank Proposal** (September 2006). The Nuclear Threat Initiative offered to contribute $50 million to the IAEA to help create an international LEU stockpile controlled by the Agency that could be made accessible on a non-discriminatory, non-political basis should other supply arrangements be disrupted.[78] The offer was contingent on the conditions that one or more IAEA member states contribute an additional $100 million in funding or an equivalent value of LEU, and that the IAEA takes the necessary actions to approve the establishment of the reserve. The first requirement was met in March 2009, but the IAEA Director General's proposal to prepare a detailed scheme on how an IAEA LEU bank for assurance of supply would be established and operated was rejected in June 2009 by the IAEA Board of Governors.

- **Russian LEU Reserve Proposal** (June 2007). As part of its initiative to establish an international uranium enrichment centre, the Russian Federation proposed the creation of a guaranteed reserve of 120t of LEU in Angarsk. Russia agreed to cover all the costs associated with the establishment of the LEU reserve, its storage and maintenance, the application of IAEA safeguards, and ensuring safety and security. Following a request from the IAEA Director General to withdraw material from the reserve, Russia would deliver the required amount of LEU to the IAEA with all the necessary export licenses and authorizations required under Russian law. The IAEA would not own the LEU reserve, but would control and assure the supply of material from the reserve to any "non-nuclear-weapon State member of the IAEA experiencing a disruption in the supply of LEU for nuclear power plants not related to technical or commercial considerations".[79] In November 2009, the IAEA Board of Governors approved the establishment of the Russian guaranteed reserve of LEU and in March 2010 the IAEA and the Russian Federation signed an agreement to establish the reserve.[80]

Addressing the reasons underlying the acquisition of fuel-cycle technologies

To be successful, multilateral fuel-cycle arrangements will need to address the reasons that may encourage states to acquire domestic fuel-cycle technologies. Those reasons may include a desire to ensure the security of fuel supply and reduce external dependence on foreign suppliers; commercial interests in making profits from selling materials and services on the market; national prestige; and the desire to expand national security options by acquiring a virtual nuclear weapons capability.

By diversifying the roster of suppliers and offering last-resort instruments and additional legal tools to guarantee uninterrupted access to nuclear fuel, the proposed supplemental mechanisms focus primarily upon energy security and confidence. Thus, fuel banks and assurance of supply mechanisms may address states' concerns about security of supply. However, these proposals do not address commercial interests or national prestige.

None of the proposed supplemental mechanisms is designed to actually change the way in which nuclear technology is currently managed,

namely the highly national control of nuclear activities. That could be achieved only through true multilateralization, whereby all sensitive fuel cycle facilities would be under multilateral control and ownership and under IAEA safeguards. Only a truly multilateral regime, however radical and unrealistic that idea may seem at present, is likely to remove existing tensions between the three pillars of the NPT and address concerns about discrimination inherent in the international non-proliferation regime.

Former IAEA Director General ElBaradei proposed the following progressive steps to craft a new multilateral framework that is equitable and accessible to all users of nuclear energy acting in accordance with agreed nuclear non-proliferation norms:

- assuring the supply of fuel for nuclear power plants;
- limiting future enrichment and reprocessing to multilateral operations; and
- converting enrichment and reprocessing facilities from national to multilateral operations over time.[81]

Some of the existing proposals for multilateral approaches to the nuclear fuel cycle and assurance of nuclear fuel supply go in the direction of greater multilateralization. Those proposals can be categorized into two groups: new infrastructure proposals and multilateral facility proposals.

New infrastructure proposals

- **Russian Global Nuclear Power Infrastructure** (January 2006). Russia outlined a proposal to create "a global infrastructure that will give all interested countries equal access to nuclear energy, while stressing reliable compliance with the requirements of the non-proliferation regime", including the "creation of a system of international centers providing nuclear fuel cycle services, including enrichment, on a non-discriminatory basis and under the control of the IAEA" as a key element in developing this new infrastructure.[82] The Russian initiative does not explicitly mention comprehensive multilateralization of the whole nuclear fuel cycle or some of its parts. But the creation of the proposed global infrastructure, as well as of a truly multilateral fuel-cycle framework, is a complex endeavour that will need to be addressed through a series of steps. Certainly the creation of a system

of international centres providing enrichment and reprocessing services is a necessary step towards true multilateralization.

- **Austrian Proposal on Multilateralization of the Nuclear Fuel Cycle** (May 2007). Austria proposed true multilateralization of the nuclear fuel cycle through two parallel tracks. The first track would focus on "building transparency and mutual confidence, and, crucially, allowing IAEA to build a fully comprehensive picture of each State's nuclear capabilities and activities" through the creation of an IAEA "cradle to grave" information system.[83] The second track would focus on eventual multilateralization of fuel cycle facilities worldwide through progressive steps leading to "a legally binding international instrument [which] would limit the production or reprocessing of all nuclear material for civilian nuclear programmes to facilities under multilateral control".[84] The Austrian proposal also envisages pooling sensitive nuclear material in a limited number of multilateral storage facilities around the world, under IAEA safeguards. This is the only proposal that presents a road map towards comprehensive multilateralization of the fuel cycle, even if many practical details of this plan are still to be defined.

Multilateral facility proposals

- **Russian International Uranium Enrichment Centre** (January 2007). As a first practical step towards the creation of a "global nuclear power infrastructure", Russia has established a model International Uranium Enrichment Centre (IUEC) in Angarsk "to provide IUEC participating organizations with guaranteed access to uranium enrichment capabilities".[85] The Centre was formally brought into existence with the signing of an agreement between Kazakhstan and Russian on 10 May 2007. Armenia and Ukraine have already joined the IUEC agreement, and after buying stakes in the Centre they should become full IUEC members before the end of 2010.[86] The Centre is open for other states, which meet their commitments under the NPT and share the objectives of the IUEC, to join. The Centre is envisioned as a mechanism for providing guaranteed supplies of uranium enrichment services first of all to its members, but not to them exclusively. The IUEC stockholders would either have guaranteed access to enriched uranium product or a share in the profits. The IUEC is structured in such a way that no access to Russian enrichment technology or classified information will be granted to the members. Actually

the relevant technology is located in another facility—the Angarsk Electrolysis Chemical Complex—which is not currently part of the multilateral arrangement.

- **German Multilateral Enrichment Sanctuary Project** (May 2007). Germany proposed the creation of a new multilateral enrichment facility established by a group of interested states in a special extraterritorial area called the Multilateral Enrichment Sanctuary, supervised by the IAEA.[87] A group of interested states will invite their national industries to set up a joint, multinational commercial enrichment company, which will finance, construct, own and operate the enrichment plant. A host state would cede administrative and certain sovereign rights in a part of its territory to the IAEA, similar to a host state granting certain rights—including rights over a defined territory—to international organizations. The IAEA would administer the Multilateral Enrichment Sanctuary and act as the nuclear regulator and supervisor for the operation of the enrichment facility, the role which is normally carried out by a state body. The plant "would have to be constructed as a 'black box' and would therefore only be accessed and maintained by the supplier [of enrichment technology]".[88]

- **Uranium Enrichment International Consortium Proposal** (October 2007). The Gulf Cooperation Council, an organization that includes Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates, put forward an initiative that invited all interested states of the Middle East to participate in the establishment of an international uranium enrichment consortium, which would be based in a neutral country outside the region.[89] All member states of the consortium in the region could thus secure the supply of nuclear fuel for their power plants, but they would not have access to enrichment technology (the supplier of the black box technology was not specified). Unfortunately, this initiative, the only multilateral proposal that originated from non-supplier states, has not been developed further.

Dealing with existing and future fuel-cycle facilities

The added value of these multilateral facility proposals lies in their efforts to deal with the second (limiting future enrichment and reprocessing to multilateral operations) and third (converting enrichment and reprocessing

facilities from national to multilateral operations) steps needed to establish a new multilateral fuel-cycle framework.

The Russian IUEC falls short of directly placing an existing Russian national enrichment facility—the Angarsk Electrolysis Chemical Complex—under multilateral control. Currently the IUEC and the enrichment plant are operated separately. The IUEC does not have its own uranium enrichment capacity and would instead negotiate contracts for uranium enrichment services with the enrichment plant. Nevertheless, in the process of the establishment of the IUEC, the Russian government included the Angarsk Electrolysis Chemical Complex into the list of Russian nuclear facilities that could be subject to the IAEA safeguards in the framework of the Safeguards Agreement between Russia and the IAEA. In the future there may be some form of merger between the two entities; for example, the IUEC could become a stakeholder of the Angarsk enrichment complex.

Russia, however, controls the majority stake in the IUEC and can therefore take all strategic decisions regarding the company without the input or the support of the other partners. Moreover, Russia has exclusive control over the enrichment plant itself, in which no foreign participation is currently envisioned. This leaves little room for others to participate in decision-making and operations, and thus may not offer sufficient incentives for participation.

The German Multilateral Enrichment Sanctuary Project offers an alternative model for truly multilateral fuel-cycle facilities that would be consistent with a world moving towards nuclear disarmament. The proposed joint ownership of an enrichment plant, with no single party having the majority stake, could address national prestige concerns and fears that the multilateral fuel-cycle approaches seek to reinforce the current "two-tier" system of supplier and non-supplier states. Of course, the creation of such a multilateral facility would require the support of current nuclear technology holders and their governments.

The Gulf Cooperation Council proposal offers a promising example of a regional approach to multilateralization, being especially important as it is the only proposal originating from non-suppliers. Non-supplier states should have a right to establish multilateral facilities with partners of their choice and in the locations of their choice, provided that they are financially able to do so and an existing supplier commits to furnish

safeguarded black box technology. Regional cooperation on multilateral nuclear fuel cycle projects could serve as an important trust-building measure, strengthening regional security and reducing suspicions among participating states about others' nuclear intentions.

CHAPTER 5

REVAMPING THE GRAND BARGAIN

In their 1965 drafts for a non-proliferation treaty, the United States and the Soviet Union called for a treaty of unlimited duration that would prohibit states possessing nuclear weapons from disseminating them to states that did not have them, and that would prohibit those not having nuclear weapons from acquiring them. Neither draft contained any article on nuclear disarmament or the peaceful use of nuclear energy.[90] The two tried to frame a treaty to suit, first of all, their own interests and to impose obligations and responsibilities on states without nuclear weapons. The latter, however, wished to receive a fair bargain in return for their voluntary renunciation of nuclear weapons. Unwilling to legitimize a world divided indefinitely between the five states possessing nuclear weapons and all others, the states without nuclear weapons successfully pressured the superpowers into including article IV and article VI in the final text of the NPT.

Since then the NPT has often been perceived as a bargain, under which non-nuclear-weapon states have agreed to accept the discriminatory nature of the treaty in trade for guarantees that they would have the inalienable right to develop peaceful applications of nuclear energy and that the nuclear-weapon states would undertake to negotiate towards complete nuclear disarmament.

However, beyond certain treaty agreements, the nuclear-weapon states have avoided committing themselves to any time-bound plans for nuclear disarmament. Those states still generally hold that nuclear weapons are an important component of their security. At the same time they advocate for more non-proliferation commitments from non-nuclear-weapon states. Some non-nuclear-weapon states believe that the perceived failure of the nuclear-weapon states to move more decisively towards nuclear disarmament constitutes non-compliance with NPT obligations. These states channelled their frustration with slow progress on disarmament

into efforts to impede new non-proliferation measures such as the universalization of the additional protocol to IAEA safeguards agreements.

SHORTFALLS OF THE ORIGINAL BARGAIN

Having nuclear quasi-non-proliferation—where a growing number of non-nuclear-weapon states acquire virtual capabilities—and nuclear quasi-disarmament—where nuclear-weapon states delay taking more decisive disarmament steps—creates frictions and disagreements within the international non-proliferation regime. How can nuclear-weapon states realistically expect the rest of the world to think or act differently as long as they position nuclear weapons prominently in their security strategies? How can non-nuclear-weapon states realistically expect nuclear weapons to be eliminated as long as they advocate for the spread of sensitive fuel-cycle technologies, and thus the spread of virtual weapons capabilities?

As Scott Sagan pointed out, the perception of the NPT as an exchange of non-proliferation for the peaceful use of nuclear energy and disarmament, which is rather common among governmental officials and independent experts, is "unfortunate because it limits the prospects for crafting a more comprehensive and more equitable implementation of the basic NPT bargains, based on shared responsibilities between [nuclear-weapon states] and [non-nuclear-weapon states], in the future".[91] The widespread perception that article IV applies to non-nuclear-weapon states while article VI applies to nuclear-weapon states is even more unfortunate. Both articles are equally applicable to all states parties.

The burden of revitalizing and fulfilling the NPT grand bargain is not reserved for any one group of states. As Sagan noted, it is a shared responsibility of all states parties. Even the states that are currently outside the NPT should be engaged in this process. It is fruitless to discuss comprehensive nuclear disarmament if the four nuclear-armed states would not join this process at some stage. Likewise, any attempts to manage sensitive nuclear technologies through multilateral arrangements that could be perceived as inequitable and discriminatory, and that would perpetuate a division between "haves" and "have-nots" in terms of the peaceful use of nuclear energy, are not likely to garner much support.

Shared responsibilities, however, do not mean equal responsibilities. As far as nuclear disarmament is concerned, states possessing nuclear weapons hold the main responsibility to lead this process. But non-nuclear-weapon states also have critical responsibilities and a constructive role to play in creating the conditions that would make a world without nuclear weapons stable and verifiable. Both nuclear-weapon and non-nuclear-weapon states should decide what best serves their interests: the current system of the national control of sensitive nuclear activities which would lead to the spread of virtual nuclear weapons capabilities, or an alternative system based on international cooperation that could prevent such spread while making the benefits of the peaceful application of nuclear technology available to all states.

The persistent obstacles to progress towards nuclear disarmament show that the disarmament process requires a sense of shared responsibility. The Comprehensive Nuclear-Test-Ban Treaty was opened to signature in 1996. But today, almost 15 years later, nine states are still blocking its entry into force: two nuclear-weapon states (China and the United States), three non-nuclear weapon states (Egypt, Indonesia and Iran) and the four nuclear-armed states (the Democratic People's Republic of Korea, India, Israel and Pakistan). A Fissile Material Cut-Off Treaty, another important disarmament agreement mentioned in the final documents of all NPT Review Conferences, would require a concerted effort from the 65 members of the Conference on Disarmament, including all nuclear-weapon and nuclear-armed states. Progress towards nuclear disarmament does not depend exclusively on the five nuclear-weapon states.

THE 2010 NPT REVIEW CONFERENCE

The latest NPT Review Conference concluded at the end of May 2010 with the adoption by consensus of a final document that includes both a review of commitments and a series of forward-looking concrete steps that states must take to strengthen the three pillars of the NPT. The agreed action plan broke new ground by specifying a set of measurable benchmarks to facilitate the assessment of progress towards the main goals of the NPT over the next five-year review cycle.[92] The 2005 Review Conference had ended in failure, and there were concerns that a similar outcome for the 2010 Conference would jeopardize the future of the non-proliferation regime. But the states parties came together and reaffirmed their commitment to

the NPT bargain and their common interest in ensuring that this regime does not unravel.

Those promising achievements notwithstanding, the Conference exposed considerable disagreements among the states parties. A gap is especially evident in perceptions of nuclear disarmament. Many non-nuclear-weapon states wanted to see a disarmament action plan with milestones and practical steps, and proposals for elements of such a plan—including convening an international meeting in four years to establish a time-line for ridding the world of nuclear weapons—were included into the report of Main Committee I.[93] But opposition from the nuclear-weapon states excluded many of those proposals from the text of the final document. States parties demonstrated diverse views on other issues discussed at the Conference, including tougher non-proliferation measures, the peaceful use of nuclear energy, multilateral approaches to the nuclear fuel cycle, regional issues and the withdrawal cause. After painstaking formal and informal negotiations, conference participants released a diluted text—the inevitable outcome of diplomatic compromise. The final document of the 2010 NPT Review Conference can be considered as an instance of incremental success, which has sustained the Treaty but hardly could ease its inherent tensions.

Nevertheless, the document is valuable. The non-proliferation section of the action plan for the first time "encourages all States parties which have not yet done so to conclude and to bring into force additional protocols as soon as possible".[94] For the first time, the disarmament section articulated "the objective of achieving a world without nuclear weapons"[95] as the goal of nuclear disarmament. The document also affirmed "that the final phase of the nuclear disarmament process and other related measures should be pursued within an agreed legal framework, which a majority of States parties believe should include specified timelines".[96] The peaceful uses of nuclear energy section of the action plan called for continued discussions "in a non-discriminatory and transparent manner under the auspices of IAEA or regional fora, [of] the development of multilateral approaches to the nuclear fuel cycle".[97]

The next review conference in 2015 will provide an opportunity to examine and assess the potential of that action plan in strengthening the non-proliferation regime and fulfilling the goals of the NPT. The inherited weaknesses and tensions of the original grand bargain, however, may

complicate this process. In fact, the final document of the 2010 Review Conference gave "perhaps the most emphatic affirmation of the right to nuclear energy for peaceful purposes"[98] and national fuel cycle policies. Nationally controlled fuel cycles combined with the dissemination of nuclear knowledge and technology would increase the likelihood that individual states could acquire virtual nuclear weapon capabilities, thus undermining the non-proliferation and disarmament goals of the NPT.

POSSIBLE PARAMETERS OF A REVAMPED NPT BARGAIN

Even though the original NPT bargain has proved its worth in limiting the spread of nuclear weapons over 40 years, a revamped bargain may be in order to enhance the NPT regime and other multilateral non-proliferation and disarmament mechanisms. As former IAEA Director General ElBaradei aptly pointed out a few years ago: "The [NPT] has served us well for 35 years. But unless we regard it as part of a living, dynamic regime capable of evolving to match changing realities, it will fade into irrelevance and leave us vulnerable and unprotected".[99]

A revamped grand bargain has to be able to remove, or at least reduce considerably, the inequalities within the non-proliferation regime, promote nuclear disarmament and provide politically workable mechanisms for managing sensitive nuclear technologies. While such mechanisms would not hamper the use of nuclear energy for electricity generation, medicine or agriculture, they would decrease incentives for and marginalize the acquisition of virtual nuclear weapons capabilities. The multilateralization of the nuclear fuel cycle would be the bedrock of this revamped non-proliferation regime. However, non-nuclear-weapon states would not adhere to additional non-proliferation commitments and restrictions on their peaceful nuclear activities so long as nuclear-weapon states do not make decisive progress towards complete nuclear disarmament.

A revamped grand bargain would rely on three distinct but inextricably linked commitments:

- **All states would reaffirm their non-proliferation commitments and place their nuclear material and facilities under IAEA safeguards.** As a first step, the states possessing nuclear weapons could place all their non-military nuclear facilities and materials under IAEA safeguards. As

nuclear disarmament would move forward, the application of nuclear safeguards within those countries could expand to the final goal of full-scope safeguards.

The additional protocol[100] to IAEA safeguards agreements[101] should become universal and mandatory. Today, some states refuse to sign additional protocols on the grounds that, unlike comprehensive, or full-scope, safeguards agreements, they are not stipulated in the text of the NPT. Article III of the NPT, however, states plainly that each non-nuclear-weapon state should "accept safeguards, as set forth in an agreement to be negotiated and concluded with the International Atomic Energy Agency in accordance with the Statute of the International Atomic Energy Agency and the Agency's safeguards system". The NPT does not specify the contents of a safeguard agreement or the scope of the IAEA safeguards system. After the NPT entered into force, it was agreed that the comprehensive safeguards agreement manifested this "safeguards system". But changing security threats require new standards for safeguards that should include the mandatory additional protocol.

The universal application of safeguards would remove one of the fundamental discriminatory clauses of the NPT whereby only non-nuclear-weapon states are legally obliged to accept IAEA safeguards "on all source or special fissionable material in all peaceful nuclear activities". To enable the Agency to carry out the difficult and increasingly daunting duty of safeguarding nuclear facilities and materials in the nuclear-weapon states would require reinforcing IAEA capabilities in terms of budget, personnel and technology.

- **All states would agree to pursue sensitive nuclear fuel-cycle activities exclusively under multilateral control.** Creating a multilateral fuel-cycle framework could reduce the proliferation risks associated with sensitive nuclear technologies and enhance nuclear security. Governments would commit to convert existing sensitive fuel-cycle plants into multilateral operations and establish all future plants exclusively on a multilateral basis.

  A multilateral fuel-cycle framework would provide every state that wishes to make use of this option with a vested interest and participation in fuel cycle services, and would address concerns that a

two-tier system of "haves" and "have-nots" of the benefits of nuclear technology may be perpetuated by supplier states to satisfy political or economic interests. Lastly, true multilateralization of the nuclear fuel cycle would facilitate the application of the IAEA safeguards and ameliorate concerns about virtual nuclear weapons capabilities.

- **All states would unequivocally undertake "to accomplish the total elimination of … nuclear arsenals leading to nuclear disarmament".** The possible steps towards nuclear disarmament, which have long been demanded by many non-nuclear-weapon states, are well known and incorporated in several UN documents as well as in the reports of various commissions and panels—for example, the 13 practical steps agreed at the 2000 NPT Review Conference,[102] the report of the Weapons of Mass Destruction Commission[103] and the report of the International Commission on Nuclear Nonproliferation and Disarmament.[104] States possessing nuclear weapons would take concrete and credible steps and make more proactive and substantive progress towards ultimately achieving global, verifiable nuclear disarmament. All states, nuclear and non-nuclear, would contribute to achieving nuclear disarmament by pursuing in good faith and eventually concluding complementary agreements on conventional arms control and missile defence.

  The revamped bargain would depart from current policies and practices. Suppliers of fuel cycle services are reluctant to cede control over their existing facilities and place them in a multilateral framework. The nuclear-weapon states are reluctant to accept a time-bound framework of concrete steps towards complete nuclear disarmament. The non-nuclear-weapon states fear that multilateral arrangements for the nuclear fuel cycle might deprive them of their right to develop a domestic fuel-cycle capacity.

  To achieve its goals, the revamped bargain should be universal. Engaging the non-NPT states would be a huge challenge, but would be crucial to the success of the bargain. The final document of the 2010 NPT Review Conference calls on those states to "accede to [the NPT] without further delay and without any conditions", which means that they should join as non-nuclear-weapon states. This does not seem to be feasible, but, in the meantime, some transitional mechanisms to facilitate their accession to the non-proliferation regime under some

special status may be discussed. Such transitional mechanisms could include a special protocol whereby non-signatories can pledge their commitment to the goals and commitments of the revamped grand bargain without formally joining the NPT.

The painstaking discussions during the 2010 NPT Review Conference demonstrated the difficulty for states to reach consensus not only on radical ideas but even on small incremental measures. However, the widespread dissatisfaction with the implementation of article IV and article VI of the NPT, as well as concerns over the status and prospects of the Treaty, could one day compel its signatories to seriously consider less conservative ideas such as multilateralization of the fuel cycle.

CHAPTER 6

CONCLUSIONS

The dual-use nature of nuclear technology makes it practically impossible to clearly separate peaceful and military applications of nuclear energy. There is a wide grey area of sensitive nuclear technologies: uranium enrichment, plutonium separation, manufacture of plutonium and mixed uranium/plutonium fuel. These technologies produce fissile material, a key ingredient on which both peaceful and military applications of nuclear energy depend.

The main threat to the non-proliferation regime comes from the possibility that more non-nuclear-weapon states, striving for energy self-sufficiency, commercial profits, national prestige or security, might develop complete fuel cycles. The further spread of sensitive nuclear technologies would put additional strain on the non-proliferation regime, exacerbating intrinsic tensions between the three pillars of the NPT—non-proliferation, the peaceful use of nuclear energy and disarmament.

First, this could lead to a new wave of proliferation involving "virtual nuclear weapons states", which have developed capabilities needed to produce plutonium or HEU and could possess the knowledge, non-nuclear materials and components needed to make nuclear weapons, but stop just short of assembling such weapons. Second, the nuclear-weapon states may be unlikely to take practical steps towards complete nuclear disarmament if there are many virtual nuclear weapon states.

The IAEA safeguards system is an extremely important mechanism helping to reassure the international community that nuclear energy is utilized by states exclusively for peaceful purposes. But the nature of processing makes bulk-handling facilities, such as uranium enrichment and spent fuel reprocessing facilities, very difficult to safeguard. Even the most effective verification system possible could not produce complete confidence that small amounts of weapon-usable material have not been diverted from these facilities.

If technical measures alone are insufficient to compensate for the contradictions of the existing nuclear non-proliferation regime, then institutional—non-technical in nature—measures, such as the multilateralization of the nuclear fuel cycle, could be marshalled to manage access to sensitive materials, facilities and technologies.

Although multilateralization cannot change the dual-use nature of nuclear technology, it can change the way in which nuclear technology is currently managed. With no nationally controlled enrichment or reprocessing facilities, no state will have direct access to weapon-usable fissile materials and no state will be able to quickly and secretly manufacture nuclear weapons. Even if it is unable to resolve the technical challenges of safeguarding bulk-handling facilities, the multilateralization of the nuclear fuel cycle can facilitate the application of IAEA safeguards by guaranteeing high standards of transparency and cooperation.

The 2010 NPT Review Conference demonstrated states parties' recommitment to the original NPT bargain and their common interest in ensuring that this regime is not weakened. The conference also showed that a new momentum for nuclear disarmament is building around the world. At the same time, the final document of the Conference showed that reaching a consensus among 189 states on the most sensitive issues of national security is enormously difficult. The result is small incremental steps, instead of any radical moves.

But the inherited tensions between the three pillars of the NPT might complicate the implementation of the agreed action plan and put additional strain on the regime.

To remove the existing tensions, a revamped grand bargain is needed. It should be universal and be able to strengthen the non-proliferation regime, to avoid inequalities between the states parties, to promote nuclear disarmament and to provide politically workable mechanisms of managing sensitive nuclear technologies.

A revamped, universal grand bargain will not be possible until all states are prepared to sacrifice options that they are not ready to give up today, namely the right to a full nationally controlled nuclear fuel cycle and the perpetual possession of nuclear weapons. Such a bargain would inevitably require NPT states parties and non-NPT states to agree to a fundamental

change in the current regime in the name of achieving the goals of non-proliferation, safe and secure utilization of nuclear power, and complete nuclear disarmament.

Notes

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2 Zhang X., "The Riddle of 'Inalienable Right' in Article IV of the Treaty on the Non-Proliferation of Nuclear Weapons: Intentional Ambiguity", *Chinese Journal of International Law*, vol. 5, no. 3, 2006.

3 For example, the discovery of Iraq's clandestine nuclear weapons programme following the 1990–1991 Iraqi occupation of Kuwait, the discovery in the early 1990s of non-compliance of the People's Democratic Republic of Korea with its non-proliferation obligations, Libya's acknowledgment in 2003 that it had a nuclear weapons-related programme for some 20 years, as well as unresolved questions the IAEA still has on Iran's nuclear activities.

4 The following statements can be found at <http://www.un.org/en/conf/npt/2010/statements/statements.shtml>.

5 Statement by Minister of External Relations of Brazil Celso Amorim to the 2010 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, 3 May 2010.

6 Statement by H.E. Tetsuro Fukuyama, State Secretary for Foreign Affairs of Japan, to the 2010 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, 4 May 2010.

7 Statement by US Secretary of State Hillary Rodham Clinton to the 2010 Review Conference of the Treaty on the Non-Proliferation of Nuclear Weapons, 3 May 2010.

8 Statement by H.E, Ahmed Aboul-Gheit, Minister for Foreign Affairs of the Arab Republic of Egypt, to the 2010 Review Conference of the Treaty on the Non-Proliferation of Nuclear Weapons, 5 May 2010.

9 Statement by Dr. Werner Hoyer, Minister of State at the Foreign Office of Germany, to the 2010 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, 4 May 2010.

10 R. Norris and H. Kristensen, "Nuclear Notebook: Worldwide Deployments of Nuclear Weapons", *Bulletin of the Atomic Scientists*, vol. 65, no. 6, 2009, p. 86.

11 See the 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 (Parts I and II), 2000, pp. 14–5.

12 Ibid, p. 14.

13 "Joint Statement by President Dmitriy Medvedev of the Russian Federation and President Barack Obama of the United States of America", 1 April 2009,

<www.whitehouse.gov/the_press_office/Joint-Statement-by-President-Dmitriy-Medvedev-of-the-Russian-Federation-and-President-Barack-Obama-of-the-United-States-of-America/>.

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16 See "Remarks by President Barack Obama", 5 April 2009, <www.whitehouse.gov/the_press_office/Remarks-By-President-Barack-Obama-In-Prague-As-Delivered>.

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[27] Final Document of the 2010 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, UN document NPT/CONF.2010/50 (Vol. I), 2010, para. 31.

[28] Official Records of the Disarmament Commission, supplement for January to December 1965, document DC/227, annex 1, § A.

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[32] 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 (Parts I and II), 2000, p. 14.

[33] Final Document of the 1995 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, UN document NPT/CONF.1995/32 (Part I), 1995, p. 9.

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[61] Ibid.

[62] IAEA, *The Structure and Content of Agreements between the Agency and States Required in Connection with the Treaty on the Non-proliferation of Nuclear Weapons*, document INFCIRC/153 (Corrected), June 1972, para. 29. (emphasis added)

[63] The MUF is calculated as: MUF = (PB + X – Y) – PE, where PB is the beginning physical inventory; X is the sum of increases in inventory; Y is the sum of decreases in inventory and PE is the ending physical inventory of nuclear material at the facility (see *IAEA Safeguards Glossary*, IAEA, 2002, p. 55).

[64] Expected accountancy capability is: $E = 3.29\ \delta_E\ A = 3.29\ \sigma_{MUF}$, where A is the amount of material in the material balance expressed as the larger of the inventory or throughput. The factor 3.29 corresponds to a detection probability of 0.95 (the probability, if diversion of a given amount of nuclear material has occurred, that IAEA safeguards activities will lead to detection), and false alarm probability of 0.05 (the probability that statistical analysis of accountancy verification data would indicate that an amount of nuclear material is missing when, in fact, no diversion has occurred). δ_E is the expected measurement uncertainty for the material balance (i.e., the expected accuracy of MUF (see *IAEA Safeguards Glossary*, IAEA, 1987, p. 27). The expected measurement uncertainty δ_E is 1% for aqueous plutonium reprocessing, 0.5% for plutonium fabrication, 0.2% for uranium enrichment, and 0.3% for uranium fabrication (see *IAEA Safeguards Glossary*, IAEA, 2001, p. 53).

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98 D. Choubey, "Understanding the 2010 NPT Review Conference", 3 June 2010, <www.carnegieendowment.org/publications/index.cfm?fa=view&id=40910>.

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100 Prompted by the discovery of nuclear weapon-related activities in Iraq and the Democratic People's Republic of Korea in the early 1990s, the IAEA Board of Governors approved the Model Additional Protocol (see INFCIRC/540) in May 1997, enhancing the IAEA's ability to detect undeclared nuclear activities. However, additional protocols, unlike comprehensive safeguards agreements, are voluntary.

[101] In 1972 the IAEA approved INFCIRC/153(Corr.), a model "comprehensive safeguards agreement" that enacted safeguards on all of a non-nuclear-weapon state's declared source or special fissionable material in all peaceful nuclear activities within its territory, as required by article III of the NPT.

[102] 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 (Parts I and II), 2000, pp. 14–5.

[103] *Weapons of Terror: Freeing the World of Nuclear, Biological and Chemical Arms*, Weapons of Mass Destruction Commission, 2006.

[104] *Eliminating Nuclear Threats. Report of the International Commission on Nuclear Non-Proliferation and Disarmament*, International Commission on Nuclear Non-Proliferation and Disarmament, 2009.

ABBREVIATIONS

ETC	Enrichment Technology Company Limited
HEU	high-enriched uranium
IAEA	International Atomic Energy Agency
IUEC	International Uranium Enrichment Centre
LEU	low-enriched uranium
MUF	material unaccounted for
NAM	Non-Aligned Movement
NPT	Treaty on the Non-Proliferation of Nuclear Weapons