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Multilateralization of the Nuclear Fuel Cycle
A Long Road Ahead

Yury Yudin

UNIDIR/2011/5

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UNIDIR
United Nations Institute for Disarmament Research
Geneva, Switzerland

UNITED NATIONS

New York and Geneva, 2011

About the cover

Reception of a transport cask for spent nuclear fuel at Svensk Kärnbränslehantering AB's Canister Laboratory in Oskarshamn, Sweden.

Photograph courtesy of Svensk Kärnbränslehantering AB.

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UNIDIR/2011/5

UNITED NATIONS PUBLICATIONS
Sales No. GV.E.11.0.4
ISBN 978-92-9045-201-0
eISBN 978-92-1-055069-7

The United Nations Institute for Disarmament Research (UNIDIR)—an autonomous institute within the United Nations—conducts research on disarmament and security. UNIDIR is based in Geneva, Switzerland, the centre for bilateral and multilateral disarmament and non-proliferation negotiations, and home of the Conference on Disarmament. The Institute explores current issues pertaining to the variety of existing and future armaments, as well as global diplomacy and local tensions and conflicts. Working with researchers, diplomats, government officials, NGOs and other institutions since 1980, UNIDIR acts as a bridge between the research community and governments. UNIDIR's activities are funded by contributions from governments and donor foundations. The Institute's web site can be found at:

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ACKNOWLEDGEMENTS

The author would like to give special thanks to Bruno Pellaud and Lawrence Scheinman who provided useful comments on early drafts of the manuscript.

Thanks also to the UNIDIR staff for their support and advice. Thanks to Theresa Hitchens and Kerstin Vignard for their practical, administrative and managerial advice. Thanks to Jason Powers, who provided excellent editorial assistance, and to Anita Blétry for production assistance. Thanks to Anna Stockklauser who communicated with Permanent Missions in Geneva concerning the questionnaire and who drafted a substantial portion of Part II of this publication. Thanks to Ting-Fung Chan and Fabian Froehlich who provided assistance at the final stage of drafting the manuscript.

UNIDIR would like to specially thank all respondents to the questionnaire.

Finally, the Institute wishes to thank the Governments of Austria, the Republic of Korea, the Russian Federation, Sweden, the United Arab Emirates and the United Kingdom, and the Taipei Cultural and Economic Delegation in Geneva, for having generously funded the project Multilateral Approaches to the Nuclear Fuel Cycle.

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FOREWORD

The use of nuclear energy for peaceful purposes will continue to be strongly supported by states as one of the three fundamental pillars of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), along with disarmament and non-proliferation. However, while widely being acknowledged as a cornerstone of the international non-proliferation regime, the NPT is not a perfect treaty and has its weaknesses and contradictions. One of these weaknesses arises from the inherent dual-use nature of nuclear energy. The spread of certain nuclear fuel-cycle technologies, above all uranium enrichment and spent fuel reprocessing, could undermine the founding bargain of the NPT. States seeking to benefit from nuclear energy must build on the NPT, strengthening the treaty instead of weakening it. Multilateralization of the nuclear fuel cycle is a measure to reduce the risks associated with the expansion of civil nuclear energy.

In September 2008, UNIDIR launched a study on multilateral approaches to the nuclear fuel cycle. One of the main objectives of the study was to develop a deeper understanding of the advantages and disadvantages of multilateral arrangements. Multilateral approaches to the nuclear fuel cycle by no means constitute a "magic bullet" to solve the world's non-proliferation problems. Nevertheless, the proliferation risks posed by internationally owned and staffed nuclear fuel-cycle facilities are significantly less than those posed by numerous national facilities. Moreover, multilateral approaches could help to create, if properly arranged, an equitable and economically beneficial environment for utilizing nuclear energy for peaceful purposes by providing participating states with a vested interest in the major elements of fuel-cycle services.

This book addresses some obstacles to further progress in multilateralization of the nuclear fuel cycle, as well as prospects for regional cooperation using Eastern and South-Eastern Asia as a case study. Our hope is that this study will help to illuminate the critical issues that have to be resolved to promote new multilateral approaches to the nuclear fuel cycle, for both the front-end and the back-end, to provide states with secure and non-discriminatory access to the benefits of peaceful nuclear energy while strengthening the nuclear non-proliferation regime.

This book is the final publication of the three-year project Multilateral Approaches to the Nuclear Fuel Cycle. I would like to extend my personal thanks to the Governments of Austria, the Republic of Korea, the Russian Federation, Sweden, the United Arab Emirates and the United Kingdom, and also to the Taipei Cultural and Economic Delegation in Geneva, for having funded the project and thus enabling this small contribution to the ongoing discussions on this important subject.

Theresa Hitchens
Director
UNIDIR

INTRODUCTION

More than 60 years into the nuclear age, the world continues to wrestle with the problem of the inherent dual use of nuclear energy. The possibility that the same nuclear facilities can be used to produce both fissile material to generate nuclear power and fissile material for nuclear weapons lies behind the concerns over the spread of sensitive nuclear technologies—uranium enrichment and spent fuel reprocessing.

Despite the revival of the debate on the dangers of nuclear power after the severe nuclear accident at the Japanese Fukushima Daiichi nuclear power plant in March 2011, the desire to ensure a reliable supply of electricity and to reduce threats to energy security could sustain interest in nuclear power in many countries, especially those with fast-growing economies and limited domestic sources of energy. This could lead to growing risks of nuclear proliferation created by the spread of sensitive nuclear technologies.

At the same time, the growth of interest in nuclear power can serve as an important opportunity to improve the related safety, security and non-proliferation regimes through increasing multilateral cooperation and controlling the flow of nuclear materials "from cradle to grave". Nuclear proliferation risks stemming from dissemination of uranium enrichment and spent fuel reprocessing technologies point to the need for the development of a multilateral framework for the nuclear fuel cycle. Such a framework could best be achieved through establishing various multilateral mechanisms in order to strengthen the non-proliferation regime and provide states with secure and equitable access to the benefits of peaceful nuclear energy—taking certain aspects of nuclear energy (those considered to be intrinsically dangerous) out of national hands and placing them in multinational or international hands.

As a confidence-building measure, multilateral arrangements could provide enhanced assurance to the partners and the international community that the most sensitive nuclear technologies would be made less vulnerable to misuse for military purposes. On the economic side, large multinational fuel-cycle facilities could provide cost-effectiveness and economies of scale compared to smaller national facilities. They also could eliminate for

states the trouble and expense of building national plants and developing domestic fuel-cycle technologies while at the same time providing states with a vested interest in the major elements of fuel-cycle services.

The first part of this book provides a historical overview of the issue of multilateralization of the nuclear fuel cycle and discusses its present situation and future prospects.

Interest in institutional arrangements for the nuclear fuel cycle dates back to the start of the nuclear age. The first effort to define a policy on the international control of atomic energy—the Acheson–Lilienthal Report—dates back to 1946. In the 1970s and 1980s several feasibility studies on multilateral approaches to the nuclear fuel cycle were undertaken. Although these studies generally drew favourable conclusions regarding the technical and economic viability of multilateral approaches, no further pursuit of those approaches followed, not least due to the general lack of political will and the disinclination of some states to renounce sovereign control over nuclear technology.

Today we see greater progress in the direction of the practical implementation of multilateral fuel-cycle arrangements than during the 1970s and 1980s. Four proposals for multilateral approaches to the nuclear fuel cycle are in various stages of implementation: the Russian International Uranium Enrichment Center (IUEC), the Russian guaranteed low-enriched uranium (LEU) reserve, the IAEA LEU bank and the United Kingdom's nuclear fuel assurance proposal.

The IUEC was established in 2007 and today three states—the Russian Federation, Kazakhstan and Ukraine—are IUEC stockholders. Armenia should become a full IUEC member after buying stakes in the Centre in 2011. The IUEC provides its partners with guaranteed access to enriched uranium product or a share in profits. On 17 December 2010, the Russian Federation also inaugurated the world's first multilateral reserve of LEU for supply to state members of the IAEA experiencing a disruption in supply of LEU for nuclear power plants not related to technical or commercial considerations.

On 3 December 2010, the IAEA Board of Governors adopted a resolution authorizing the Director General to establish an LEU bank that will be owned and managed by the Agency, to serve as a mechanism of last resort

to back up the commercial market in the event that an IAEA member state experiences a disruption in normal supply of LEU that is not related to technical or commercial considerations. The IAEA LEU bank is currently in the process of being established.

The United Kingdom's nuclear fuel assurance proposal is designed to enhance confidence in commercial fuel supplies. Basically, the proposal envisions agreements between a supplier state and a non-supplier state, overseen by the IAEA, that commercial LEU supply contracts will not be disrupted for any non-commercial reason other than those directly related to nuclear non-proliferation concerns. On 10 March 2011 the IAEA Board of Governors voted in favour of the proposal.

Despite these successes, the future of multilateralization of the nuclear fuel cycle is unclear. While the idea of multilateralization of the nuclear fuel cycle has received support from many governments, particularly of supplier states, it should be noted that the policies of leading supplier states towards multilateralization of the nuclear fuel cycle are uncoordinated and subject to change. At this point, a coordinated strategy for multilateralization does not exist.

The proposals for multilateral approaches have run into a strong opposition from many non-supplier states, owing to the fear that the proposed mechanisms could result in a "cartel" of suppliers, create a new export control regime and infringe on the perceived inalienable right to use nuclear energy for peaceful purposes. Often bitter disputes on multilateralization between suppliers and non-suppliers reflect disagreements between more developed and less developed states on a broader set of political and economic issues.

On the other hand, no technology holder has expressed any inclination to seriously discuss the conversion of their national fuel-cycle facilities into multilateral operations and ideas for such conversion have never been seriously discussed at the national or international level. Opponents of conversion of national fuel-cycle facilities argue that this would involve too many complex political, legal and financial issues. However, nuclear suppliers should understand that existing nationally controlled enrichment and reprocessing facilities do create a discrimination problem. Their existence makes it more difficult to convince other states not to pursue nationally controlled facilities of their own. Any far-reaching multilateral

fuel-cycle mechanism must inevitably be universal in its demands on participants in order to gain the support of an overwhelming majority of states.

To overcome this unwillingness and engender political will towards multilateralization, it will be necessary to build a broad coalition of states, which would include both supplier and non-supplier states, supporting a politically attractive and economically sound strategy towards multilateralization of the nuclear fuel cycle.

Assurances of supply of front-end services, such as LEU banks or supplier guarantees, cannot satisfy the assurance of non-proliferation—that is, reduce the proliferation risks arising from additional states acquiring sensitive nuclear technologies and from existing civilian fuel-cycle facilities—and have only limited potential to satisfy the assurance of supply and services—that is, encourage the development of nuclear energy by assuring states that they will have reliable and uninterrupted access to nuclear goods and services. Multilateral fuel-cycle facilities could be more promising in the ability to simultaneously satisfy assurance of supply and assurance of non-proliferation by providing non-supplier states with guaranteed supplies of material and services and vested interest in the major elements of the nuclear fuel cycle. Such facilities would provide the opportunity for customer states to appraise at first hand the potential benefits of participation in multilateral fuel-cycle facilities.

Despite the fact that most states are satisfied with the current situation and acknowledge that the international market for front-end fuel-cycle services works well, the majority of proposals on multilateral approaches to the nuclear fuel cycle cover only front-end issues. The problems associated with the world's growing inventory of spent fuel remain mostly disregarded, even as the management of spent fuel is one of the greatest challenges of nuclear power. Multilateral solutions to back-end fuel-cycle problems could provide substantial benefits to both supplier and non-supplier states. Nuclear fuel leasing arrangements—so-called "cradle to grave" fuel-cycle services—where suppliers fabricate and deliver fresh nuclear fuel to non-supplier states with nuclear reactors and then take back the used fuel after it has been irradiated, could potentially be very attractive for many states.

An international interim storage facility could be a first practical step towards a multilateral back end for the nuclear fuel cycle. Such a facility could

provide additional opportunities for states having problems with storage and disposal of spent nuclear fuel, as well as time for further scientific and technological advances in managing spent fuel and radioactive wastes. It could also prevent some states currently facing difficulties in expanding storage capacity from rushing down the more proliferation-sensitive and economically questionable path of reprocessing spent nuclear fuel.

Politically and economically attractive voluntary front-end and back-end multilateral arrangements could pave the way for a legally binding agreement to put all sensitive fuel-cycle facilities exclusively under multilateral control.

The second part of this book discusses prospects for regional approaches to the nuclear fuel cycle in Eastern and South-Eastern Asia. Nuclear power is expected to increase greatly in the region. There are numerous potential partners for cooperation, including those with established nuclear power programmes (China, Japan, the Republic of Korea) and newcomers (Indonesia, Malaysia, Viet Nam), those with complete domestic fuel cycles (China, Japan), those with partial domestic fuel cycles and those without any facilities whatsoever.

To better understand the attitudes in the region towards multilateral approaches to the nuclear fuel cycle and to gauge levels of support, a questionnaire was sent to 14 states in Eastern and South-Eastern Asia as well as to Chinese Taipei via the Taipei Cultural and Economic Delegation in Geneva.

The responses received show that all respondents acknowledge that multilateral approaches could reduce the threat of nuclear proliferation by reducing the incentives for states to develop domestic sensitive fuel-cycle technology, and by increasing transparency and mutual trust about the peaceful nature of fuel cycle-related activities. They also support the view that multilateralization of the nuclear fuel cycle would facilitate the peaceful use of nuclear energy and contribute to economic development.

A majority of respondents hold that the implementation of regional multilateral fuel-cycle approaches in Eastern and South-Eastern Asia is feasible. However, respondents identified a number of obstacles that may hamper implementation: (1) the lack of experience in regional cooperation; (2) historical animosities and the lack of trust among states in

the region; (3) the gap in economic development and the use of nuclear energy among states in the region; and (4) the unresolved nuclear issue of the Democratic People's Republic of Korea.

Nuclear fuel leasing and take-back offers by multilaterally organized suppliers received the highest ratings from respondents in terms of non-proliferation effectiveness, economic benefits and feasibility. Respondents also considered global and regional multilateral interim storage and long-term disposal facilities for spent fuel and radioactive waste as attractive projects for actors in the region.

In general, respondents gave considerably higher ratings to back-end proposals than to front-end proposals. At the same time, no noteworthy differences in the perception of regional versus global multilateral approaches were observed.

PART I

MULTILATERALIZATION OF THE FUEL CYCLE: HISTORY AND PROSPECTS

THE NUCLEAR RENAISSANCE AND THE INTERNATIONAL NON-PROLIFERATION REGIME

More than 60 years into the nuclear age, the world continues to wrestle with the problem of the fine line between civilian and military applications of nuclear energy. The main challenge has been "to prevent the use of atomic energy for destructive purposes and to promote the use of it for the benefit of society".[1] At the heart of the problem is the fact that military and civilian nuclear production cycles are interchangeable and interdependent, since in much of their course they use identical, or nearly identical, materials, technology and equipment. Historically, nearly all principal technologies of the uranium fuel cycle were developed in dedicated nuclear weapon programmes of the United States, the Soviet Union, the United Kingdom, France and China before civilian nuclear energy existed. Only after those technologies—and the fissile materials they produced—had been used to make the atomic bomb did politicians, scientists and engineers start to seriously ponder their peaceful applications.

Today there are still no technological barriers between the production of fissile material for fuelling power nuclear reactors and the production of fissile material for fuelling nuclear explosives. 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.

NUCLEAR RENAISSANCE

Over the last two decades the nuclear industry has been relatively dormant, or even in decline. In 1993 18 per cent of electricity generated worldwide (2.17 trillion kWh) was derived from nuclear power.[2] By 2007 this share had dropped to less than 14 per cent. While in absolute terms the production of electricity by nuclear power plants increased to 2.6 trillion kWh,[3] this growth of about 20 per cent is rather modest when compared to the 55 per cent rise in global electricity production for the same period. During 2008 and 2009, nuclear-generated electricity remained steady at about 2.6 trillion kWh annually.[4]

However, since about 2001 there has been much talk that nuclear energy is poised for a global expansion, or "renaissance". Projections of future growth have been many times revised upwards, even despite the worldwide financial crisis beginning in 2008. What factors are driving this change?

Driving factors

The first factor is energy security. Reliable access to reasonably priced energy is essential for the functioning of modern economies and societies. Limited supply, uneven distribution and the rising prices for end-users of fossil fuels, resulting from upward price pressures on international markets, have created a need to pursue alternative cost-competitive energy sources including nuclear power. This is exacerbated by the anticipated increase in global energy demand. The International Energy Agency of the Organization for Economic Cooperation and Development (OECD) in its *World Energy Outlook* for 2010 projected "world electricity demand rising at an annual rate of 2.7% between 2008 and 2020, and 1.8% per year over the period 2020 to 2035",[5] or 80 per cent growth between 2008 and 2035. The Energy Information Administration of the Department of Energy of the United States in its *International Energy Outlook* for 2010 estimated that world net electricity generation would increase by 87 per cent between 2007 and 2035, "from 18.8 trillion kilowatt hours in 2007 to 25.0 trillion kilowatt hours in 2020 and 35.2 trillion kilowatthours in 2035".[6] This increase in global electricity demand will mostly be driven by emerging economies. The *World Energy Outlook* predicted that "more than 80% of incremental electricity demand between 2008 and 2035 comes from non-OECD countries, led by China, where, in 2035, demand is projected to equal that of the United States and European Union combined".[7]

The second factor is the increased awareness of the dangers of anthropogenic climate change from the emission of carbon dioxide and other greenhouse gases, which is believed to be responsible for the rise in average temperatures that have been observed around the globe. Over the last decade, the nuclear industry has been successful at presenting the environmental case for nuclear power as a clean, "emission-free" energy source. Today many experts and governmental officials consider nuclear power as one of the major contributors to the global effort to reduce emissions of greenhouse gases.

In February 2010, President Barack Obama of the United States asserted that "nuclear energy remains our largest source of fuel that produces no carbon emissions. To meet our growing energy needs and prevent the worst consequences of climate change, we'll need to increase our supply of nuclear power. It's that simple".[8] Meeting with a group of international experts in September 2010, Prime Minister Vladimir Putin of the Russian Federation said the only "real and powerful alternative" to oil and gas is nuclear energy.[9] In a speech to the United Nations General Assembly, President Hu Jintao of China declared, "In the years ahead, China will further integrate our actions on climate change into our economic and social development tasks … [W]e will vigorously develop renewable energy and nuclear energy".[10] John Ritch, Director General of the World Nuclear Association, is quoted as saying that "atomic energy was the only source that could meet the world's rising energy needs without threatening the environment".[11] Even Patrick Moore, one of the co-founders and first members of Greenpeace, has renounced his anti-nuclear views and now argues that nuclear power "may just be the energy source that can save our planet from another possible disaster: catastrophic climate change".[12]

It is true that the fission of uranium in a nuclear power reactor produces no greenhouse gases. However, emissions of greenhouse gases result from every other industrial step associated with the generation of nuclear energy—uranium ore mining and milling; uranium conversion and enrichment; the manufacture of fresh fuel; the construction, operation and decommissioning of nuclear facilities; spent fuel reprocessing; and the transportation, clean-up, intermediate storage and long-term disposal of nuclear waste. While it is broadly agreed that emissions of greenhouse gases from nuclear power are lower than those from burning fossil fuels, quantitative assessments of emissions often contradict each other. A 2009 paper examined the varying results from three different life-cycle assessments, which report indirect CO_2 emissions ranging from around 8g to 337g CO_2/kWh(e).[13] The comparison of those assessments shows that results largely depend upon the inputs, the assumptions and simplifications in different steps of the assessments. While 8g CO_2/kWh(e) means virtually zero carbon emissions even when compared to indirect emissions of solar and wind energy, 337g CO_2/kWh(e) is comparable to the emissions of a combined-cycle gas turbine plant, which can be as low as 350g CO_2/kWh(e), although this is still noticeably lower than the emissions of subcritical pulverized-coal-combustion power plants, which can amount to 830g CO_2/kWh(e).[14]

The third factor is prestige. Civilian nuclear energy has often been identified as a symbol of modernity and economic progress, despite the fact that almost all nuclear power technologies used today were developed in the 1950s and 1960s. Building nuclear reactors and fuel-cycle facilities could be perceived by some states as a way to "catch up" with more developed states and to increase their rank, role and prestige at the international level. Such considerations, rooted more in psychology than in hard economic and technological analysis, might influence the decisions of some states to seek to develop nuclear energy capacity.

Obstacles

Even though the aforementioned factors encourage the expansion of nuclear power, the future is more complicated. The first stumbling block to expansion is the cost. Nuclear reactors are capital-intensive projects that can easily cost billions of dollars—the projected overall cost of the two reactors currently under pre-construction at the Vogtle Nuclear Power Plant in the United States, which have a combined generating capacity of about 2.2 GW(e), is expected to be up to US$ 14 billion[15]—and the construction of which may take ten years or more. For such projects, the time horizon for return on investment is distant. Choosing to build a nuclear power plant is thus a risky decision depending on complex and unpredictable factors, such as the future cost of fossil fuels, the carbon taxes, if any, placed on fossil fuel power plants through governmental policy, and the future cost of renewable energy technologies.

Secondly, despite the fact that safety measures are today significantly better than in the days of the Chernobyl accident, the general public still has fears about nuclear energy. The past 10 years showed a gradual reversal of these attitudes as nuclear power plants have been performing at higher safety levels than twenty years ago. However, the nuclear incident at the Fukushima Daiichi power plant in March 2011, where many safety measures failed following an earthquake and tsunami, reawakened this deep-seated distrust of nuclear power.

The third major obstacle to the expansion of civilian nuclear energy is the host of unresolved challenges in the long-term management of nuclear waste. The management and disposal of radioactive waste is one of the most difficult problems currently facing the nuclear power industry. In most countries, scientists and engineers claim that geologic repositories

constructed in rock formations hundreds of meters below ground are a safe and economically viable method of long-term disposal of waste. However, no such repository has yet been completed, as they are difficult and costly to establish and local communities are generally not enthusiastic about having such repositories nearby. As of the beginning of 2011, Finland is the only country that has a geologic repository for long-term disposal of spent nuclear fuel under construction, while Sweden will start construction of a repository in 2015.[16]

Satisfactory arrangements for the back end of the nuclear fuel cycle (in terms of economics, environment, non-proliferation, and so forth) are still needed to make nuclear energy sustainable in the long run. Other barriers to a nuclear renaissance include sufficient security of nuclear facilities, industrial limitations, personnel shortages in the nuclear sector and public opposition. The scope and pace of nuclear expansion or decline in different countries would depend on government policy towards civilian nuclear energy, which in turn would be affected by all these factors, both favourable and disadvantageous. Although not so many states with established nuclear power industries are vigorously working towards expanding their nuclear capacity, several states that do not have nuclear power capabilities show a growing interest in civilian nuclear energy.

The current situation

As of June 2011, 440 nuclear power reactors were in operation globally with a total net installed electrical generating capacity of 374 GW(e). Sixty-five plants are under construction, to have a net capacity of 63 GW(e).[17] Of these 65 reactors, 43 are in Asia, 11 are in the Russia Federation, 8 are in Europe (including 6 in Eastern Europe), 2 are in South America and 1 is in North America. Some 60 states have turned to the IAEA for guidance as they consider whether to introduce nuclear power to their energy mix, and about a dozen are actively developing the appropriate technical, regulatory and safety infrastructure for civilian nuclear power programmes. IAEA Director General Yukiya Amano stated in February 2011 that "We expect between 10 to 25 new countries to bring their first nuclear power plant online by 2030".[18]

The region with the largest number of states with active nuclear industries and the largest number of reactors under construction is Asia, with China and India playing the leading roles. The Russia Federation and some states

of Eastern Europe have recently shown strong interest in the expansion of nuclear energy, although in February 2011 the Russian government decided to reduce investment in the state atomic energy corporation Rosatom.[19] Some African, Middle Eastern and Latin American states have also shown interest in civilian nuclear energy. In Northern America and Western Europe the nuclear renaissance is largely stalled. For the most part, countries with expanding economies and with stronger governmental participation in the nuclear industry and in the economy in general seem to be more likely to experience a nuclear renaissance than developed countries, in which there is less state control and more pressure on decision makers from the electorate.

The impact of Fukushima Daiichi

In discussions on the obstacles to the expansion of nuclear power, many experts have agreed that a major accident at a nuclear power plant would not only have a serious impact on human and environmental health, but also weigh heavily on the entire nuclear industry, perhaps effectively putting an end to any nuclear renaissance. On 11 March 2011 such an event occurred. A powerful earthquake followed by a 14-metre tsunami crippled three reactors at the Fukushima Daiichi nuclear power plant in Japan. The accident ranked at the highest level (level 7) of the International Nuclear and Radiological Event Scale. This rank is described as a "major release of radioactive material with widespread health and environmental effects requiring implementation of planned and extended countermeasures".[20] The released radioactivity, the exact amount of which is debated, has led to the contamination of soil and seawater with radioactive isotopes.[21] For the protection of civilians, an exclusion zone with a radius of 30km was set up around the plant.[22]

What could happen with the expected expansion of nuclear energy after the Fukushima accident? A prevailing view in the months since the accident is that nuclear industry will see a slow-down in growth, if not an outright decline. In some countries, the effect on popular and political support for nuclear power has been significant. Germany[23] and Switzerland[24] have announced plans to phase out nuclear power. Italian voters rejected plans to revive nuclear energy in the country.[25] The Japanese government, which had envisioned a new fleet of nuclear reactors prior to the March disaster, abandoned plans to expand nuclear power.[26]

However, many states—among them China, France, India, Poland, the Russian Federation, Saudi Arabia, Slovakia, Slovenia, South Africa, Turkey, the United Kingdom and Viet Nam—are still committed to nuclear power. A report on the future of nuclear power by the Economist Intelligence Unit concluded that by 2020 the world will be producing 27 per cent more nuclear-generated electricity than it did in 2010.[27] Despite the revival of the debate on the dangers of nuclear power, the desire to ensure a reliable supply of electricity and to reduce threats to energy security could sustain interest in nuclear power in many countries, especially those with fast-growing economies and limited domestic sources of energy.

While the nuclear industry is not dead in the water, some lessons ought to be gleaned from the Fukushima accident, particularly for multilateral approaches to the nuclear fuel cycle. Since the Three Mile Island accident of 1979 and the Chernobyl accident of 1986, a lot of work has been done by the IAEA and the nuclear industry to identify the weaknesses of nuclear reactors as well as to improve design safety and operating procedures. As a result, the safety record of nuclear power plants has improved worldwide and the nuclear industry has made a strong case for the improved reliability of nuclear power reactors. But the Fukushima accident shows that gaps still exist in systems for ensuring nuclear safety. A declaration by IAEA member states, adopted by the Ministerial Conference on Nuclear Safety in June 2010, had called for a number of improvements to global nuclear safety and pointed to the need to improve national, regional and international emergency preparedness and response to nuclear accidents.[28] But, it has taken a major nuclear accident to prompt serious reconsideration of approaches to nuclear safety.

It has been argued that a "transforming event" might be needed to push the idea of internationalization of sensitive nuclear technologies further.[29] If the Fukushima accident has anything to teach policymakers and the nuclear industry, it is that innovative and vigorous approaches must be undertaken to ensure nuclear safety and security.

In the aftermath of this accident, decisions on new nuclear projects will likely be delayed by several months or years, depending on the country. This will provide additional time for the international community to develop and attempt different political approaches to dealing with sensitive nuclear technologies and non-proliferation. It would be unwise to waste this time.

NUCLEAR POWER AND THE NON-PROLIFERATION REGIME

Since the earliest days of civilian nuclear power, discussions on how to minimize the proliferation risks of nuclear fuel-cycle operations have been centred on the connection between peaceful and military applications of nuclear energy. The principal danger arises from the so-called sensitive nuclear technologies—enrichment of uranium, reprocessing of spent fuel and handling of plutonium—because these technologies can produce fissile materials (high-enriched uranium and separated plutonium) that are directly usable in nuclear weapons.

Existing international mechanisms

In response to the risks of nuclear proliferation, the international community has established an elaborate set of agreements and institutions, none of which have proven to be entirely satisfactory. The cornerstone of the existing non-proliferation regime is the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). It is intended to halt the spread of nuclear weapons and eventually to eliminate them, while allowing and, in some assessments, promoting the peaceful application of nuclear energy. A complex compromise between five states that possess nuclear weapons and 184 states that do not, the NPT rests on three fundamental pillars—non-proliferation, disarmament and the peaceful use of nuclear energy. Its main stipulations are as follows:

Article I. The five nuclear-weapon states are not to transfer nuclear weapons to any recipient whatsoever, and not in any way to assist, encourage, or induce any non-nuclear-weapon state to manufacture or otherwise acquire nuclear weapons.

Article II. Non-nuclear-weapon states undertake not to manufacture or otherwise acquire nuclear weapons, and not to seek or receive any assistance in the manufacture of nuclear weapons.

Article IV. All states parties have the inalienable right “to develop research, production and use of nuclear energy for peaceful purposes”.

Article VI. All states parties undertake to pursue negotiations in good faith towards nuclear disarmament.

But the balance among these pillars is jeopardized by the inherent dual-use nature of nuclear technology and the way in which nuclear technology is typically managed, namely the highly national control of nuclear activities. The ongoing dissemination of nuclear knowledge and technology is leading to the further spread of sensitive nuclear technologies. Even if states' nuclear intentions are totally peaceful, the development of sensitive nuclear technologies nevertheless would give them access to weapons-grade material.

Such "virtual" nuclear weapons capabilities put additional strain on the non-proliferation pillar of the NPT because, if the political decision is made, virtual capabilities can be converted into actual capabilities in a relatively short period of time. These capabilities also pose challenges to nuclear disarmament because, firstly, nuclear-weapon states may be unwilling to take further steps towards the prohibition of nuclear weapons if more states acquire the capability to produce plutonium or highly enriched uranium and, secondly, a nuclear-weapon-free world with *nationally controlled* fuel cycles would be unverifiable and unstable.

The main challenge that the international community faces is to find a way to manage the global nuclear fuel cycle in order to reduce proliferation risks to acceptable levels, provide all states with non-discriminatory access to peaceful applications of nuclear technology and remove certain roadblocks to nuclear disarmament.

Today the supervision of nuclear fuel cycles is carried out through IAEA safeguards, and export control mechanisms. The performance record of these mechanisms is mixed.

IAEA safeguards

The purpose of the IAEA safeguards system is to provide credible assurance to the international community that nuclear material and other specified items are not diverted from peaceful nuclear uses. According to article 3 of the NPT, IAEA safeguards "shall be applied on all source or special fissionable material in all peaceful nuclear activities" of non-nuclear-weapon states parties.

Without a system of safeguards, a non-proliferation treaty would depend on states parties' word and good faith that they will not use any nuclear

capabilities they develop for destructive purposes. Fears of possible violations and suspicions of the imagined intentions of other parties of the treaty would most likely lead to the breakdown of such a regime. Therefore, the IAEA safeguards system is a key element of the present regime, providing confidence that all states parties respect their non-proliferation commitments. The system certainly deserves part of credit for the often-praised success of the NPT in limiting, although not entirely preventing, the further spread of nuclear weapons.

However, on several occasions in the past IAEA safeguards were not able to deter some non-nuclear-weapon states with comprehensive safeguards agreements in force from conducting undeclared nuclear activities, which went undetected. Iraq's clandestine nuclear weapons programme was discovered following the Gulf War of 1991, undeclared nuclear activities in Iran—later officially acknowledged—were revealed in 2002 by a dissident group, and Libya acknowledged in 2003—following the seizure of a shipment of uranium-enrichment components bound for the country—that it had conducted a nuclear weapons-related programme for some 20 years.

Since the early 1990s, a number of measures have been implemented to give the IAEA the authority and technical tools it needs to ensure the non-diversion of declared nuclear material, and the absence of undeclared nuclear material and activities in non-nuclear-weapon states with comprehensive safeguards agreements in force. Some of these measures were implemented under the authority of comprehensive safeguards agreements, whereas others required additional legal authority provided by a new legal instrument, the Additional Protocol.

The measures taken have undoubtedly strengthened the effectiveness and improved the efficiency of IAEA safeguards, but some challenges and shortcomings still exist. How effectively the Agency can fulfil its declared mission—to verify through its inspection system that states comply with their non-proliferation commitments to use nuclear material and facilities only for peaceful purposes—depends on the extent to which the Agency has the necessary legal authority, verification equipment and techniques, and adequate financial and human resources. Moreover, a state's cooperation and transparency are very important because a state could deny information or obstruct access to IAEA inspectors.

As mentioned, the legal authority of the Agency was expanded with the Additional Protocol. Although voluntary, it is nevertheless an important legal instrument providing further authority for the IAEA to search for undeclared nuclear materials and activities. As of 20 December 2010, only 98 of 184 non-nuclear-weapon states have brought additional protocols into force.[30] Some states with significant nuclear activities (for example Argentina, Brazil, Egypt, Iran, Syria and Venezuela) have refused either to sign or enforce an additional protocol for various national reasons. Moreover, the IAEA's legal authority to investigate possible weaponization activities that are not directly linked to nuclear material is limited because both safeguards agreements and additional protocols are focused on nuclear material.

While the IAEA constantly works to enhance its technical tools, even the best verification equipment and techniques have their limits, especially when applied to bulk-handling facilities such as plants for conversion, enrichment, fuel fabrication or spent-fuel reprocessing. For such facilities, it is very difficult to ensure that a small percentage of nuclear material—a few kilograms among tons—have not been diverted. A large processing facility has an inventory of bulk material that changes continuously. The ingoing and outgoing quantities of nuclear material, such as plutonium in reprocessing and uranium in enrichment plants, can only be measured with a degree of uncertainty. During bulk-handling operations, an amount of material inevitably becomes stuck inside processing equipment, piping and filters. As a result, a non-zero material inventory difference (the difference between real inventory and the stock of nuclear material in the account books) is to be expected for bulk-handling facilities—even in the absence of diversion.

Thus safeguarding bulk-handling facilities, especially reprocessing plants, is a daunting endeavour both technically and financially. Today there are only two major reprocessing plants safeguarded by the IAEA in the non-nuclear-weapon states, the Tokai and Rokkasho facilities in Japan. These two plants alone account for 20 per cent of the total safeguards inspection efforts of the IAEA.[31]

The IAEA regular budget for nuclear verification in 2008 was slightly less than €114 million, which is rather slim when taking into account the many demands on this budget—in that year 1,131 nuclear facilities and 159,000 significant quantities[32] of nuclear material were under safeguards, and

2,040 inspections were conducted.[33] The IAEA regular budget for nuclear verification in 2009 was slightly more than €117 million,[34] a very modest increase of only 2.6 per cent. The expansion of the nuclear power industry would substantially increase the workload of the IAEA, presenting new challenges for the already strained financial and human resources of the Agency.

Export control mechanisms

Nuclear export control mechanisms work by establishing, on a state level, standards and procedures regulating exports of certain sensitive materials and technologies. The basis of nuclear export controls is article III.2 of the NPT, which prohibits states parties from providing "(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 is subject to IAEA safeguards.

Soon after the NPT came into force in 1970, two export control regimes—the Zangger Committee and the Nuclear Suppliers Group—were established to restrict the export of dual-use materials through guidelines on the sensitive materials and technologies that could be transferred. At the NPT Review Conferences many states parties have expressed their support for effective and transparent export controls. But some NPT states parties belonging to the Non-Aligned Movement have criticized the discriminatory nature of export controls and claimed that they harm their economic development.

The emergence of nuclear black markets, such as the operation set up by Pakistan's A.Q. Khan, has called into question the effectiveness and adequacy of export control regimes. In 2004, then IAEA Director General Mohamed ElBaradei stressed:

> The relative ease with which A.Q. Khan and associates were able to set up and operate a multinational illicit network demonstrates clearly the inadequacy of the present export control system. Nuclear components designed in one country could be manufactured in another, shipped through a third (which may have appeared to be a legitimate user), assembled in a fourth, and designated for eventual turnkey use in a fifth.

> The fact that so many companies and individuals could be involved is extremely worrying. And the fact that, in most cases, this could occur apparently without the knowledge of their own governments, clearly points to the inadequacy of national systems of oversight for sensitive equipment and technology.
>
> The present system of nuclear export controls is clearly deficient. The system relies on informal arrangements that are not only non-binding, but also limited in membership, and many countries with growing industrial capacity are not included. Moreover, at present there is no linkage between the export control system and the verification system.[35]

Need for new institutional mechanisms

While the monitoring of the global fuel cycle is difficult now, the future will bring even more daunting challenges. The nuclear renaissance might further expose the vulnerabilities of the IAEA safeguards system, and export control regimes. Besides constructing nuclear reactors for the production of electricity, states that today are planning to enter the nuclear power business could as well consider developing their own fuel-cycle facilities and nuclear know-how, resulting in the further spread of sensitive nuclear technologies.

The absence of technological barriers between the production of fissile materials for peace and production for war makes it impossible to use only technical measures to compensate for the limitations of the existing nuclear non-proliferation regime. What is needed are additional international institutional mechanisms involving various political, economic or diplomatic strategies for controlling access to sensitive materials, facilities or technologies. Since 2003 there have been renewed calls for the utilization of multilateral approaches to the nuclear fuel cycle in order to strengthen the non-proliferation regime and provide states with secure and equitable access to the benefits of peaceful nuclear energy. Multilateralization of the nuclear fuel cycle, in a broad sense, means taking certain aspects of nuclear energy (those considered to be intrinsically dangerous) out of national hands and placing them in multinational or international hands.

As their advocates argue, multilateral fuel cycles could provide a better way to reduce proliferation risks as compared to purely national fuel cycles. As a confidence-building measure, multilateral arrangements could provide

enhanced assurance to the partners and the international community that the most sensitive nuclear technologies are less vulnerable to misuse for military purposes. Joint facilities would be operated in a framework where ownership, control and operation are shared among a number of states or international organizations. Having a multinational staff puts all partners under a greater degree of peer scrutiny, making it more difficult and risky to try to divert nuclear material. This may also constitute an obstacle against breakout by the host partner. If the host state were seeking to seize the facility, there would be other partners it would have to expel. The ensuing confrontation between this state and the other partners and the international community would constitute a considerable political barrier to such an action.

Even if multilateralization of the nuclear fuel cycle cannot change the dual-use nature of nuclear technology, it could change the way in which nuclear technology is managed. Without nationally controlled enrichment or reprocessing facilities, no state would have direct access to weapon-usable fissile materials, or be able to quickly and secretly manufacture nuclear weapons.

On the economic side, large multinational fuel-cycle facilities could provide cost-effectiveness and economies of scale compared to smaller national facilities. They also could eliminate for states the trouble and expense of building national plants and developing their own fuel-cycle technologies. Even if, for perceived economic reasons, a state embarks on the development of domestic fuel-cycle technologies, especially uranium enrichment, it would inevitably be several decades behind the state of the art. Because this gap could not be closed quickly, the state would most likely be unable to compete on the international market with established suppliers of uranium enrichment services.

However, multilateral approaches—by providing states with a vested interest in the major elements of fuel-cycle services—could help to create an equitable environment for any state to participate in joint ownership, management, operation, decision-making, as well as profit-sharing and participation in other activities not necessarily involving direct access to sensitive nuclear technologies. Being an equity partner in an advanced technology enterprise with seasoned professional technical staff could be a meaningful attraction in its own right to many states that are interested in

nuclear energy. In addition, participation could boost economies, reduce reliance on increasingly costly fossil fuels and reduce pollution.

Despite the arguments in support of multilateral approaches, the case to be made in favour of them is not entirely straightforward. The history of such approaches, as shall be seen, demonstrates that states often have differing points of view on the benefits, convenience and desirability of multilateral approaches.

MULTILATERAL APPROACHES: PAST AND PRESENT

EARLIER EFFORTS TOWARDS MULTILATERALIZATION

Interest in institutional arrangements for the nuclear fuel cycle dates back to the start of the nuclear age. The *Report on the International Control of Atomic Energy*, generally known as the Acheson–Lilienthal Report, was issued by a committee chaired by Dean Acheson and David Lilienthal in March 1946. It was the first effort to define a policy on the international control of atomic energy. The report called for a United Nations authority to own and control all uranium deposits and all fissile material, and to ensure that atomic research was conducted for peaceful purposes only. Many ideas of the Acheson-Lilienthal Report were used in the formal proposal for the international control of atomic energy, known as the Baruch Plan, presented by the United States government to the United Nations Atomic Energy Commission at its first meeting in June 1946. However, the plan never came to fruition due to conflicting national objectives at the time.

In the second half of 1970s the world again turned to the multilateral management of the nuclear fuel cycle. This was motivated by fears that a new wave of proliferation might result in response to India's "peaceful nuclear explosion" of 1974 and expectations of an rise in the number of nuclear facilities in order to meet global energy demands, much similar to today's concerns over the spread of sensitive nuclear technologies and expectations of a nuclear renaissance. But at that time the major concern was with the proliferation hazards attendant upon the back end of the fuel cycle, specifically spent fuel reprocessing and plutonium recycling, while today the focus has largely shifted to the front end, specifically uranium enrichment.

In the 1970s and 1980s several feasibility studies on multilateral approaches to the nuclear fuel cycle were undertaken. The IAEA study on regional nuclear fuel-cycle centres[36] was initiated in 1975 to examine the economic, safety, safeguards and security aspects of a multilateral approach to planning and establishing nuclear fuel-cycle facilities compared to a wholly national approach. The study focused on the back end of the nuclear fuel cycle, specifically, spent fuel reprocessing and plutonium containment. The International Nuclear Fuel Cycle Evaluation[37] exercise

of 1977–1980 touched upon various aspects of assurances of long-term supply of nuclear fuel and services, including multinational or international backup or safety net arrangements, an international nuclear fuel bank, the possibility of regional fuel-cycle facilities and prospects for multilateral cooperation on plutonium storage. The IAEA Expert Group on International Plutonium Storage (1978–1982)[38] moved away from the discussion of regional fuel-cycle centres to examine the prospects for IAEA-supervised management, storage and disposition of spent nuclear fuel. Finally, the IAEA Committee on Assurances of Supply (1980–1987) provided a forum for in-depth discussion on the issue of internationalization of the nuclear fuel cycle.

Although these studies generally drew favourable conclusions regarding the technical and economic viability of multilateral approaches, no further pursuit of those approaches followed, not least due to the general lack of political will and the disinclination of some states to renounce sovereign control over nuclear technology. However, the continuing spread of nuclear technology and knowledge, along with the emergence of nuclear black markets, has led to renewed interest in multilateral approaches to the nuclear fuel cycle. In 2003 then IAEA Director General Mohamed ElBaradei proposed to revisit multilateral approaches in order to strengthen the nuclear non-proliferation regime while not impeding the development of nuclear energy for states wishing to pursue that option. In 2003, he outlined a three-pronged approach to limiting the processing of weapon-usable material (separated plutonium and high-enriched uranium) in civilian nuclear fuel cycles. In particular, he proposed placing all enrichment and reprocessing facilities under multinational control and considering multinational approaches to the management and disposal of spent fuel and radioactive waste.[39]

Building on the ideas laid out by the 2005 report of the IAEA International Expert Group on Multilateral Approaches to the Nuclear Fuel Cycle, ElBaradei proposed a three-stage process for developing a new framework for the utilization of the nuclear energy based on multilateral approaches:

> The *first* step would be to establish a system for assuring supply of fuel for nuclear power reactors—and, if necessary, supply of the actual reactors. The *second* step would be to have all *new* enrichment and reprocessing activities in future put exclusively under multilateral control. And the *third* step would be to convert all *existing* enrichment and reprocessing facilities from national to multilateral operations.[40]

The development of the proposed framework would start from the establishment of relatively straightforward multilateral mechanisms that could provide additional supply guaranties, possibly with the IAEA as guarantor, and thus complement and reinforce the existing commercial nuclear market. As long as those mechanisms do not require states to forgo the development or operation of independent domestic fuel-cycle facilities, they would not clash with the NPT provisions on the peaceful use of nuclear energy. From the non-proliferation perspective, such complementary fuel assurance mechanisms can be seen as confidence-building measures—but not guarantees—against the risk that some states might choose to proliferate. The best that might be hoped for is that some states, according to their individual perception of advantage, might find voluntary multilateral mechanisms sufficiently attractive and thus refrain from the national construction and operation of sensitive fuel-cycle facilities.

The second and third stages of the plan, if accomplished, would amount to true, or comprehensive, multilateralization of certain parts of the nuclear fuel cycle, first of all uranium enrichment and plutonium reprocessing. These stages are more contentious because they explicitly go beyond the NPT legal framework in that they would amount to a change in the scope of article IV of the NPT, which stipulates the "inalienable right" for each state party to pursue their own national peaceful nuclear programmes, including enrichment and reprocessing activities. This right is conditional only upon states parties meeting their obligations under articles I, II and III. The 2005 report of the IAEA International Expert Group confirms that "a new binding international norm stipulating that sensitive fuel-cycle activities are to be conducted exclusively in the context of multilateral mechanisms and no longer as a national undertaking would amount to a change in the scope of Article IV of the NPT".[41]

Such a norm is not entirely impossible, but would likely only be agreed upon in the context of broad negotiations, and for many states could "probably only be realized through universal principles applying to all States".[42] This means that any negotiated restrictions on independent fuel-cycle facilities would need to apply equally to nuclear-weapon states, non-nuclear-weapon states and non-NPT states, thus bringing all to the same level of obligation without exception. At that time, multilateralization of sensitive nuclear technologies could become a universal, binding principle. Given the deep divisions that exist between groups of states on issues

pertaining to nuclear non-proliferation, disarmament and the peaceful use of nuclear energy, this would be not an easy task to achieve.

It could be more straightforward to have all states parties agree on having all new enrichment and reprocessing activities put exclusively under multilateral control in the future because in this case many complex political, legal and financial issues, which appear when the conversion of existing plants is considered, would not be involved. As all those plants are commercial companies, how to buy out the interests of current shareholders? How much it would cost? Who should pay for it? How does one convince the shareholders to give up shares in favour of new multilateral partners? How does one overcome the possible resistance of industry and technology holders? However, such a "partial solution" is likely to be unacceptable for some non-supplier states, which might consider it as an attempt of the states that currently have nuclear technology to preserve their national facilities while excluding others from the "club".

Pending a negotiated, binding international norm for sensitive fuel-cycle activities, multilateral fuel-cycle facilities could be built from scratch or created by converting existing national operations into multilateral ones on an exclusively voluntary basis. The hope is that the economic and political incentives offered by multilateral ventures would lead many states to prefer this way to the more independent but challenging alternative.

CURRENT STATUS OF MULTILATERALIZATION PROPOSALS

In 2005–2007, in response to ElBaradei's call to revisit multilateral approaches, governments, nuclear industry and international organizations put forward a dozen proposals regarding multilateral approaches to the nuclear fuel cycle and assurances of nuclear fuel supply.[43] These proposals vary considerably in their vision, scope, goals, implementation timelines and degree of elaboration. Many of them, designed as "guarantees-in-depth" or supplemental instruments for the existing nuclear marketplace, seek to provide extra assurances of LEU supply to offer states attractive alternatives to developing their own uranium enrichment capacities. 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 assurance

of supply instruments can be separated into two subgroups: supplier guarantees and LEU banks (often referred to as fuel banks).

The second group of proposals seeks to establish multilateral uranium enrichment facilities, while the third group comprises the most far-reaching visions for global multilateral fuel-cycle infrastructure. The following is a brief description of the existing proposals (details can be found in annex A).

Group 1A
Assurance of fuel supply proposals: supplier guarantees

- World Nuclear Association proposal for ensuring security of supply—collective guarantees of supply of uranium enrichment services provided by nuclear industry and supported by governments and the IAEA.
- Six-country concept—assurances of supply of uranium enrichment services provided by supplier states and supported by the IAEA.
- Japanese standby arrangements proposal—assurances of supply of all front-end fuel-cycle services.
- UK nuclear fuel assurance proposal—assurances of supply of uranium enrichment services provided by supplier governments through guaranteed export licenses.

Group 1B
Assurance of fuel supply proposals: LEU banks

- US LEU reserve—a nationally controlled reserve of LEU as a backup to an international assurance supply mechanism.
- Russian guaranteed LEU reserve—an IAEA-safeguarded and controlled reserve of 120t of LEU in Angarsk provided and maintained by the Russian Federation.
- IAEA LEU bank—an LEU reserve owned and managed by the IAEA.

Group 2
Multilateral uranium enrichment facility proposals

- Russian International Uranium Enrichment Centre—a multinational uranium enrichment centre in Russia under IAEA safeguards with no access to enrichment technology by stakeholders.

- German multilateral enrichment sanctuary project—an IAEA-controlled international uranium enrichment plant in an extraterritorial area with no access to technology by stakeholders.
- Gulf Cooperation Council multinational nuclear consortium proposal—an international uranium enrichment consortium for the Middle East that could be based in a neutral country outside the region with no access to enrichment technology by stakeholders.

Group 3
Global multilateral infrastructure proposals

- Russian Global Nuclear Power Infrastructure—a system of international centres providing fuel-cycle services on a non-discriminatory basis and under IAEA control.
- US Global Nuclear Energy Partnership—the full spectrum of front-end and back-end services provided by a limited number of supplier states using new proliferation-resistant technologies.
- Austrian proposal on multilateralization of the nuclear fuel cycle—a multilateral framework of supervision of all stages of the nuclear fuel cycle.

Many of these proposals are similar to those made by the feasibility studies on multilateral approaches to the nuclear fuel cycle in the 1970s and 1980s. Additional guaranties from nuclear suppliers, fuel banks and multilateral fuel-cycle facilities were discussed then as now, but thirty years ago none of those ideas led anywhere. Today, however, we see greater progress in the direction of the practical implementation of multilateral fuel-cycle arrangements. Four of the aforementioned proposals have been pursued: the Russian International Uranium Enrichment Centre, the Russian guaranteed LEU reserve, the IAEA LEU bank and the UK nuclear fuel assurance proposal.

In May 2007 the Russian Federation and Kazakhstan signed an intergovernmental agreement establishing an International Uranium Enrichment Centre (IUEC) "to provide IUEC participating organizations with guaranteed access to uranium enrichment capabilities".[44] IUEC stockholders would either have guaranteed access to enriched uranium product or a share in profits. Today three states—the Russian Federation, Kazakhstan and Ukraine—are IUEC stockholders, Armenia should become a full IUEC member after buying stakes in the Centre later in 2011.

Mongolia is expected to join, and other states are welcome to become stockholders.

In March 2010 the IAEA and the Russian Federation signed an agreement to establish a reserve of 120t of LEU for supply to the Agency for its member states.[45] The reserve, located in Angarsk, is owned by the Russian Federation but is safeguarded and controlled by the IAEA. Upon notification from the IAEA Director General, the Russian Federation will deliver the requested amount of LEU from the guaranteed reserve to the IAEA for further supply to a "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".[46] On 17 December 2010, the world's first multilateral LEU reserve was officially inaugurated.[47]

On 3 December 2010, the IAEA Board of Governors adopted a resolution authorizing the Director General to establish an LEU bank that will be owned and managed by the Agency "to serve as a mechanism of last resort to back up the commercial market without distorting the market, in the event that a Member State's supply of LEU is disrupted and cannot be restored by commercial means and that such State fulfils the eligibility criteria".[48] The Board authorized the Director General to accept voluntary contributions of more than US$ 150 million pledged by 31 member states and the Nuclear Threat Initiative, a US non-governmental organization, for the creation of an IAEA LEU bank. The Director General was also requested to negotiate with one or more member states that would be interested in acting as host state for the bank, and draft a Host State Agreement for approval by the Board.[49]

The Government of the United Kingdom, supported by Germany and the Netherlands, has vigorously pursued its nuclear fuel assurance proposal, designed to enhance confidence in commercial fuel supplies. Basically, the proposal envisions agreements between a supplier state and a customer state, overseen by the IAEA, that commercial LEU supply contracts will not be disrupted for any non-commercial reasons other than those directly related to nuclear non-proliferation concerns. On 10 March 2011 the IAEA Board of Governors voted in favour of the proposal.

Support from supplier states

The idea of multilateralization of the nuclear fuel cycle has received support from many governments, particularly of supplier states. In January 2006, during a meeting of the Council of the Eurasian Economic Union, then President of the Russian Federation Vladimir Putin outlined an initiative 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.[50]

In June 2006 six governments that operate commercial uranium enrichment plants providing services on the international market—France, Germany, the Netherlands, the Russian Federation, the United Kingdom and the United States—proposed a three-tier system for ensuring security of supply of uranium enrichment services.[51] In September the six-country proposal was backed up by a complementary proposal from Japan.[52]

On 5 April 2009, US President Barack Obama said that "we should build a new framework for civil nuclear cooperation, including an international fuel bank, so that countries can access peaceful power without increasing the risks of proliferation".[53] In a statement on behalf of the European Union at the 2010 NPT Review Conference, Catherine Ashton, High Representative of the European Union for Foreign Affairs and Security Policy, called for "broadening acceptance and support of the concept of responsible development of the peaceful uses of nuclear energy in the best safety, security and non-proliferation conditions and of multilateral approaches to the nuclear fuel cycle".[54]

Despite this support, it should be noted that the policies of leading supplier states towards the multilateralization of the nuclear fuel cycle are uncoordinated and subject to change.

In February 2004 US President George W. Bush proposed a plan that would have effectively denied uranium enrichment and spent fuel reprocessing technologies to states not already in possession of them.[55] The Bush administration had to drop this idea after it ran into strong opposition not only from non-supplier states but also from the members

of the Nuclear Suppliers Group. It then put forward the Global Nuclear Energy Partnership initiative, which initially contained a similar proposal to create a consortium of states with advanced nuclear technology ("fuel-cycle states" according to the initial language) that would provide the full spectrum of fuel-cycle services and reactors to states that "refrain" from fuel-cycle activities ("reactor states"). This proposal also met with strong disapproval, and the United States later shelved its plans to require states that joined the partnership to forswear enrichment and reprocessing. The Obama administration effectively cancelled the initiative and transformed its international component into the International Framework for Nuclear Energy Cooperation, which seeks to be "a forum for cooperation among participating states to explore mutually beneficial approaches to ensure the use of nuclear energy for peaceful purposes proceeds in a manner that is efficient and meets the highest standards of safety, security and non-proliferation".[56]

Ellen Tauscher, US Under Secretary of State for Arms Control and International Security, stated in January 2010 that "we must ensure that the expansion of nuclear energy does not lead to the spread of enrichment and reprocessing technologies that can be used to make nuclear materials for nuclear weapons".[57] She said that "the United States is leading the international community to develop assurances of reliable fuel supply, beginning with fuel banks", while "creating a national enriched uranium reserve to support fuel supply assurances by downblending highly enriched uranium no longer needed for national security purposes". She praised the Russian LEU reserve in Angarsk and the United Kingdom-led enrichment bond concept. At the same time she expressed scepticism towards creating internationally-controlled enrichment centres. As for the back end of the nuclear fuel cycle, Tauscher said that "no nation, with the possible exception of Sweden and Finland, has satisfactorily resolved the question of the disposition of used fuel once it is discharged from a power reactor" and that the Obama administration will continue working with international partners to seek options for handling spent nuclear fuel and radioactive waste.

As can be seen, since 2004 the US position has changed from advocating the denial of sensitive nuclear technology to non-supplier states and planning to create a global supply infrastructure having its focus on the back end of the nuclear fuel cycle, to supporting assurances of supply of front-end services, holding sceptical attitudes towards internationally

controlled enrichment centres and seeing no readily available solution for the back end of the fuel cycle.

The Russian Federation believes that "multilateral approaches to the nuclear fuel cycle open the best way to implement in practice the core principle of inextricable link between the three pillars of the NPT".[58] It has advocated the concept of the Global Nuclear Power Infrastructure, although many details remain undefined and it has not taken action to develop the concept beyond the establishment of the IUEC in Angarsk.

France has maintained an obscure position on multilateral approaches to the nuclear fuel cycle. Although it supported on the IAEA Board of Governors the establishment of the two LEU banks and was a part of the six-country concept suggesting a multilateral mechanism for reliable access to nuclear fuel, France has never clearly stated its policy towards the multilateralization of the fuel cycle.

China has adopted a "wait-and-see" attitude on the issue, stating:

> China in principle supports all endeavors aimed at strengthening the international nuclear non-proliferation regime. We hope that the international community can seek a practical scheme [for multilateral approaches to the nuclear fuel cycle] acceptable to all through thorough consultations. Such a scheme should not only promote the goal of preventing the proliferation of nuclear weapons, but also be conducive to realizing the rights of peaceful uses of nuclear energy of all countries, especially developing countries.[59]

The Republic of Korea has stated its full support for "international efforts to realize the goal and spirit of initiatives on multilateral approaches to the nuclear fuel cycle and is willing to constructively participate in discussions on this subject". Because expanding spent fuel storage capacities on its territory is a major political challenge, the Republic of Korea is interested in proposals on multilateral approaches that "comprehend the entire nuclear fuel cycle and [it] supports the idea of international reprocessing and reprocessing/recycling centers".[60]

Germany proposed a project aimed at providing for the establishment of a multilateral uranium enrichment plant in a territory administered by the IAEA (see annex A).

Japan has a long-standing interest in multilateral nuclear cooperation. In the mid-1990s several proposals for an Asian nuclear cooperation regime were put forward by Japanese officials and academics.[61] These were focused around the idea of the creation of an Asian equivalent of the European Atomic Energy Community. The proposal covered several spheres of potential cooperation: nuclear safety, energy distribution, industrial and scientific cooperation, regional safeguards and transparency measures, regional export controls, plutonium management, and spent fuel and radioactive waste management. In 2006 Japan proposed the establishment of an international information system, to be administered by the IAEA, to help prevent interruptions in nuclear fuel supplies (see annex A). At the same time, Japan appears to be cautious about proposals aimed at the internationalization of national fuel-cycle capacities.

While many supplier states support the idea of multilateralization of the nuclear fuel cycle, their hopes and views on what to take are different. At this point, a coordinated strategy to multilateralize the nuclear fuel cycle does not exist.

Opposition from non-supplier states

The proposals for multilateral approaches to the nuclear fuel cycle have run into a strong opposition from many non-supplier states owing to the fear that the proposed mechanisms could result in a "cartel" of suppliers, create a new export control regime, infringe on the perceived inalienable right to use nuclear energy for peaceful purposes, and so on.[62] The tension between supplier and non-supplier states on the issue of multilateral approaches is illustrated by the votes of the IAEA Board of Governors on resolution GOV/2009/81 of 27 November 2009, authorizing the Russian Federation to establish a guaranteed LEU reserve, resolution GOV/2010/70 of 3 December 2010, approving the creation of an IAEA LEU bank, and resolution GOV/2011/10 of 10 March 2011, approving the United Kingdom's nuclear fuel assurance proposal.

At the November 2009 board meeting, approval for the Russian LEU reserve came with eight dissenting votes and three abstentions among the 35 board members. The eight dissenting votes were Argentina, Brazil, Cuba, Egypt, Malaysia, Pakistan, South Africa and Venezuela, while India, Kenya and Turkey abstained.[63] The members voting in favour of the resolution were Afghanistan, Australia, Burkina Faso, Cameroon, Canada,

China, Denmark, France, Germany, Japan, Mongolia, the Netherlands, New Zealand, Peru, Romania, the Russian Federation, the Republic of Korea, Spain, Switzerland, Ukraine, the United Kingdom, the United States and Uruguay (Azerbaijan was absent from the vote).

At the December 2010 board meeting, approval of the IAEA LEU bank came with six abstentions—Argentina, Brazil, Ecuador, South Africa, Tunisia and Venezuela. Pakistan registered no vote at all.[64] The members voting in favour were Australia, Azerbaijan, Belgium, Cameroon, Canada, the Czech Republic, Chile, China, Denmark, France, Germany, India, Italy, Japan, Jordan, Kenya, Mongolia, the Netherlands, Niger, Peru, Portugal, The Republic of Korea, the Russian Federation, Singapore, Ukraine, the United Arab Emirates, the United Kingdom and the United States.

At the March 2011 board meeting, approval for the nuclear fuel assurance proposal came with eight abstentions—Argentina, Brazil, Ecuador, Peru, Singapore, South Africa, Tunisia and Venezuela.[65] Pakistan was absent from the vote.

These arrangements were mostly favoured by supplier states and their allies, while a number of non-supplier states—most prominently Argentina, Brazil, Cuba, Egypt, Indonesia, Iran, Malaysia, Pakistan, South Africa, Syria and Venezuela—have not supported these arrangements and the multilateralization of the nuclear fuel cycle in general. The positions of these member states also determine, to a large extent, the coordinated positions on the issue of the Non-Aligned Movement and the Group of 77, international organizations that promote the interests and priorities of developing countries.

Notwithstanding that the IAEA LEU bank is envisaged solely as a backup mechanism to the normal operation of the nuclear market, and that the rights of customer states will not in any way be compromised or diminished by its creation, the bank was harshly criticized by some IAEA member states. In a statement at the 2010 NPT Review Conference, Ahmed Aboul-Gheit, Minister for Foreign Affairs of Egypt, disapproved of the establishment of “an international fuel bank that would codify the negative practices of the Nuclear Suppliers Group” and said that “the increasing interest by non-nuclear-weapon-States Parties to the Treaty to make use of the developmental benefits of nuclear energy” should not be used as a basis to impose additional restrictions on them.[66] Similarly, Ali

Asghar Soltanieh, Iran's permanent representative to the IAEA, expressed opposition to the establishment of the LEU bank, saying that it would lead to "nuclear apartheid".[67]

The bitter dispute on multilateral approaches to the nuclear fuel cycle—which reflect divisions between the "Western Group"[68] along with other like-minded states and the Non-Aligned Movement on many issues including nuclear non-proliferation and disarmament—was evident in the cautious language of the final document of the 2010 NPT Review Conference. The document's action plan states:

> Action 58: Continue to discuss further, in a non-discriminatory and transparent manner under the auspices of IAEA or regional forums, the development of multilateral approaches to the nuclear fuel cycle, including the possibilities of creating mechanisms for assurance of nuclear fuel supply, as well as possible schemes dealing with the back end of the fuel cycle without affecting rights under the Treaty and without prejudice to national fuel-cycle policies, while tackling the technical, legal and economic complexities surrounding these issues, including, in this regard, the requirement of IAEA full scope safeguards.[69]

The chairman's draft of Main Committee III of the 2010 NPT Review Conference, which addressed implementation of Treaty provisions relating to peaceful uses of nuclear energy, read "The Conference notes the various proposals in the field of multilateral approaches to the nuclear fuel cycle and assurance of nuclear fuel supply and encourages all efforts to further develop them in conformity with the Treaty and the IAEA Statute",[70] but this language did not find its way into the final document of the conference as it was resisted by some NPT states parties.

The IAEA position

A vocal advocate of multilateral approaches to the nuclear fuel cycle, former IAEA Director General Mohamed ElBaradei revived interest, among governments, non-governmental organizations and academia in multilateral approaches as a means to strengthen the international nuclear non-proliferation regime while not impeding the development of nuclear energy by states wishing to follow that path. Under his leadership, the IAEA was, to a large extent, a focal point for international efforts towards the multilateralization of the nuclear fuel cycle.

The change in IAEA leadership has had an impact on the debate over multilateral approaches to the nuclear fuel cycle and assurances of nuclear fuel supply. IAEA Director General Yukiya Amano did not mention multilateralization of the nuclear fuel cycle in his acceptance speech at the Fifty-third Regular Session of the IAEA General Conference in September 2009, and barely mentioned it in his statement to the NPT Review Conference in May 2010. Under Amano's leadership, the Agency has changed its policies to become less transparent and less willing to discuss multilateral approaches with other organizations, especially if they do not represent governments of member states. The sensitivity of this issue on the part of IAEA member states is usually offered as an explanation for this closed-door policy. Even if the current Director General were as supportive of multilateral approaches as ElBaradei had been, the less-open style his administration has shown thus far might lead to the perception of a serious change in the level of support from the IAEA to multilateralization of the nuclear fuel cycle.

There seems to be a move away from ElBaradei's proposal of a new binding international norm stipulating that sensitive fuel-cycle activities are to be conducted exclusively in the context of multilateral approaches and no longer as national undertakings, perhaps because many member states regarded this as changing the scope of article IV of the NPT. The efforts of the IAEA are now focused on establishing multilateral mechanisms with voluntary participation, such as LEU banks, to back up existing commercial supply mechanisms for states in good standing with the non-proliferation regime.

So, despite several practical advances, the future of multilateral fuel-cycle arrangements is unclear because multilateralization has become a sensitive political topic among NPT states parties and IAEA member states. Some states (especially the leading states of the Non-Aligned Movement and the G-77) do not want any discussion on the matter, whereas advocates of multilateralization have not presented any long-term vision or policies. It is not clear at this time what impact IAEA leadership will have on the debate over multilateralization.

POLITICAL OBSTACLES TO MULTILATERALIZATION

APPEAL OF NATIONAL NUCLEAR CAPABILITY

It is widely agreed that the spread of sensitive fuel-cycle technologies would undermine the balance among the three pillars of the NPT. The dissemination of sensitive nuclear technologies could hurt not only the non-proliferation pillar, but the disarmament pillar as well. The spread of virtual nuclear weapon capabilities could discourage nuclear-weapon states from taking concrete steps towards disarmament. On the other hand, slow progress in reducing nuclear arsenals and the fact that nuclear powers still tend to position nuclear weapons as the bedrock of their security architecture influence the attitudes and decisions of non-nuclear-weapon states.[71] If a non-nuclear-weapon state decides to develop a virtual nuclear weapon programme, its decision may be determined, at least in part, by the policies of those states legally in possession of nuclear weapons. Nuclear-weapon-states working towards a world without nuclear weapons and non-nuclear-weapon states acquiring virtual nuclear weapon capabilities would be clearly contradictory and unhelpful for nuclear disarmament.

Many politicians and experts have emphasized that the strengthening of the international non-proliferation regime entails dissuading states from developing national facilities for uranium enrichment and spent fuel reprocessing. Multilateralization of the nuclear fuel cycle has been praised as being able to change the way in which nuclear technology is managed, thus removing the tensions between the three pillars of the NPT and providing all states with non-discriminatory access to the benefits of peaceful applications of nuclear technology while barring direct access to weapon-usable nuclear material.

However, many non-supplier states are reluctant to forgo their right to develop or acquire technologies for nuclear enrichment and reprocessing. In a statement made at a UNIDIR seminar on multilateral approaches to the nuclear fuel-cycle, Ambassador Leslie Mbangambi Gumbi of South Africa posited that multilateral arrangements should not “even hint at the possibility that [non-nuclear-weapon states parties], in conformity with their legal obligations under the NPT, should forgo their Article IV

inalienable right[s], including the right to pursue domestic nuclear fuel capabilities, as well as access to advanced technologies".[72]

In response to opposition from non-supplier states, advocates of multilateralization have turned to voluntary multilateral mechanisms that provide additional assurances of uninterrupted supply in the form of legally binding supplier guarantees or LEU banks, and in doing so offer states alternatives to acquiring national enrichment capacities. But these mechanisms have limited ability to check the spread of sensitive nuclear technologies. No matter how attractive assurances of supply may be, not all states may choose to forgo national fuel-cycle development. The significant financial and technical costs of domestic enrichment notwithstanding, powerful incentives such as prospective profits and national pride could sustain many states' desire to acquire sensitive fuel-cycle technologies.

The unwillingness of non-supplier states to renounce sovereign control over nuclear technology is often considered as one of the strongest barriers to multilateralization of the nuclear fuel cycle. Is this unwillingness conditional? In other words, on what conditions might non-supplier states agree to forgo independent fuel-cycle capabilities in favour of multilateral approaches?

The development of domestic fuel-cycle technologies, including uranium enrichment and spent fuel reprocessing, may have strong political, economic and security appeal to some states. This appeal could be driven by the following reasons:

- the desire to ensure the security of fuel supply and reduce external dependence on existing suppliers;
- commercial interest in selling materials and services on the market;
- national prestige (or "nuclear nationalism"); and
- the desire to develop a virtual nuclear weapon capability.

States are often reluctant to give in to the demands of international agreements that compromise sovereignty, especially when independence, equity and security are concerned. Many non-supplier states would never agree to additional discrimination within the non-proliferation regime, beyond what is already present in the distinction between the NPT nuclear-weapon states and non-nuclear-weapon states. They would resist a two-tier system of "haves" and "have-nots" of nuclear technology and in

its place demand a fair and equitable arrangement with equal rights and obligations for all participants.

But is it only non-supplier states that do not want to give up the right to nuclear fuel-cycle technologies? Are nuclear suppliers prepared for concessions on their part? As of today, no technology holder has expressed any inclination to seriously discuss the conversion of their national fuel-cycle facilities into multilateral operations and ideas for such conversion have never been seriously discussed at a national or international level. Opponents of conversion of national fuel-cycle facilities argue that this would involve too many complex political, legal and financial issues. But nuclear suppliers should understand that any far-reaching multilateral fuel-cycle mechanism must inevitably be universal in its demands on participants in order to gain the support of an overwhelming majority of states.

LEGACY OF EXCLUSIVENESS AND COERCIVENESS

A legacy of exclusiveness and coerciveness may make the future of multilateral approaches to the nuclear fuel cycle rather dim. Many non-supplier states have expressed concerns that suppliers may try to broaden the NPT division between nuclear-weapon states and non-nuclear-weapon states under the guise of non-proliferation. This suspicion can be traced, at least in part, to some early proposals for multilateral approaches—the 2004 Bush proposal, the Global Nuclear Energy Partnership, the six-country concept, and the World Nuclear Association proposal—that required non-supplier states to forgo domestic development of sensitive fuel-cycle technologies. Such preconditions were met with strong disapproval. These proposals can be blamed for giving rise to a false impression that multilateral fuel-cycle mechanisms necessarily imply discrimination between nuclear technology haves and have-nots. Furthermore, it is sometimes believed that comprehensive multilateralization of the nuclear fuel cycle would mean that "customers promise not to develop any indigenous fuel-cycle capacity and to buy nuclear fuel from exclusively from [existing] suppliers", and that the proponents of multilateralization aim at "legitimizing a 'nuclear cartel' using non-proliferation as pretext under an eye-catching multilateral umbrella".[73] This is an unfortunate interpretation of the idea of true, or comprehensive, multilateralization of the nuclear fuel cycle, which would actually entail putting *all* sensitive fuel-cycle facilities worldwide

under multilateral ownership and control, thus making the playing field more equitable instead of more discriminatory.

Today the majority of proposals for the multilateralization of the nuclear fuel cycle do not require states to forgo any rights under article IV of the NPT and do not foreclose the possibility of states to have domestic fuel-cycle facilities. Of course, these proposals fall short of comprehensive multilateralization, but they could contribute to the building of confidence between supplier and non-supplier states. Nevertheless, the legacy of these proposals could be problematic. As noted earlier, the Russian LEU reserve, the IAEA LEU bank and the United Kingdom's nuclear fuel assurance proposal were approved by a majority of votes in the IAEA Board of Governors, while marginalizing the voices of developing, non-supplier states on the Board. This is the case because, according to article VI of the IAEA Statute, the composition of the 35-member Board is determined in such a way that the seats are held by states "most advanced in the technology of atomic energy including the production of source materials". The marginalization of developing, non-supplier states could cause resentment and further strain the political atmosphere within the IAEA, where high levels of polarization on the topic of multilateralization already exist between the G-77 and non-aligned states on the one hand, and Western states and their allies on the other, thus raising concerns about the political viability of future multilateral fuel-cycle arrangements. Pushing approval of multilateral mechanisms through the Board of Governors without proper consultations with non-supplier states, even if the chances are slim that those states might relax their opposition to multilateralization, could confirm suspicions that multilateralization is an exclusive venture enforced by coercive and non-consensual means.

With a few exceptions, the existing proposals for multilateral approaches have been developed by supplier states. A serious weakness of these proposals lies in the failure to have consulted during their development with non-supplier states and to have taken into account the interests and needs of all states, not just supplier states. Non-supplier states have often emphasized the need for transparency and inclusiveness in discussions on sensitive matters such as the nuclear fuel cycle.[74] The prevailing dynamic of multilateralization efforts (in which supplier states have charge), which can be seen not only in the proposals but also in the political and diplomatic promotion of them, could limit the prospects for success of multilateralization initiatives.

LACK OF CLARITY ON MULTILATERALIZATION AND THE ALTERNATIVES

Multilateral arrangements for the nuclear fuel cycle should offer states an attractive alternative to the trouble and expense of developing national sensitive nuclear technologies by offering various incentives to those that decide to avail themselves of these arrangements. However, some non-supplier states have criticized the lack of clarity on the stated political, economic, energy and security benefits of participation in multilateral approaches to the nuclear fuel cycle.

But, while making strong points about the difficulties inherent in multilateral approaches, opponents often fail to clearly present their own alternatives, motives, intentions and interests. Do they oppose multilateral approaches in general, or do they oppose specific designs and arrangements? Do they seek particular political, economic, energy and security benefits from multilateralization? How do they suggest that one strike a balance between the peaceful uses of nuclear energy and the proliferation risks stemming from sensitive nuclear technologies? Some non-supplier states maintain the position that there is no nexus between peaceful use of nuclear energy and nuclear weapon capability, and that no proliferation risks could arise from national fuel cycles. But, it should be acknowledged—to ignore the problem of proliferation can only aggravate it.

The main question here is how to convince states with a strong interest in developing national fuel-cycle capabilities that it could be in their interest to pursue multilateralization. Supplementary fuel assurance mechanisms, such as the Russian LEU reserve and the IAEA LEU bank, may only modestly reduce incentives to establish national fuel-cycle facilities, as the benefits of relying on such mechanisms may be considered insufficient by some non-supplier states. Multilateral mechanisms should respond to the needs and motivations of non-supplier states, where they are clearly articulated. If these motivations concern equality and involvement, for example, such mechanisms could provide a vested interest in major elements of fuel-cycle services, such as participation in ownership, management, operation, decision-making, profit-sharing and other activities short of direct access to sensitive nuclear technologies.

Moreover, as a wide variety of needs and motivations underpin the decision to undertake national fuel-cycle programmes, only a combination

of diverse incentives (political and military alliances, trade, economic, military cooperation, and so forth) could persuade states to select multilateral mechanisms over national development.

NEED FOR COORDINATED POLITICAL ACTION

No coalition of states has emerged with a politically attractive or economically sound strategy to build and sustain momentum concerning multilateral arrangements for the fuel cycle. In order to ensure progress, one must expand the number of states in favour of such approaches and strengthen their conviction. Too few states have come together to advocate strongly in favour of multilateralization.

As noted earlier, almost every proposal for a multilateral approach has come from the supplier states, and has been supported by them or their close allies. Nevertheless, even these states have not come up with a common strategy towards multilateralization; rather, as noted above, they have sometimes pursued policies that could be viewed as inconsistent and contradictory.

As for non-supplier states, many of them see multilateral approaches to the nuclear fuel cycle as attempts to perpetuate the supplier–client dynamic of the "two-tier" system of nuclear haves and have-nots, or to establish a cartel aimed at controlling international markets and depriving developing countries of equal opportunity. Such a perception fuels animosity towards multilateral mechanisms, especially among the Non-Aligned Movement and the G-77, and constitutes one of the greatest stumbling blocks to progress in multilateral approaches. Without securing support from at least some of these key players, the idea of multilateralization is most likely doomed to stagnation or even failure.

The challenge will be to create a wide coalition of states, including both supplier states and a considerable number of non-supplier states, with an innovative, politically attractive and economically sound strategy for multilateralization of the nuclear fuel cycle.

Matters pertaining to nuclear energy are usually crowded out by other matters on the agendas of governments. But the promotion and implementation of multilateral fuel-cycle arrangements will require

substantive and sustained investment of political capital. In addition to resolving legal matters, host states for multilateral fuel-cycle facilities will need to build local and regional coalitions of support. The prospects for building such coalitions across governmental institutions, civil society and regional actors are, at best, unclear.

Another complicating factor is that discussions on multilateral arrangements have not been undertaken beyond the IAEA and the NPT Review Conferences. The diversification of opportunities and forums for high-level dialogue and negotiations on multilateral approaches is crucial to maximizing the likelihood that more governments will feel involved in the process and grant multilateralization the attention it deserves, and that interest groups will give the concept more political salience.

It will be crucial to preserve the momentum of discussions on multilateral approaches at the highest governmental and intergovernmental levels. Upon delivery of specific political mandates following from such discussions, technical discussions on the specifics of potential arrangements can take place within more specialized frameworks. However, the discussion of multilateralization should not be restricted solely to governments. The public, academia and civil society should be actively involved in discussions on nuclear energy, non-proliferation and multilateral approaches to the nuclear fuel cycle.

INTEGRATING MULTILATERAL ARRANGEMENTS INTO EXISTING COOPERATION MECHANISMS

THE RIGHT TO PEACEFUL USE OF NUCLEAR ENERGY AND MULTILATERALIZATION

To compensate non-nuclear-weapon states parties of the NPT for renouncing the right to nuclear weapons, the Treaty guaranties "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". This right has been confirmed at all NPT review conferences, including the 2010 Review Conference, which reaffirmed 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, III and IV 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.[75]

Paragraph 2 of Article IV also stipulates that all the parties to the Treaty "undertake to facilitate, and have the right to participate in, the fullest possible exchange of equipment, materials and scientific and technological information for the peaceful use of nuclear energy".

The peaceful use of nuclear energy has been a sensitive issue among supplier and non-supplier states parties of the NPT. In the past, many non-nuclear-weapons states have raised issues concerning this article. These have centred on the reluctance of nuclear technology holders to provide technical assistance or share their nuclear know-how with others. In this regard, international export control mechanisms, and in particular the Nuclear Suppliers Group, have been criticized for seeking to control nuclear and dual-use exports, which in the opinion of some non-nuclear-weapon states could be considered as a violation of article IV.

Advocates of controls on nuclear trade have argued for restrictions by reasoning that once a state has its own enrichment and reprocessing capabilities, it cannot be ruled out that these technologies might be used to create weapon-grade fissile materials. Accordingly, transfers of facilities, equipment, or technology for the production of high-enriched uranium or plutonium could be regarded as a violation of articles I and II of the NPT.

Although the claim that bulk-handling facilities are difficult to effectively safeguard against diversion of nuclear material is basically correct, and there is an obvious tension between the inalienable right to developing peaceful nuclear capabilities and compliance with articles I and II, nothing in the text of the NPT can be unequivocally interpreted as prohibiting the development and operation of domestic enrichment and reprocessing facilities. Moreover, the history of NPT negotiations shows that negotiating parties had no intention to impose such a prohibition. William Foster, the US representative for negotiating the NPT in the Eighteen-Nation Committee on Disarmament, stated, "these provisions [of article IV] make it clear that the treaty would promote, not discourage, national development and international co-operation with respect to peaceful application of atomic energy. This applies to research, production and use as well as to information, equipment and materials".[76] He had previously stressed that "a non-proliferation treaty which prohibits the manufacture or acquisition of nuclear explosives would not restrict the dissemination of application technology in any fashion. Accordingly, we must vigorously reject the implication … that somehow what [supplier states] have in mind might be the establishment of 'an atomic super-commercial monopoly'".[77] In an aide-mémoire of 17 November 1967, the Swiss Government interpreted articles I and II as not covering "exploitation of uranium deposits, enrichment of uranium, extraction of plutonium from nuclear fuels, or manufacture of fuel elements or heavy water, when these processes are carried out for civil purposes".[78]

Non-nuclear-weapon states, in particular those belonging to the Non-Aligned Movement (NAM) and the G-77, have vehemently criticized restrictions on nuclear trade and technology transfer as inconsistent with the spirit of article IV and the NPT "grand bargain". In a statement at the 2010 NPT Review Conference, the non-aligned states parties confirmed their position:

> The NAM States Parties to the NPT underscore the inalienable right of States Parties to research, produce, and use nuclear technology for peaceful purposes without discrimination. Nothing in our discussion here should detract from the provisions in the Treaty for the development of peaceful uses of energy. The unimpeded and non-discriminatory transfer of nuclear technology for peaceful purposes must be ensured. …
>
> Article IV is explicit on this subject, and the NAM States Parties do not see any room for reinterpretation or setting of conditions for the peaceful uses of nuclear energy. The undue restrictions currently being applied to many developing countries Parties to the NPT are regrettable, and should be removed.[79]

Any far-reaching plans for multilateralization, such as making all new enrichment and reprocessing facilities multilateral or converting existing national facilities into multilateral operations, will inevitably require a deep change in the current international nuclear non-proliferation regime. Achieving this change would be extremely difficult. Reopening the NPT for negotiation could have the destructive consequences of losing or seriously undermining the cornerstone of the regime. A possible way forward could be to negotiate a revamped "grand bargain" among the NPT states parties, so as to conclude a new agreement going beyond the current NPT and strengthening all three pillars. To say the least, this seems to be unrealistic in the current political climate. Moreover, to fully achieve its goals, a revamped bargain would inevitably need to be universal and would have to engage the non-NPT states, which makes the task even more daunting.

An alternative could be to change the rules of the Nuclear Suppliers Group by agreeing, for example, that sensitive nuclear technologies would be supplied exclusively to multilateral fuel-cycle facilities. This would require the consensus of 46 members, instead of 189 NPT states parties and four non-NPT states. But a consensus within the Group is elusive as well, and even if achieved would likely cause major disagreements and tensions within the non-proliferation regime as it would be considered a violation of article IV by many non-nuclear-weapon states parties.

VOLUNTARY MULTILATERAL ARRANGEMENTS

Without a new legal framework, any multilateral mechanism could only exist in the form of voluntary arrangements, thus not in any way affecting the inalienable right of article IV. But even so, such arrangements could be helpful, if properly arranged, in providing states with non-discriminatory access to the benefits of peaceful applications of nuclear technology while barring direct access to weapon-usable nuclear material.

Fuel supply assurances

Assurances of supply of front-end services, such as LEU banks or supplier guarantees, have symbolic meaning in that they could encourage further developments on the issue of multilateralization. Their practical significance, however, is limited. First, they all deal with the front end of the nuclear fuel cycle, specifically with LEU supply. Currently the global nuclear market functions reasonably well and there is no shortage of supply of front-end services. Second, these mechanisms are envisaged as a last resort in the case of politically motivated disruption of normal commercial supplies. However, political disruptions are quite rare; in fact, only a few political disruptions of nuclear fuel supply have ever occurred and neither involved sanctions from an entire coalition of supplier states, but rather from individual governments or companies. Third, only states in good standing with the IAEA would be able to avail themselves of assurance of supply mechanisms. But these states would most likely be able to buy enriched uranium freely on the commercial market without the need for new multilateral arrangements. For such states, these mechanisms are largely a solution to a problem they do not face.

The IAEA International Expert Group on Multilateral Approaches to the Nuclear Fuel Cycle stated in its report that "two primary deciding factors dominate all assessments of multilateral nuclear approaches, namely 'assurance of non-proliferation' and 'assurance of supply and services' … As a matter of fact, multilateral approaches could be a way to satisfy both objectives".[80] But LEU banks or supplier guarantees cannot satisfy the assurance of non-proliferation—that is, reduce the proliferation risks arising from additional states acquiring sensitive nuclear technologies and from existing civilian fuel-cycle facilities—and have only limited potential to satisfy the assurance of supply and services—that is, encourage the

development of nuclear energy by assuring states that they will have reliable and uninterrupted access to nuclear goods and services.

Front-end multilateral facilities

Multilateral fuel-cycle facilities seem to be more promising in the ability to satisfy these two objectives by providing non-supplier states with guaranteed supplies of material and services and vested interest in the major elements of the nuclear fuel cycle. Such facilities would provide the opportunity for customer states to appraise at first hand the potential benefits of participation in multilateral fuel-cycle facilities. If their experience with voluntary multilateral facilities proves satisfactory, it could help pave the way for future negotiations on a revamped "grand bargain".

For the front end of the nuclear fuel cycle, there already are two multinational enrichment consortia, URENCO and EURODIF, representing two different models of multinational ownership and operation.

URENCO represents one approach, where each of the partners (Germany, the Netherlands and the United Kingdom) owns and operates a gas centrifuge enrichment facility within its borders, and shares knowledge of the centrifuge technology with the others. URENCO supplies uranium enrichment services to other countries based on the unanimous agreement of the participants.

EURODIF represents another approach that involves five participating states—Belgium, France, Italy, Iran and Spain—but has only one gaseous diffusion enrichment facility, in France. It is a consortium intended to serve the domestic fuel requirements of its members. The level of investment of each EURODIF member corresponds to its percentage share of the product. Management, operations and sensitive enrichment technology remain under the control of France. The consortium provides its participants with security of supply and an equity share in a production enterprise. The organization of the Russian IUEC is similar in some respects to the EURODIF model, with all partners making financial contributions to the joint venture, but the Russian Federation effectively controlling the operation of the enrichment facility and sensitive enrichment technology. However, IUEC stockholders can choose between having a guaranteed supply of enriched uranium product, or sharing in the Centre's profits.

Both models have their drawbacks. The URENCO model implies the sharing of enrichment technology, which could stimulate an unnecessary dissemination of sensitive nuclear technologies. The EURODIF model offers only limited "entitlement" motivations for customer states to participate as the host state retains exclusive control over the enrichment facility.

Another multinational enrichment facility, URENCO USA/LES[81] built by URENCO's subsidiary LES, commenced operation in New Mexico on 11 June 2010. The construction of the project will continue until the plant reaches the planned 5.7 million SWU capacity. URENCO USA/LES is the first enrichment facility to be built in the United States in 30 years and the first ever to use centrifuge enrichment technology that is "black boxed" so that personnel cannot access the technology. The French company AREVA will soon begin the construction of the Eagle Rock Enrichment Facility in Idaho, which will also feature black-box centrifuge technology. The enrichment technology for both plants is provided by the Enrichment Technology Company (ETC), a joint venture of URENCO and AREVA. ETC comprises all of URENCO's centrifuge design, manufacturing and related research and development. These two large-scale black-box enrichment plants could serve as models for innovative multinational arrangements and advanced approaches to the protection of sensitive technology.

A model multilateral uranium enrichment facility would be a jointly owned facility in which no partner has a controlling interest (as in holding a majority of shares). All partners would participate in management, operation, decision-making and profit-sharing, while black-box enrichment technology would be supplied by an acknowledged technology holder. This model is largely similar to that used by Germany for its proposed multilateral enrichment plant.

Back-end arrangements

Despite the fact that most states are satisfied with the current situation and acknowledge that the international market of front-end fuel-cycle services works well, the majority of proposals on multilateral approaches to the nuclear fuel cycle cover only front-end issues. The problems associated with the world's growing inventory of spent fuel remain mostly disregarded, even while the management of spent fuel is one of the greatest challenges of nuclear power. Multilateral solutions to back-end fuel-cycle problems could provide substantial benefits to both supplier and non-supplier states.

Nuclear fuel leasing arrangements, where suppliers fabricate and deliver fresh nuclear fuel to non-supplier states with nuclear reactors and then take back the used fuel after it has been irradiated, could potentially be very attractive for many states, but today suppliers are unwilling to take back spent fuel because they do not have readily available long-term solutions for this fuel, such as functioning geological repositories. Establishing geological repositories is politically and technically challenging, as the termination of the US$ 8 billion Yucca Mountain project in the United States has demonstrated.

But there could be room for the multilateral interim storage projects. Current technologies for dry interim storage are well developed and are already in use in a number of countries. An international interim storage facility could be a first practical step towards a multilateral back end for the nuclear fuel cycle. Such a facility could provide additional opportunities for states having problems with storage and disposal of spent nuclear fuel, as well as time for further scientific and technological advances in managing spent fuel and radioactive wastes. It could also prevent some states currently facing difficulties in expanding storage capacity, such as the Republic of Korea, from rushing into the more sensitive and economically questionable reprocessing of spent nuclear fuel.

In general, multilateral back-end arrangements could be more attractive for potential customers than front-end ones. Ambassador Leslie Mbangambi Gumbi, a consistent critic of multilateral approaches, surprisingly said that "the multilateralization of the nuclear fuel cycle could help in limiting the spread of the problem of dealing with problems at the back end of the nuclear fuel cycle such as spent fuel and radioactive waste".[82]

BILATERAL NUCLEAR COOPERATION AGREEMENTS AND MULTILATERALIZATION

In his "Atoms for Peace" speech in December 1953, US President Dwight Eisenhower encouraged nuclear supplier states to promote international cooperation with non-supplier states. This laid the ground for the widespread dissemination of civilian nuclear knowledge and technology mostly through bilateral cooperation among states. Since the 1950s more than 2,200 bilateral civilian nuclear cooperation agreements (NCAs) have been signed to govern the exchange of nuclear technology, materials or

knowledge for peaceful purposes. Recently, with a nuclear renaissance on the horizon, such agreements have been signed more rapidly. About 400 agreements were signed between 2000 and 2008.

Some researchers argue that all types of civilian nuclear assistance raise the risks of nuclear proliferation because such cooperation provides states with nuclear technology and material, and helps establish expertise and infrastructure that could be used for weapon-related purposes.[83] Nevertheless, the more common opinion is that NCAs are rather innocuous from a non-proliferation standpoint because nuclear suppliers generally restrict transfers of sensitive nuclear technologies, such as uranium enrichment and plutonium separation, which can be used to produce weapon-usable fissile materials.

Both supplier and non-supplier states consider NCAs as principal vehicles to realize the right of NPT states parties to use nuclear energy for peaceful purposes. For example, the United States has made it clear that it sees "great value in having the US government and US industry deeply involved in the nuclear programs of developing countries, to help create high standards for safety and security and nonproliferation".[84]

In 2009 the United States signed an NCA with the United Arab Emirates. According to this agreement, the United Arab Emirates commits not to enrich uranium or reprocess spent fuel and not to hold these sensitive technologies. Some governmental officials and non-proliferation advocates rushed to assert that this NCA should be a "global gold standard" for all future NCAs.[85] But subsequently a number of states (Jordan, Saudi Arabia and Viet Nam) refused to include these non-proliferation conditions in their civilian NCAs with the United States. The Republic of Korea, for example, wants to renew its cooperative agreement with the United States, which expires in 2014, on new terms to allow the reprocessing of US-supplied nuclear fuel.

Other established nuclear suppliers, such as France and the Russian Federation, may decline to adopt more stringent non-proliferation standards in NCAs they sign with non-nuclear-weapon states. States such as China and the Republic of Korea have become more assertive in pursuing their interests in the international nuclear market, thus making competition tougher. Moreover, the geopolitical and economic interests of states may be out of sync with non-proliferation concerns and powerful

states could use their political and economic weight to pressure others, even through multinational bodies such as the Nuclear Suppliers Group. Under pressure from states such as France, the Russian Federation, the United Kingdom and the United States, for example, other members of the Group agreed to give a waiver to India in 2008, thus not requiring India to have full-scope IAEA safeguards as a pre-condition for Group members to export nuclear material and fuel for use in Indian civilian nuclear facilities. None of the Group members had the appetite to confront China over the Sino–Pakistani nuclear reactor deal in 2010.

Even Japan is now struggling to find a balance between stringent non-proliferation standards and the necessity to find more export destinations for nuclear equipment in order to boost the national economy, as the country has entered into talks with India on an NCA. India has signed neither the NPT nor the Comprehensive Nuclear-Test-Ban Treaty and still produces weapon-grade nuclear materials, which makes Japan hesitant. However, the United States and France have urged Japan to sign a nuclear deal with India, a move that would clear the way for General Electric and AREVA to use Japanese suppliers for Indian nuclear projects.

The state of geopolitics and the desire to sell nuclear technologies amid tough international competition behind NCAs may eventually lead to the weakening of non-proliferation standards, allowing for easier transfer of sensitive nuclear technologies. This would offer non-supplier states an alternative and relatively cheap way—at least compared with the cost of nuclear power plants—to acquire domestic fuel cycles, thus reducing the attractiveness of multilateral fuel-cycle arrangements.

TECHNICAL AND LEGAL ISSUES

Notwithstanding the potential benefits, multilateralization of the nuclear fuel cycle raises important questions and issues. Here are three important questions that will need to be resolved for every multilateral facility:

- by what criteria would states be eligible or ineligible to participate;
- on whose territory should the facility be (or whether it should be extraterritorial); and
- how much would technology be shared at the facility, if at all.

(For a deeper discussion on the questions surrounding the establishment and operation of multilateral facilities, see the previous book in this series: Yury Yudin, *Multilateralization of the Nuclear Fuel Cycle: The First Practical Steps*, UNIDIR, 2011.)

Whereas choices on these issues have already been made for existing multinational facilities such as those of URENCO, EURODIF and the Russian Federation, not all of them are completely satisfactory for advocates of the multilateralization of the nuclear fuel cycle.

Eligibility

The definition and application of a set of criteria for participation in multilateral fuel-cycle arrangements are outstanding tasks. Recently developed multilateral mechanisms—the IUEC, the IAEA LEU bank and the Russian LEU reserve—have similar but not identical eligibility criteria.

Article 5 of the founding document of the IUEC—the Agreement between the Government of the Republic of Kazakhstan and the Government of the Russian Federation on Foundation of the International Uranium Enrichment Center—stipulates that "The Center is open for interested entities of the third states that perform the obligations under the Nuclear Weapons Non-Proliferation Treaty of July 1, 1968 and share the objectives and tasks of the Center". This implies that IUEC partners should be NPT states parties, both nuclear-weapon states and non-nuclear-weapon states can participate, non-nuclear-weapon states should have comprehensive, or full-scope, safeguards agreements with the IAEA, and as the phrase "perform the obligations" implies, all IUEC partners should be in good standing with their IAEA safeguards obligations as indicated in the Agency's safeguards implementation reports.

The founding document of the IAEA LEU bank, on the other hand, mentions the following criteria that member states of the Agency have to fulfil in exchange for LEU supplies:

> 19. LEU from the IAEA LEU bank, as a mechanism of last resort, shall only be supplied to a Member State:
>
> (a) that is experiencing a supply disruption of LEU to a nuclear power plant due to exceptional circumstances impacting availability and/or

> transfer and is unable to secure LEU from the commercial market, State-to-State arrangements, or by any other such means;
>
> (b) with respect to which the Agency has drawn the conclusion in the most recent Safeguards Implementation Report (SIR) that there has been no diversion of declared nuclear material and no issues relating to safeguards implementation in that Member State are under consideration by the Board of Governors;
>
> (c) that has brought into force a comprehensive safeguards agreement requiring the application of safeguards to all its peaceful nuclear activities and pursuant to which safeguards are to be applied to the LEU that is supplied through the IAEA LEU bank; and
>
> (d) for which the Director General has concluded that the Member State fulfils the criteria listed in sub-paragraphs (a), (b) and (c) above.[86]

Thus, a state should be an IAEA member state and an NPT non-nuclear-weapon state party (as per the requirement to enforce a comprehensive safeguards agreement) that is in good standing with its IAEA safeguards obligations to be eligible for LEU from the bank.

LEU from the Russian guaranteed reserve can be supplied to:

> IAEA Member States, with respect to which the IAEA has drawn the conclusion that there has been no diversion of declared nuclear material and concerning which no issues are under consideration by the IAEA Board of Governors relating to the application of IAEA safeguards. The LEU could be transferred to any non-nuclear-weapon State only when the receiving State has brought into force an agreement with the IAEA requiring the application of safeguards on all its peaceful nuclear activities.[87]

NPT membership and the enforcement of a comprehensive safeguards agreement are not required. For example, India, which is an IAEA member state, a non-NPT state and a non-nuclear-weapon state according to the definition of article IX of the NPT, and which has placed all its peaceful nuclear activities under IAEA safeguards, could be considered as eligible to participate.

Certainly, eligibility criteria for participation in multilateral arrangements should not be too restrictive because this would be the best way to defeat

the whole undertaking. They can vary from one multilateral arrangement to another. As for the three considered mechanisms, they have only one common criterion: a state's good standing with IAEA safeguards obligations. Should they have other common criteria as well? Should only NPT states parties participate, or could non-NPT states be allowed to take advantage of these mechanisms as well? Some non-supplier states argue for the former. Ambassador Leslie Mbangambi Gumbi, for example, stressed that "it is a cause of concern that the proposals [for multilateral approaches to the nuclear fuel cycle] are generally silent on NPT membership and the requirement to have comprehensive safeguards agreements with the Agency".[88] If non-NPT states and states not in good standing with the IAEA are allowed to participate, many NPT state parties would see that as rewarding the "bad behaviour" of those states. But totally excluding such states may be counterproductive as well, as this could stimulate the development of independent fuel-cycle capabilities. Moreover, we have already seen some non-NPT states participate in bilateral nuclear cooperation, as in the cases of India and Pakistan. These and similar bilateral arrangements that may follow will help further develop national fuel cycles of those states, although it might be more prudent to cooperate under multilateral instead of bilateral arrangements.

The challenges, promises and possibilities of involvement in multilateral fuel-cycle mechanisms of non-NPT states and states not currently in good standing with the IAEA deserve to be thoroughly discussed.

Location of facilities

Decisions on the location of multilateral nuclear fuel-cycle facilities have to take into account constraints ranging from existing nuclear infrastructure, the safety and non-proliferation record of potential hosts, ease of access to facilities, quality of governance and "political attractiveness".

A politically attractive location for a multilateral facility is one that will provide a palatable compromise between supplier states' fears of non-proliferation and the Non-Aligned Movement and G-77 states' constant concerns over cartelization. There will never be a perfect balance, but designing and negotiating a multilateral facility in a participatory manner (that is, among suppliers and non-suppliers) will enhance prospects for success and reduce risks of diplomatic opposition and stalemate.

From the point of view of balance, it is desirable that the host state would not be a supplier of enrichment services, so as to make the proposal acceptable to non-supplier states. NPT states parties are already committed by article IV, paragraph 2, to favour "the developing areas of the world". In technical and economic terms, it is highly desirable that the host state has a nuclear infrastructure and expertise in safe and secure storage, handling and transportation of nuclear materials. In this case it should also have appropriate legal frameworks, both legislative and regulatory.

Existing nuclear infrastructure would allow for a reduction in the costs of establishing the facility and for the training of local personnel, as it is not expected that most of the personnel at the facility would be foreign. Also, appropriate nuclear safety and security would need to be assured by the host state's nuclear regulatory authority. Still, other than the technical and economic considerations, there is no reason to exclude states that do not already possess nuclear technology.

The host state should be an IAEA member state with both the IAEA safeguard agreement and the additional protocol in force. It should also be party to relevant international agreements, such as the Vienna Convention on Civil Liability for Nuclear Damage, the Convention on Nuclear Safety, the Convention on the Physical Protection of Nuclear Material and the Convention on Early Notification of a Nuclear Accident.

The host state agreement needed to establish a multilateral nuclear fuel-cycle facility could be either a part of the founding agreement or a separate legal document. It should address the rights and responsibilities of the host state, cover the issue of liability for nuclear damage as well as corresponding privileges and immunities for partners. The host state should have the right to pull out of the partnership provided that an appropriate amount of time is allowed to relocate the facility and that issues related to covering the costs of relocation are resolved.

Safety must be one of the prime considerations. In general, sites prone to natural disasters, such as earthquakes, are better excluded, but this need not disqualify whole countries. Sea access, so that no neighbouring state can block the transport of nuclear materials, could be taken into consideration. However, the importance of this factor would depend on the transit agreements with the host state's neighbours.

Other economic issues, such as energy, transportation, communications infrastructure and expected costs of construction and operation of the facility in comparison to other states should also be considered because the facility has to be competitive on the international or regional market.

The support of the local population is important. Even though the government of the host state has to ensure the feasibility of the project, strong opposition from the population could endanger long-term political support and complicate the operation of a multilateral facility.

The German multilateral enrichment proposal envisages a facility established in an extraterritorial area under IAEA supervision. According to the proposal, "a host country would cede the administration and certain sovereign rights to the IAEA in a part of its territory". The host state would have to transfer functional immunities to the IAEA to such an extent that the operation of the enrichment plant would be protected from any potential interference by the host state or others. The IAEA, in this case, would act as the nuclear regulator and supervisor for the operation of the enrichment facility, a role which is normally carried out by a state body. The Agency would "be responsible for licensing, inspection, enforcement, and import and export controls", although some of these tasks could be delegated to host state authorities. Although having a multilateral fuel-cycle facility in an extraterritorial area would provide additional assurances against its takeover by the host state, the German proposal entails numerous complicating legal and practical issues that have to be resolved. It is not clear what would be the legal status of the territory, how an international organization like the IAEA would manage it and who would provide protection as well as basic support services such as electricity, heating and sewage.

Christopher Paine and Thomas Cochran of the Natural Resources Defense Council recently proposed a similar idea of states granting to an international agency exclusive extraterritorial rights to sites where sensitive fuel-cycle activities are conducted, similar in some respects to the right of governments to maintain and secure their embassies in other countries.[89] Extraterritorial sites would be leased by the agency for the duration of construction, operation and decommissioning of the sensitive fuel-cycle facility, and the agency would provide continuous close monitoring and non-proliferation assurances for all fuel-cycle activities that would come

under its purview. However, it would not interfere with normal day-to-day operations of fuel-cycle facilities and management of those sites.

Establishing multilateral sensitive fuel-cycle facilities in extraterritorial sites would increase the potential costs should a host state contemplate expelling multilateral partners and taking over the facility. The advantages and disadvantages of this approach fall outside the scope of this study but are worthy of discussion.

Technology sharing and protection

Most proposals for multilateral fuel-cycle facilities depend on a black-box approach, in which sensitive technology is supplied to a host state on a pre-fabricated basis and operators do not have access to any information related to its design and manufacture. At the end of a facility's operational life, the operator will call on the technology holder to "declassify" the facility before the operator can start decommissioning the plant. But black boxing is no silver bullet and has its own limitations, as it could help develop national expertise and know-how on the production of weapon-grade materials even without giving away information on how to design and manufacture sensitive nuclear equipment.

For uranium enrichment, the black-box method is not without its own proliferation risk. This method prevents the facility operator from learning how to make centrifuges. But the technology holder will need to provide the operator with the necessary information to enable it to operate the enrichment plants safely and efficiently. Once the operator gets a working centrifuge cascade it does not really need to know how to make centrifuges. Modern centrifuges are very reliable and even if some small percentage of them breaks with time this would not have a significant effect on the performance of the whole cascade. And at some point the host state could get rid of multinational partners and the IAEA and it could redesign the cascade—which would not require very clever engineering and would not take very long—to make it produce high-enriched uranium instead of low-enriched uranium. For modern enrichment cascades, that could be achieved in one to three years depending on experience and engineering expertise.[90] Of course, the multinational partners and the IAEA would immediately be aware of the host state's intentions because it would first have to take over the facility. This would give the international community time to organize and coordinate some form of response.

Could this risk be reduced by, for example, staffing the most sensitive operational areas with personnel representing all multinational partners? What technical features, if any, could be included into centrifuges to make them more proliferation resistant in the case of a black-boxed facility being taken-over? These and similar questions should be thoroughly studied by technology holders and the IAEA.

Nevertheless, the problem of technology transfer will remain. As noted earlier, many non-nuclear-weapon states have repeatedly criticized supplier states for their failure to ensure "unimpeded and non-discriminatory transfer of nuclear technology" for peaceful purposes. Would those states be satisfied with the black-box method, where technology holders would retain their superior capabilities even in the case of comprehensive multilateralization of the nuclear fuel cycle?

Still, from the non-proliferation point of view, the black-box concept is desirable because it limits the spread of technology. It is also desirable from the point of view of peaceful uses of nuclear energy, because it can allow non-discriminatory access to the benefits of peaceful applications of nuclear technology. The protection of technology already happens in other fields. All over the world people benefit from airplanes and computers without insisting on transfer of technology. While nuclear technology has been widely perceived as a special technology, one cannot force the technology holder to sell the technology when the they only want to share its benefits and products. Non-supplier states do not enjoy the absolute right to automatically acquire the technology, nor is acquisition necessary to be able to benefit from its products. Taking into account the proliferation implications of sensitive nuclear technology, its sharing among all multilateral partners would lead to its unwarranted spread, thus increasing risks of nuclear proliferation and defeating the whole undertaking.

Considering the long and difficult history of this issue, the problem of technology sharing and non-proliferation may prove to have no solution that would be satisfactory for every state and, therefore, to be another serious obstacle in the way of multilateralization of the nuclear fuel cycle.

CONCLUSIONS

1. Despite recent success in the implementation of a few proposals for multilateral mechanisms for assuring the supply of LEU, the fate of multilateral approaches to the nuclear fuel cycle is far from clear. Supplier states do not have a coherent policy on the issue and do not show any interest in discussing the conversion of their national fuel-cycle facilities to multilateral operations. Non-supplier states resist multilateral approaches because of fears of possible infringement on their right to peaceful nuclear research and development under article IV of the NPT. The general lack of political will and the disinclination of states to renounce sovereign control over nuclear technology are among the strongest barriers to multilateralization.

2. To overcome this unwillingness and engender political will towards multilateralization, it will be necessary to build a broad coalition of states, which would include both supplier and non-supplier states, with a politically attractive and economically sound strategy towards multilateralization of the nuclear fuel cycle. The creation of this coalition could be spearheaded by dedicated efforts on the part of a few politically influential states.

3. Despite its role as the world's centre of cooperation in the nuclear field, the IAEA should not be the only forum for discussions on the development of multilateral approaches to the nuclear fuel cycle. Other political fora, such as various international and regional political organizations, academia, think tanks and the nuclear industry should be engaged more intensely.

4. Assuming that political will can be engendered, an incentive-driven approach to multilateralization must put a premium on the benefits of joining multilateral ventures and foregoing the establishment of national nuclear facilities. These benefits might include higher likelihood of attracting direct foreign investment, and opportunities to form lucrative trade pacts and gain membership in significant regional organizations. As membership in multilateral fuel-cycle facilities expands over time, it may become a trend. The opportunity cost for the states that do not join would increase.

5. Assurances of fuel supply in the form of additional guaranties from suppliers and LEU banks are likely to have only limited impact on states' decisions to develop sensitive nuclear technologies. Nevertheless, fuel assurance arrangements should be further promoted because they still could be attractive for some states that may be concerned about security of supply. If successful, such arrangements could encourage further developments on the issue of multilateralization of the nuclear fuel cycle.

6. As developing an international norm to have all sensitive fuel cycle facilities internationalized appears unlikely in the current political climate, a gradual approach to multilateralization should be taken. Serious consideration should be given to placing enrichment and reprocessing facilities under some form of multilateral control. Multilateral facilities can help limit the spread of domestic sensitive nuclear technologies, simultaneously providing all states with non-discriminatory access to the benefits of peaceful applications of nuclear technology.

7. The establishment of multilateral fuel cycle facilities raises important legal, economic and technical issues. States with no previous experience with nuclear energy operations that want to engage in a multilateral fuel-cycle venture will require resources from which to develop the necessary expertise. The support of the current technology holders will therefore be crucial.

8. To strengthen the protection of sensitive technology, protection provisions will have to be part of discussions on multilateral approaches at the earliest stages. The IAEA and the nuclear industry should further scrutinize the black-box approach to work out the optimum procedures for safeguarding and protection.

9. The scarcity of proposals on multilateral approaches to the back end of the nuclear fuel cycle is an outstanding gap in existing multilateral concepts. While most states are reasonably satisfied with the assurance of supply available from existing market arrangements, multilateral back-end arrangements, such as lease and take-back of nuclear fuel and international interim storage of spent nuclear fuel, could be more attractive for potential customers than front-end arrangements, and accordingly could be a vehicle for moving the whole undertaking forward.

An international or regional spent fuel storage/disposal facility would reduce the perceived need on the part of some states for the reprocessing of spent fuel, because one of the greatest incentives for reprocessing is the temporary relief that it offers from the accumulation of spent fuel. The feasibility of multilateral spent fuel storage/disposal facilities and other multilateral back-end arrangements should therefore be seriously explored.

10. Approaching the question of multilateralization of the fuel cycle would be better served by soliciting ideas, interests, preferences and the like from states in a given region rather than offering "take it or leave it" options. In the aftermath of the Fukushima accident, time may be on our side and we should not miss the opportunity to facilitate safe, secure access to nuclear energy while strengthening barriers to its military uses.

PART II

PROSPECTS FOR MULTILATERALIZATION IN EASTERN AND SOUTH-EASTERN ASIA

OPPORTUNITIES FOR NUCLEAR COOPERATION IN EASTERN AND SOUTH-EASTERN ASIA*

Politics aside, Eastern and South-Eastern Asia currently present perhaps the most diverse opportunities for regional nuclear cooperation, particularly for multilateral fuel cycle arrangements.

Steady expansion of nuclear power is expected in the region in the coming years. According to the World Nuclear Association, of 154 nuclear power reactors planned worldwide as of July 2011—meaning approval, funding or major commitments are in place and commissioning of the reactors into commercial operation can be expected within the next 10 years or so—72 are in Eastern and South-Eastern Asia. For nuclear power reactors currently under construction, 35 out of 63 are located in the region (see annex C for an overview of existing and projected state nuclear programmes there).[1] The region is home to the world's "locomotive" of nuclear expansion, China. While today only a small portion of its electricity is produced by nuclear reactors, China's future plans, which include 27 nuclear power reactors under construction, with an additional 52 being planned and 120 proposed,[2] are very impressive.

The expansion of nuclear power in the region is driven by a number of factors:

- many states of the region face steep growth in energy demand and are trying to expand their generating capacity using all possible energy sources to power growing economies and populations;
- in many states, domestic sources of energy are very limited, and thus the states are dependent on imported fuels, which makes energy supply security and the development of energy independence a high priority;
- concerns over environmental problems from the use of fossil fuels and the increased awareness of the dangers and negative effects of global warming and anthropogenic climate change stimulate the search for energy sources with reduced atmospheric emissions; and

* Prepared with the valuable assistance of Anna Stockklauser.

- building nuclear reactors and fuel cycle facilities could be perceived by some states as a way to catch up with more developed states, to increase their rank, role and prestige internationally.

In the mid-term, these driving forces will most likely continue to affect regional energy policies and maintain interest in nuclear energy among regional players. Moreover, a relative weakness of democratic institutions and civil society in many countries of this region, as compared with countries in Europe and Northern America, makes it easier for governments and nuclear industry to pursue their chosen policies, even after events as momentous as the nuclear accident at the Japanese Fukushima Daiichi nuclear power plant.

The states of Eastern and South-Eastern Asia are quite varied with regard to nuclear weapons, nuclear power and sensitive nuclear technologies. Among them are:

- a Treaty on the Non-Proliferation of Nuclear Weapons (NPT) nuclear-weapon state, having nuclear power and sensitive nuclear technologies and facilities (China);
- a non-NPT state possessing nuclear explosive devices, if not deliverable nuclear weapons, not having nuclear power but having sensitive nuclear technologies and facilities (the Democratic People's Republic of Korea);[3]
- an NPT non-nuclear-weapon state, having nuclear power and sensitive nuclear technologies and facilities (Japan);
- an NPT non-nuclear-weapon state having nuclear power but having no sensitive nuclear technologies and facilities (the Republic of Korea); and
- NPT non-nuclear-weapon states having no nuclear power and no sensitive nuclear technologies and facilities, some of which are seriously considering embarking on nuclear power programmes (among them Indonesia, Malaysia and Viet Nam).

The regional diversity in the level of use of nuclear energy may present several opportunities for development of regional multilateral fuel cycle arrangements. Concerning the front end of the fuel cycle, the growing number of nuclear power reactors will require securing a steady supply

of enriched uranium for their operation. The desire to ensure security of fuel supply and to reduce dependence on foreign suppliers may give an impetus to more states in the region to embark on the development of their own uranium enrichment capacity. Even putting aside the fact that such developments would increase proliferation risks and further exacerbate the security situation, as gas centrifuge facilities, the prevailing uranium enrichment technology today, are difficult to detect and verify and can easily be converted from peaceful to military use, a state embarking on the development of domestic fuel cycle technologies, especially uranium enrichment, would inevitably be several decades behind state-of-the-art centrifuge technology. Thus, such a state most likely would not be able to compete with established suppliers of uranium enrichment services because its domestically produced enriched uranium would be more expensive.

The establishment of a multilateral regional enrichment facility could reduce the dependence on foreign suppliers and give all partners assured access to enrichment services and opportunities to participate in management and operation of a uranium enrichment plant. To be competitive, such a plant would need to have modern centrifuge technology. While several states in the region have centrifugal enrichment facilities, none of them supply enrichment services on the international market. Numerous problems with malfunctioning centrifuges at Japan's Rokkasho Uranium Enrichment Plant forced the facility to cease production of enriched uranium as of December 2010.[4] China does not have its own centrifugal enrichment technology but operates two centrifuge enrichment facilities supplied by Russia.

With no regional holders of state-of-the-art centrifuge technology, the technology for a multilateral plant could be supplied by Techsnabexport or URENCO, which have supplied centrifuge equipment on a "black box" basis in the past—Russia has built two enrichment facilities in China, and the Enrichment Technology Company), a joint venture of URENCO and AREVA, has provided the technology for two enrichment plants in the United States and for one plant in France.

Concerning the back end of the fuel cycle, there is the question of the disposition of spent fuel. Several operators of nuclear power plants in the region already face serious problems in dealing with their spent nuclear fuel as expanding storage capacity on their territories presents major political challenges. Nuclear newcomer states will inevitably have the same

problems in the future. Establishing a centralized, regional interim storage facility or geological repository could alleviate political tensions around this problem. Such storage facility could also reduce the perceived need for the reprocessing of spent fuel, as one of the greatest incentives of reprocessing is relief from accumulation of spent fuel. If a site could be found in the region for mid- or long-term storage or disposition of spent fuel, a regional facility could allow partners to achieve substantial economies of scale by sharing fixed capital costs, operating costs and financial liabilities.

There are, however, certain ethical and fairness issues that come into play. There is a common perception that countries that utilize nuclear power should bear the burden of handling their spent fuel and radioactive waste. The proposal of a regional facility could result in public opposition to the creation of what might be perceived as a nuclear "dump". To obtain public and political support, a regional multilateral arrangement for a spent fuel facility would have to be based on a fair sharing of benefits and obligations among the partners, including the host state. The facility would have to be built according to the highest standards of safety and security, and the host country should expect to receive significant income through payments from participating states.

As well, some states in the region engage or are interested in spent fuel reprocessing. China and Japan have facilities to reprocess spent fuel from commercial power reactors, while the Republic of Korea is debating whether to reprocess its spent fuel. The reprocessing of spent nuclear fuel is one the most controversial fuel cycle activities from the non-proliferation standpoint because of the resulting stocks of separated plutonium, which raise the possibility of states having a relatively "easy" path to nuclear weapon capability given the nature of the material.

There are several reasons that states in Eastern and South-Eastern Asia might want to pursue reprocessing. First, they could be seeking a way to resolve the problem of spent fuel storage. Plutonium separated from spent fuel could be recycled into mixed plutonium–uranium oxide fuel for light-water nuclear reactors. However, the economics of such recycling is debatable, and a "twice-through", instead of "once-through", fuel cycle does not dramatically reduce the amount of spent fuel to be disposed of.

Second, states might desire to recycle reprocessed plutonium, uranium and other actinides into fuel for a type of nuclear reactor called a fast neutron

breeder reactor, thus closing the nuclear fuel cycle by breeding nuclear fuels from abundant sources of depleted uranium and thorium, and reducing the total radiotoxicity of nuclear waste. However, after several decades of research and development and the investment of billions of dollars, the promise of an economically competitive, safe and reliable fast breeder reactor remains largely unfulfilled. Nevertheless, some states in Eastern and South-Eastern Asia, notably China, Japan and the Republic of Korea, continue their efforts to commercialize this type of reactor.

If states in the region are going to pursue the reprocessing of spent fuel, doing so in a multilateral manner could offer certain economic and security benefits. As with a regional storage/disposal facility, a multilateral regional reprocessing facility could allow partners to achieve substantial economies of scale by sharing fixed capital costs, operating costs and financial liabilities. Its partners would be under a greater degree of peer scrutiny, making it difficult and risky to cheat, and would allow for reduced suspicions over states' motives for reprocessing. Of course, the reprocessing facility and technology, as well as the produced material, would have to be under appropriate multilateral controls.

Some states in the region have already expressed their interest in multilateral arrangements for the nuclear fuel cycle. While the expansion of nuclear power in Eastern and South-Eastern Asia presents certain opportunities for regional multilateral fuel cycles arrangements, the practical realization may be endangered by political divisions and animosities, including disparities in states' perceptions of historical issues and territorial disputes. The region must also face unresolved non-proliferation issues, such as the Democratic People's Republic of Korea's nuclear programme and illicit transfers of sensitive nuclear technologies and materials.

In the mid-1990s several proposals for an Asian nuclear cooperation regime were put forward.[5] They varied according to the activities encompassed and the degree of cooperation involved, but all were focused on the idea of the creation of an "Asiatom", an Asian equivalent of Euratom, the European Atomic Energy Community. The proposal covered several spheres of potential cooperation: nuclear safety, energy distribution (interstate power grids), industrial cooperation (including research and development), regional safeguards and transparency measures, regional export controls, plutonium management, and spent fuel and radioactive waste management. None of these proposals have been implemented to a

significant degree, not least due to the disinclination of states in the region to make the political concessions necessary to build an effective nuclear cooperation regime.

However, there recently have been some encouraging signs in relation to nuclear cooperation in the region. In 2010, the Association of Southeast Asian Nations (ASEAN) agreed that the Nuclear Energy Cooperation Sub Sector Network (NEC-SSN) would serve as the key body in assisting ASEAN members in cooperation on civilian nuclear energy.[6] The first meeting of the Network was held on 18 February 2011 in Singapore. At a summit in Tokyo in May 2011, China, Japan and the Republic of Korea agreed to increase cooperation on nuclear safety.[7] The accident at the Fukushima Daiichi nuclear power plant in 2011 may provide impetus for deepening nuclear cooperation among the key regional nuclear powers. Starting from nuclear safety as the least politically controversial issue, this cooperation could then progress into more complex arrangements, perhaps including multilateral fuel-cycle facilities.

REGIONAL SURVEY ON MULTILATERAL FUEL CYCLE APPROACHES

To better understand the attitudes in the region towards multilateral approaches to the nuclear fuel cycle and to gauge the levels of support, a questionnaire was sent to 14 states in Eastern and South-Eastern Asia (Cambodia, China, the Democratic People's Republic of Korea, Indonesia, Japan, the Lao People's Democratic Republic, Malaysia, Mongolia, Myanmar, the Philippines, the Republic of Korea, Singapore, Thailand and Viet Nam). Brunei Darussalam and Timor-Leste were not included as neither have nuclear facilities of any kind, any nuclear infrastructure or any known plans or aspirations for nuclear power. The questionnaire was also sent to Chinese Taipei via the Taipei Cultural and Economic Delegation in Geneva.[8]

The questionnaire consisted of two parts (see annex B for the complete questionnaire). The focus of the first part, containing 13 questions, was on the general attitude of states towards the role that multilateral fuel-cycle approaches could play in reducing the threat of nuclear proliferation, facilitating the use of nuclear energy and contributing to economic development. The first part also addressed the questions of whether regional multilateral approaches would be more efficient in reducing proliferation risks and whether they would better correspond to states' interests than would global approaches.

The second part asked respondents to rate possible multilateral approaches in terms of feasibility, ability to prevent nuclear proliferation and concurrence with states' economic and development interests.

Seven states (Indonesia, Japan, Mongolia, Myanmar, the Philippines, the Republic of Korea and Thailand) returned completed questionnaires. China chose not to respond to the questionnaire, but instead to reiterate its official position on multilateral approaches (see p. 34). Cambodia and the Lao People's Democratic Republic stated that they do not have appropriate governmental offices to process the questionnaire. Singapore responded that it considered the questions too complex and politically sensitive to answer. There were no responses from the other states to

which the questionnaire was sent. A completed questionnaire was also received from the Atomic Energy Council of Chinese Taipei.

It should be noted that questionnaire responses should not be understood as official positions, but rather as indications of general opinion or sentiment.

COLLECTED RESPONSES TO PART I

The first question asked what were considered currently to be the greatest proliferation risks. Responses mentioned a broad range of factors. Nevertheless, several common concerns are apparent.

Most often mentioned was the threat of terrorist groups obtaining nuclear materials or nuclear weapons. Four respondents named this as the central or one of the central proliferation risks. One respondent expanded the issue to the state level and regarded nuclear materials or technology falling into the hands of determined proliferators, be they state or non-state actors, as the greatest proliferation risk. The illegal trafficking of nuclear material was also mentioned, indicating the same consequences.

The existence and continued production of nuclear weapons and weapon-grade nuclear material, and slow progress in nuclear disarmament, were also named by three respondents.

Three respondents also regarded the fact that certain states remain outside of the NPT and that nuclear-related activities of non-NPT parties are not under International Atomic Energy Agency (IAEA) safeguards as among the greatest risks.

It is interesting that the spread of sensitive fuel-cycle technologies and "virtual" nuclear weapon capabilities were not mentioned as proliferation risks. Perhaps it is believed that the development of such technologies by NPT non-nuclear-weapon states under IAEA safeguards does not pose a proliferation risk. None of the respondents mentioned the withdrawal of a state from the NPT as a proliferation risk. This differs from the belief of many Western officials and intellectuals that the spread of sensitive fuel-cycle technologies and the possible withdrawal of NPT parties are among the greatest proliferation risks.

The responses to questions 2 through 11 are summarized in table 1.

Table 1. Questions 2 through 11 of part I of the questionnaire

		Yes	No	Other*
2	Is the projected expansion of civilian nuclear power a potential threat in terms of nuclear proliferation?	4	4	
3	Can multilateral approaches to the nuclear fuel cycle reduce the threat of nuclear proliferation?	8		
4	Would multilateralization of the nuclear fuel cycle facilitate the peaceful use of nuclear energy and contribute to economic development?	7		1
5	Would multilateralization of the nuclear fuel cycle reduce the costs of nuclear energy?	6	1	1
6	Can regional multinational approaches to the nuclear fuel cycle reduce the threat of nuclear proliferation?	7		1
7	Is the implementation of regional multinational approaches more feasible than that of corresponding global approaches?	6		2
8	Are regional multinational approaches more efficient in reducing the proliferation risk than corresponding global approaches?	5	2	1
9	Do regional multinational approaches correspond to the interests of your state?	7	1	
10	Do regional multinational approaches correspond to the interests of Eastern and South-Eastern Asia?	6	2	
11	Is the implementation of regional approaches to the nuclear fuel cycle feasible in your region?	6	2	

* While "Other" was not a possible response listed in the questionnaire, some respondents indicated that certain questions could not be answered definitively yes or no.

The answer to question two was split among respondents, four considering the expansion of civilian nuclear power as a proliferation threat, and four not. However, two respondents answering "no" added that this would only be the case if effective safeguards were in place and if all nuclear material could be controlled to prevent "loopholes" in the international non-proliferation regime.

One respondent answering "yes" based this view on the fact that nuclear proliferation requires an active nuclear power industry base, thus an expanding base increases the risk. Another respondent drew a connection between an increased interest in civil nuclear energy and the spread of sensitive nuclear fuel-cycle technologies, which poses a proliferation risk.

The answers to this question reflect the dynamic, for example, at all recent NPT review conferences, where developed countries with established nuclear power industries generally tend to see a stronger risk of nuclear proliferation stemming from the peaceful use of nuclear energy than do less developed countries without, or with incipient, nuclear power programmes.

Answering question three, all respondents indicated the belief that multilateral approaches to the nuclear fuel cycle can reduce the threat of nuclear proliferation. This was the only question to receive a unanimous result without abstentions.

In comments to their answers, four respondents pointed out that multilateral alternatives would reduce the incentives for states to develop domestic nuclear fuel-cycle technology, which is costly and time consuming to develop. Such alternatives might limit the number of sensitive facilities, which would reduce the risk of diversion or theft of nuclear material. In general, it is more difficult to divert material from facilities that are owned by multiple states.

Two respondents mentioned the importance of multilateral approaches being in accordance with the right of states to pursue the development of nuclear technology for peaceful purposes. Another respondent emphasized that states must exercise their right to peaceful uses of nuclear energy "in strict accordance with the non-proliferation and safeguards agreements as contained in the NPT".

Two respondents emphasized transparency and "mutual trust" concerning the peaceful nature of enrichment and other nuclear fuel-cycle activities as important factors in the reduction of the proliferation threat, which could be promoted by multilateral approaches.

One respondent brought up the need to consider the political and economic viability of the approaches, because "unless the multilateral arrangement makes economic sense, addresses the real needs of states and is based on wide acceptance of the international community, there will be little effect on reducing proliferation risks as potential proliferators will likely remain outside the arrangement". Economic viability was also considered an important factor by another respondent, which in addition emphasized the potential of multinational approaches to solve spent fuel management problems for states with small-scale nuclear power programmes.

One respondent acknowledged that multilateral approaches would help in reducing the risk of nuclear proliferation but underlined that the realization of the nuclear disarmament commitment by the nuclear-weapon states, or at least concrete steps towards that goal in a verified manner, would constitute a more important factor in the reduction of the threat of proliferation.

Answering question four, all respondents but one supported the view that multilateralization of the nuclear fuel cycle would facilitate the peaceful use of nuclear energy and contribute to economic development. Two respondents viewed the reliable and affordable access to nuclear fuel—a front-end service—as the key mechanism of multilateral approaches that could facilitate the use of nuclear energy and contribute to economic development. Two other respondents based their view on the fact that multilateral approaches focusing on the back-end of the fuel cycle could help to solve spent-fuel management problems.

One respondent noted that the current proposals for multilateral approaches to the nuclear fuel cycle—many of which focus on supplying nuclear fuel under emergency circumstances arising from non-economic reasons—would be unlikely to have immediate and decisive impact on an actor's decision to pursue nuclear energy because they are designed only as back-up measures to the existing nuclear market. Therefore, the respondent likewise expressed the opinion that the current proposals

would have an effect on economic development, but it would most likely be in the long term.

One respondent underlined that a clear understanding of what is meant by "multilateralization" would be needed to answer the question. Nevertheless, this respondent added that, as far as mechanisms for assurance of nuclear fuel supply are concerned, they could "at least facilitate the use of nuclear energy when implemented as envisaged by the IAEA".

All respondents were positive that multilateral approaches to the nuclear fuel cycle could facilitate the peaceful use of nuclear energy, but in was noted by one respondent that the ability of such approaches to contribute to the economic development of states would depend on what goals were pursued by multilateral fuel cycle arrangements and how they would operate.

In answering question five, six respondents stated that multilateralization of the nuclear fuel cycle could reduce the costs of nuclear energy. A common view was that multinational facilities could provide the benefit of cost effectiveness and economies of scale, thereby reducing the financial burden on individual participants. It was noted, however, that the current proposals, which focus on the front end of the fuel cycle and on back-up mechanisms for the supply of fuel, would have little if any impact on reducing development and operating costs.

It was specifically noted by a respondent that proposed multilateral mechanisms that involve fuel take-back measures could particularly have the potential to significantly reduce operating costs as individual states would not have to build national spent-fuel storage/disposal facilities.

One respondent, which disagreed with the idea that multilateralization of the nuclear fuel cycle could reduce the costs of nuclear energy, expressed misgivings that multilateral approaches would result in higher costs compared to current market prices because multilateralization would impose more control on the nuclear fuel cycle (fuel fabrication, waste management and so forth), which could be costly.

The other respondent answering "no" argued that multilateral approaches could have both negative and positive effects on the costs of nuclear

energy depending on the level of multilateralization. The respondent's opinion was that the comprehensive denationalization of all existing fuel cycle facilities, as suggested by former IAEA Director General Mohamed ElBaradei, would certainly contribute to the reduction of cost of nuclear energy. However, the current proposals for multilateral approaches would "complicate and increase the cost of nuclear energy". The respondent did not elaborate on why the proposals might increase the cost of nuclear energy, but similar concerns have been expressed by some non-supplier states.[9]

Question six was similar to question three but asked specifically about regional approaches. The responses were almost unanimously positive. It was noted by a respondent that, in addition to the non-proliferation effects of multilateral approaches noted in answers to question 3, regional approaches, if successful, might "further contribute to reducing the threat of nuclear proliferation by serving as confidence building measure among participating states" by alleviating suspicions about the others' nuclear intentions.

One respondent stated that regional multilateral approaches involving spent-fuel management facilities would have a positive non-proliferation effect as compared to national spent-fuel management facilities "scattered in many countries".

The respondent answering "other" explained that a yes or no answer would depend on the region in question and noted that no regional multilateral approach has yet been implemented.

All but one respondent gave the same answer to questions 3 and 6. This indicates a general recognition by respondents of the potential effectiveness of both regional and global multilateral fuel-cycle approaches in terms of strengthening the non-proliferation regime.

Answering question seven, six respondents considered regional multilateral approaches to be more feasible than global approaches. One participant opposed this view, while another could not answer the question definitively.

The respondents that considered regional approaches more feasible largely based that answer on the assumption that states of a given region share

similar interests and needs and thus it would be easier to identify common ground for specific multilateral mechanisms that could be beneficial for all partners. One respondent considered regional approaches more feasible because it implies a limited number of participants while global approaches possibly have to balance the interests of a much larger number of participants.

Several respondents pointed out that the feasibility of regional multilateral fuel-cycle arrangements strongly depends on the region concerned, and its political and historical context. In some regions, where states have accumulated sufficient experience in multilateral cooperation, agreement on multilateral arrangements could be relatively easy to achieve. However, in other regions such cooperation may not be as easy due to a lack of trust among states. In that case, it was noted by a respondent, states may prefer to cooperate with like-minded states in global fuel-cycle frameworks rather than in regional arrangements.

Answering question eight, five respondents considered regional approaches to be more efficient than global in reducing the risk of proliferation. Several respondents stressed that regional multilateral fuel-cycle mechanisms could increase the effectiveness of IAEA safeguards. Referring to the belief that increased trust among states reduces the risk of nuclear proliferation, one respondent based its answer on the assumption that trust-building among regional partners could be easier than among global partners.

One respondent saw the smaller number of participants in regional arrangements as opposed to global arrangements as the key factor that makes regional approaches more efficient in reducing the proliferation risk. Another respondent stated that regional arrangements would be "less complex to undertake" and therefore potentially more efficient in the strengthening the non-proliferation regime at both the regional and the global level. It was noted by a respondent that a successful regional multilateral fuel cycle mechanism could potentially have a spill-over effect into other regions ultimately giving rise to a global multilateral framework.

Answering question nine, all respondents but one stated that regional approaches correspond to their interests. However, only four respondents felt that regional approaches better correspond to their interests than global approaches.

Two respondents specified that regional approaches would be especially beneficial if directed at the spent fuel and waste management aspects of the nuclear fuel cycle. However, regarding the front end of the fuel cycle, one of these respondents preferred global approaches, such as those under discussion at the IAEA, over regional approaches.

One respondent stated that regional fuel-cycle arrangements could be more efficient economically than global approaches and thus more beneficial for participants. The respondent emphasized that there have not been any concrete proposals for regional multilateral fuel-cycle approaches and that it is too early to determine whether a regional or a global multilateral approach would better suit the interests of states.

Answering question 10, six respondents stated that regional approaches correspond to the interests of Eastern and South-Eastern Asia. However, only four respondents felt that regional approaches better correspond to their interests than global approaches.

It was emphasized by a respondent that spent fuel management would be a big problem for most actors in Eastern and South-Eastern Asia and that regional approaches addressing back-end elements of the fuel cycle could be beneficial.

One respondent that replied "no" questioned whether the political situation in the region is "mature" enough to introduce a regional fuel-cycle framework, especially as many states in Eastern and South-Eastern Asia still lack experience in nuclear energy and might find little incentive to being involved in such a framework. At the same time, it was noted by a respondent that some regional actors not possessing sensitive fuel-cycle facilities might be uncomfortable with a situation where such facilities are concentrated in a small number of supplier states, and thus would prefer to establish a regional multilateral fuel-cycle mechanism with other non-supplier states.

Answering question 11, six respondents considered the implementation of a regional approach to the fuel cycle in Eastern and South-Eastern Asia to be feasible.

However, one respondent cited possible obstacles that may hamper or prevent such implementation: (1) lack of experience in regional

cooperation, (2) historical animosities and lack of trust among states in the region, (3) the gap in economic and nuclear energy development among states in the region; and (4) the unresolved nuclear issue of the Democratic People's Republic of Korea.

It was also noted by a respondent that the feasibility of regional approaches in Eastern and South-Eastern Asia may depend on the positions of states outside the region, for example the United States, which has bilateral nuclear cooperation agreements with many states in the region, which prohibit them from participating in certain fuel-cycle activities.

Answers to question 12 were diverse, with states from the region and from outside the region being mentioned as potential partners. The states that were most often indicated were China, Japan, the Republic of Korea, the Russian Federation and the United States. One respondent noted that, because there are no concrete proposals for regional multilateral arrangements, it is too early to consider specific states as potential partners. Another respondent emphasized that all states in the region could be considered as potential partners "except one state seeking nuclear weapons without accepting any IAEA safeguards nor complying with UN Security Council Resolutions".

Answering question 13 on the key reasons for non-nuclear-weapon states to develop domestic enrichment and reprocessing facilities, respondents were asked to choose among the following options:

- energy security;
- economic development;
- reduction of the cost of domestic nuclear energy production;
- national prestige; and
- creation of nuclear "hedge" capabilities against future security threats.

Three respondents selected energy security as the only motivation to develop domestic enrichment and reprocessing facilities. Two respondents selected energy security and economic development. One respondent selected the first three options. Two respondents indicated that all five factors may play role in taking decisions to develop domestic enrichment and reprocessing.

OVERVIEW OF RESPONSES TO PART I

The general feeling among respondents was that multilateral approaches to the nuclear fuel cycle can reduce the threat of nuclear proliferation, facilitate the peaceful use of nuclear energy and contribute to economic development.

One focus of this study was the question of whether regional multilateral approaches are generally preferred to global approaches and, if so, to what extent. The answers received to questions 6 through 10 show support for the idea of regional multilateral approaches. However, only half of the respondents preferred such to corresponding global approaches. However, the efficiency of regional approaches in reducing the risk of nuclear proliferation risk was generally considered to be higher than that of global approaches.

Even though no question of part I asked about preferences regarding front-end or back-end approaches, several respondents emphasized that the clearest benefits would result from multilateral approaches to the back end of the fuel cycle.

RESPONSES TO PART II

In part II of the questionnaire respondents were asked to rate 18 proposals for multilateral approaches to the nuclear fuel cycle in terms of:

- feasibility, rated from 1 (very infeasible) to 5 (very feasible);
- effectiveness, in terms of the prevention of nuclear proliferation, rated from 1 (very ineffective) to 5 (very effective);
- benefit, in terms of economic and nuclear development, rated from 1 (very disadvantageous) to 5 (very advantageous); and
- the level of support to be expected, all things considered, rated from 1 (strong opposition) to 5 (strong support).

In the following evaluation of the responses to part II, average scores up to 2.5 are termed negative, scores above 2.5 up to 3.5 neutral and scores above 3.5 positive. The majority of proposals were on average rated neutrally. If not otherwise specified in the following results the proposal was on average rated neutral.

Proposals 1–4: reserves of low enriched uranium

Proposal 1—An IAEA-administered, nationally owned and operated LEU bank accessible to all IAEA member states.

Proposal 2—An IAEA-owned and -operated LEU bank accessible to all IAEA member states.

Proposal 3—An IAEA-administered, nationally owned and operated LEU bank accessible to all states in good standing with their NPT obligations.

Proposal 4—An IAEA-owned and -operated international LEU bank accessible to all states in good standing with their NPT obligations.

Proposals 1 to 4 suggest ways that low-enriched uranium (LEU) banks, or reserves, could be organized.

Table 2. Average ratings of proposals 1–4

	Feasibility	Effectiveness	Benefit	Support
Proposal 1	**3.8**	3.3	3.3	3.4
Proposal 2	3.4	3.1	3.5	3.5
Proposal 3	**3.8**	**3.9**	3.5	**3.8**
Proposal 4	**3.6**	**3.9**	**3.8**	**3.8**

NB: <2.5 is considered a negative response, 2.5–3.5 neutral and >3.5 positive.

Two examples of LEU banks are the Russian guaranteed LEU reserve at Angarsk, which was inaugurated in December 2010, and the IAEA LEU bank, which is in the process of being established. Both banks are intended as mechanisms of last resort for states facing a disruption of supply of LEU for political reasons. They are designed as back-up mechanisms for the international market and should be triggered only in case normal commercial market supply mechanisms have failed. (For detailed discussion of these two LEU banks see annex A.)

Proposals 1 and 2 assume accessibility by all IAEA member states in good standing with their NPT obligations while proposals 3 and 4 limit access

to NPT states parties. Proposals 3 and 4 were rated more positively than proposals 1 and 2 in all four categories, that is they were considered to be more feasible, more effective in terms of non-proliferation, more beneficial in terms of economic and nuclear development, and to have more support.

However, there was no significant difference between the ratings of an IAEA-administered bank (proposals 1 and 3) and an IAEA-owned and -operated bank (proposals 2 and 4). The economic benefit of the latter was rated slightly higher, while the former were perceived as more feasible. The average ratings for these four proposals were not exceptionally high but on average were positive in all four categories, indicating general support among respondents for the establishment of LEU banks.

Proposals 5 and 6: additional guarantees provided by existing suppliers

Proposal 5—Internationally supervised additional guarantees of nuclear fuel, outside the LEU banks, provided by the existing suppliers to states that forswear enrichment and reprocessing.

Proposal 6—Internationally supervised additional guarantees of nuclear fuel, outside the LEU banks, provided by the existing suppliers to states that do not forswear enrichment and reprocessing.

Table 3. Average ratings of proposals 5–6

	Feasibility	Effectiveness	Benefit	Support
Proposal 5	3.3	**3.6**	3.4	3.4
Proposal 6	2.5	2.4	2.4	2.6

NB: <2.5 is considered a negative response, 2.5–3.5 neutral and >3.5 positive.

Proposals 5 and 6 concern internationally supervised guarantees for supplies of nuclear fuel, other than from established LEU banks, provided by existing supplier states. Proposal 5 would only allow states that forswear domestic enrichment and reprocessing to be eligible for such guarantees, while proposal 6 would not require states to forswear enrichment and reprocessing in order to participate.

The United Kingdom's nuclear fuel assurance proposal, which was recently approved by the IAEA Board of Governors, is based on the idea of additional guarantees to enhance the confidence of non-supplier states in commercial fuel supplies. (For detailed discussion see annex A.)

Proposal 6 was the only proposal that was on average rated negatively in all categories. It received no positive rating at all on effectiveness in terms of non-proliferation and on economic benefit. Proposal 5, on the other hand, received comparatively high scores among the proposals dealing with the front end of the nuclear fuel cycle. This allows the conclusion that the respondents favour multilateral supply guarantee mechanisms in which only states that forswear enrichment and reprocessing have access to fuel guarantees and that they consider this approach more feasible.

Considering the current direction of international discussions on multilateral approaches to the nuclear fuel cycle, the results regarding proposals 5 and 6 are surprising. Proposals requiring states to give up or accept limits to their rights regarding the peaceful use of nuclear power have met with strong opposition, especially from non-supplier states. The perception has been that nuclear suppliers are interested in requiring non-suppliers to forgo domestic development of sensitive technologies in order to impose on them new non-proliferation restrictions and preserve for themselves the selling of nuclear services and material on the international market.

Contrary to that perception, Japan, the only respondent with fully developed fuel-cycle technology, rated proposal 5 as disadvantageous for economic and development interests, ineffective in terms of strengthening non-proliferation and very infeasible. At the same time Japan rated proposal 6 neutrally. All other respondents that rated these proposals were non-suppliers, and their general preference of proposal 5 over proposal 6 is surprising. Even Indonesia, a powerful voice of the Non-Aligned Movement and a vocal critic of the existing proposals for multilateral approaches to the nuclear fuel cycle, did not make any distinction in rating proposals 5 and 6. This seems to suggest that not all non-supplier states will necessarily oppose multilateral arrangements that may require participating states to forgo the development of sensitive nuclear technologies.

Proposals 7 and 8: IAEA-administered multinational enrichment and reprocessing facilities

Proposal 7—IAEA-administered multinational enrichment facilities located in an extraterritorial area.

Proposal 8—IAEA-administered multinational reprocessing facilities located in an extraterritorial area.

Table 4. Average ratings of proposals 7–8

	Feasibility	Effectiveness	Benefit	Support
Proposal 7	3.3	**3.8**	3.4	3.5
Proposal 8	3.3	**3.8**	3.5	3.5

NB: <2.5 is considered a negative response, 2.5–3.5 neutral and >3.5 positive.

Proposals 7 and 8 concern IAEA-administered multinational facilities located in extraterritorial areas. While no proposal for a multinational reprocessing facility (proposal 8) has been put forward, the Multilateral Enrichment Sanctuary Project proposed by Germany corresponds to proposal 7. (For detailed discussion see annex A.)

Respondents perceived both proposals positively or neutrally in all categories. Effectiveness in terms of strengthening the non-proliferation regime received a positive average rating. The only respondent that rated both proposals negatively (in all categories) was Japan—the only respondent having domestic enrichment and reprocessing technology. Interestingly, all other respondents gave the two proposals practically the same ratings in all categories.

Proposals 9 and 10: regional multinational enrichment facilities

Proposal 9—Regional multinational enrichment centres with black-boxed enrichment technology provided by a well-known supplier.

Proposal 10—Regional multinational enrichment centres with all partners having equal access to enrichment technology.

Table 5. Average ratings of proposals 9–10

	Feasibility	Effectiveness	Benefit	Support
Proposal 9	3.0	3.3	3.3	3.4
Proposal 10	3.1	3.3	3.3	3.4

NB: <2.5 is considered a negative response, 2.5–3.5 neutral and >3.5 positive.

Proposals 9 and 10 concern the establishment of a regional multinational enrichment facilities, the difference between them being in the model of access to enrichment technology. Proposal 9 suggests black-box technology supplied by a well-known technology holder, so that none of the participating states would have access to enrichment technology. Proposal 10, on the other hand, would grant all partners equal access to the technology. The proposals are based on two existing models for multilateral uranium enrichment facilities—URENCO, where each of the partners (Germany, the Netherlands and the United Kingdom) owns and operates a gas centrifuge enrichment facility within its borders, and shares knowledge of centrifuge technology with the others; and EURODIF, which involves five participants (France, Italy, Spain, Belgium and Iran) but only one enrichment facility in France, with enrichment technology remaining under national control of the host state.

No significant difference was observed in the average ratings of these proposals in any category. Respondents generally expressed a preference for one of the two proposals, but the preference was not consistent—some rated proposal 10 higher, while others rated proposal 9 higher. Still, both proposals received relatively low scores in all categories, on average neutral. This is notably lower than the average scores for proposal 7 on an IAEA-administered (non-regional) multinational enrichment facility. It is interesting that no preference for regional facilities over global facilities was shown by the respondents.

As some respondents preferred a regional black-box facility, while others preferred equal access to enrichment technology, this suggests that, despite generally positive attitudes towards multilateral approaches, the interests and preferences of potential regional partners in Eastern and South-Eastern Asia may differ substantially when it comes to specific proposals.

Proposal 11: regional multinational reprocessing facilities

Proposal 11—Regional multinational reprocessing facilities.

Table 6. Average ratings of proposal 11

	Feasibility	Effectiveness	Benefit	Support
Proposal 11	3.0	3.5	3.4	3.5

NB: <2.5 is considered a negative response, 2.5–3.5 neutral and >3.5 positive.

Proposal 11 concerns regional reprocessing facilities and therefore relates to proposal 8. In general, the idea of a regional multilateral reprocessing facility received neutral or slightly positive ratings from respondents. Some respondents gave regional reprocessing facilities higher ratings in the categories of effectiveness and benefit but lower ratings in the category of feasibility.

As compared with proposal 8 on global multilateral reprocessing facilities, no clear preference for either type was observed. Japan, the only respondent having domestic reprocessing technology, rated proposal 8 as negative and proposal 11 as neutral. As for non-supplier respondents, some gave the same ratings to proposals 8 and 11, while some gave a slight preference to proposal 8 or proposal 11.

Proposal 12: nuclear fuel leasing and take-back offers

Proposal 12—Fuel leasing and take-back offers by multilaterally organized suppliers.

Table 7. Average ratings of proposal 12

	Feasibility	Effectiveness	Benefit	Support
Proposal 12	**4.1**	**4.3**	**4.1**	**3.9**

NB: <2.5 is considered a negative response, 2.5–3.5 neutral and >3.5 positive.

Proposals 12 to 16 deal with back-end elements of the nuclear fuel cycle other than reprocessing. Proposal 12 concerns fuel leasing and take-back

offers by multilaterally organized suppliers. Bilateral nuclear fuel take-back agreements currently exist between the Russian Federation and several states that use Russian-designed nuclear power reactors. The Russian Federation provides these states with nuclear fuel and agrees to take back the spent fuel and accept responsibility for its disposal. Proposal 12 goes one step further in suggesting that suppliers of nuclear fuel would operate within a multilateral framework to offer clients nuclear fuel leasing and take-back services. A similar idea was included in the international component of the United States' Global Nuclear Energy Partnership concept, which envisioned a consortium of states with advanced nuclear technology that would provide fuel services to states operating nuclear power reactors. It was essentially a fuel leasing approach, wherein the supplier takes responsibility for the final disposition of spent fuel.

Proposal 12 was the only proposal that was given overwhelmingly positive ratings by all respondents not having domestic fuel cycles. There was a strong consensus on its feasibility, its effectiveness in terms of non-proliferation and its economic benefit for the states. The only category in which the proposal did not exclusively receive positive scores was support, which was rated neutrally by two of the participating states. The only respondent that rated proposal 12 as neutral was Japan. But, altogether, proposal 12 received the highest ratings in all four categories.

Proposals 13–16: multilateral interim storage and long-term disposal of spent fuel and nuclear waste

Proposal 13—Global multinational interim storage of spent fuel and nuclear waste.

Proposal 14—Global multinational long-term geological repositories for spent fuel and nuclear waste.

Proposal 15—Regional multinational interim storage of spent fuel and nuclear waste.

Proposal 16—Regional multinational long-term geological repositories for spent fuel and nuclear waste.

Table 8. Average ratings of proposals 13–16

	Feasibility	Effectiveness	Benefit	Support
Proposal 13	3.3	**3.8**	**3.8**	3.4
Proposal 14	2.9	**3.9**	**3.9**	3.1
Proposal 15	3.5	**3.9**	**3.9**	**3.6**
Proposal 16	3.1	**3.9**	**4.0**	3.4

NB: <2.5 is considered a negative response, 2.5–3.5 neutral and >3.5 positive.

Proposals 13 to 16 deal with multilateral approaches to interim storage and long-term disposal of spent fuel and nuclear waste. Proposal 13 suggests global approaches to interim storage, and proposal 14 suggests global approaches to long-term geological repositories for final disposal of spent fuel and nuclear waste. Proposals 15 and 16 suggest respectively regional interim storage, and regional long-term disposal of spent fuel and nuclear waste.

The global nuclear industry has not yet found a satisfactory solution for the problem of interim storage and especially of long-term disposal of nuclear waste. Even on the national level the management of spent nuclear fuel and radioactive waste remains a pressing issue. Because of all the political and technological obstacles that the topic entails, few of the existing proposals have addressed the issue and none of the proposals currently being pursued involve the management of spent nuclear fuel or radioactive waste.

In the light of these considerations, the responses given on proposals 13 to 16 are not surprising. The effectiveness in terms of non-proliferation and economic benefit of all four proposals were almost unanimously rated positively. In these two categories the regional and global approaches were ranked almost identically. As could be expected, the ratings in the category feasibility were much lower and on average neutral. General support for the four proposals was also not very high and, on average, only positive for proposal 15. The two regional proposals, 15 and 16, were considered slightly more feasible and were more strongly supported than the global proposals.

Proposals 17 and 18: converting all future and existing sensitive fuel-cycle facilities to multilateral operations

Proposal 17—Limitation of all future nuclear enrichment and reprocessing facilities to multilateral facilities under IAEA safeguards.

Proposal 18—Conversion of all existing nuclear enrichment and reprocessing facilities currently under national control and into multinational facilities under IAEA safeguards.

Table 9. Average ratings of proposals 17–18

	Feasibility	Effectiveness	Benefit	Support
Proposal 17	3.0	**4.0**	**3.6**	3.3
Proposal 18	2.9	**4.1**	**4.0**	3.4

NB: <2.5 is considered a negative response, 2.5–3.5 neutral and >3.5 positive.

Proposal 17 suggests limiting all future nuclear enrichment and reprocessing to multilateral facilities under IAEA safeguards. Proposal 18 goes further by suggesting the conversion of all existing enrichment and reprocessing facilities currently under national control to multinational facilities under IAEA safeguards. These proposals correspond to stages two and three from the three-stage process proposed by former IAEA Director General Mohamed ElBaradei for developing a new framework for the utilization of the nuclear energy based on multilateral approaches.[10]

Proposals 17 and 18 were on average rated positively in the categories of effectiveness in terms of non-proliferation and of economic benefit. The feasibility of the both proposals received an average score about 3, with proposal 17 considered slightly more feasible. However, respondents considerably diverged in their assessments of feasibility giving ratings from 1 (very infeasible) to 5 (very feasible). Proposal 18 on average received higher ratings than proposal 17 in all categories except feasibility. With proposal 12, proposal 18 received the highest ratings for effectiveness and benefit. The only respondent that gave negative ratings to both proposals in all four categories was Japan, the only respondent having both enrichment or reprocessing facilities. It is noteworthy that Japan rated negatively the

effectiveness of these two proposals in strengthening the international non-proliferation regime.

Considering the current international debate on multilateralization of the nuclear fuel cycle, which is almost exclusively focused on rather modest back-up mechanisms of assurance of supply, and the observed disinclination of states to forgo the sovereign right to develop national fuel cycle facilities, it is surprising that the feasibility of both proposals received a neutral rating. In consideration of the generally positive support for proposal 18, it should to be noted that none of the respondents aside from Japan have enrichment or reprocessing facilities and would therefore not face any direct consequences from multilateralization.

BACK-END MECHANISMS VERSUS FRONT-END MECHANISMS

The proposals in part II of the questionnaire can be divided in two groups, one dealing with the front end of the fuel cycle, and the other with the back end. Proposals concerning the back end are 8 and 11, which deal with reprocessing facilities, and 12 to 16, which concern the management of spent fuel and radioactive waste. Proposals 17 and 18 also deal with reprocessing facilities, but in a more general way so they cannot be considered as exclusively back-end proposals for this analysis. All other proposals concerned the front end of the nuclear fuel cycle.

A significant difference was observed between the ratings of the proposals dealing with reprocessing facilities and those dealing with the storage or disposal of spent fuel and radioactive waste. The ratings that proposals 8 and 11 received did not stand out from similar front-end proposals and received neutral and positive average scores, none particularly high. The ratings of proposals 12 to 16, however, were considerably higher than the ratings of front-end proposals, especially in the categories of effectiveness and of benefit. Specifically, proposal 12 was the proposal rated highest in effectiveness, in benefit, in feasibility and in support.

REGIONAL VERSUS GLOBAL PROPOSALS

One focus of this study was to determine the support for regional as opposed to global multilateralization proposals. Part II of the questionnaire

allows a direct comparison in this regard through proposals 7, 8, 13 and 14 describing global approaches, as opposed to proposals 9, 10, 11, 15 and 16, describing regional approaches.

For proposals 7 to 11, which discuss enrichment and reprocessing facilities, a preference for the global approach was observed for both enrichment and reprocessing. For the back-end proposals 13 to 16, which suggest global and regional interim or long-term storage of spent fuel, feasibility and support for the regional proposals were ranked slightly higher, while no difference was noted in the ratings for economic benefit and effectiveness in terms of non-proliferation. However, the observed differences in the perception of regional versus global multilateral approaches are too small and too split among respondents to derive any general preference.

NON-RESPONDENTS

To better assess the attitude of regional actors to multilateral fuel-cycle approaches it would have been best to have fully completed questionnaires from all actors to which the questionnaire was sent. Unfortunately, 10 states did not respond. This raises a question: are the responses received representative of attitudes across the region? Perhaps only those actors supporting multilateral approaches responded while those that oppose them did not?

Among the respondents there are those having the full fuel cycle, those having nuclear power reactors but no sensitive fuel-cycle facilities and those that have neither nuclear power reactors nor sensitive fuel cycle facilities. Among the respondents are both developed and developing countries, belonging to different political alliances and groupings. Among the respondents only Japan could be considered as a supplier of nuclear fuel-cycle services, although its enrichment and reprocessing facilities currently serve only its domestic market.

No state possessing nuclear weapons responded to the questionnaire. However, China commented on the questionnaire by reiterating its official position on multilateral approaches, which is generally positive:

> China notices the relevant initiatives on the multilateralization of the nuclear fuel cycle in recent years. In general, we support these

> relevant proposals' objective and aims and are willing to participate actively in related discussions. We would also like to encourage all parties concerned to continue consultations and discussions on these initiatives and seek resolutions which will be accepted by all parties, thus to realize the objective of promotion the peaceful uses of nuclear energy and prevent the proliferation of nuclear weapons.

In general, it can be argued that the responses received are representative of Eastern and South-Eastern Asia, although it should be assumed that, if all regional actors had responded to the questionnaire, the average assessment of multilateral approaches might be slightly different.

CONCLUSIONS

1. Steady expansion of nuclear power is to be expected in Eastern and South-Eastern Asia. The diversity in the level of use of nuclear energy in the region may present several opportunities for development of regional multilateral fuel-cycle arrangements. As the growing number of power nuclear reactors will require a steady and assured supply of LEU and nuclear fuel, some regional actors may be uncomfortable with the concentration of enrichment facilities in a limited number of supplier states. The establishment of a multilateral regional enrichment facility could reduce dependence on foreign suppliers and give all partners assured access to enrichment services and opportunities to participate in management and operation of a uranium enrichment plant without embarking on the development of domestic uranium enrichment capacities.

Operators of nuclear power plants in the region already face serious problems in dealing with spent nuclear fuel as expanding storage capacities on their territory poses major political challenges. Newcomers will have the same problems in the future, even if right now they are less concerned with spent fuel and more concerned with fuel supply. Establishing a centralized regional interim storage facility or a regional geological repository could alleviate tensions around this problem and reduce the incentive for reprocessing spent fuel. Such a regional spent fuel storage/disposal facility could allow partners to achieve substantial economies of scale by sharing fixed capital costs, operating costs and financial liabilities.

If states in the region do pursue spent fuel reprocessing, doing this in a multilateral context could present certain economic and security benefits. As with a regional storage/disposal facility, a regional multilateral reprocessing facility could allow partners to achieve substantial economies of scale by sharing fixed capital costs, operating costs and financial liabilities. Furthermore, the partners would be under a great degree of peer scrutiny, which would hopefully ease suspicions over states' motives for reprocessing.

2. All respondents acknowledge that multilateral approaches could reduce the threat of nuclear proliferation by reducing the incentives for states to develop domestic sensitive fuel-cycle technology, and by increasing

transparency and mutual trust about the peaceful nature of enrichment and other nuclear fuel cycle-related activities.

3. All respondents support the view that multilateralization of the nuclear fuel cycle would facilitate the peaceful use of nuclear energy and contribute to economic development. Some respondents viewed the provision of reliable and cost-effective fuel supply as the key mechanism to do so. Others based their view on the fact that multilateral approaches focusing on the back end of the fuel cycle could help to solve the spent-fuel management problems of many states. At the same time it was noted that the ability of multilateral fuel-cycle approaches to contribute to the economic development of states would depend on the specific goals and mechanisms of a given approach. For example, current mechanisms for the front end of the nuclear fuel cycle might not have immediate effect on economic development as they focus on supplying LEU or nuclear fuel under emergency circumstances arising from non-economic reasons.

4. A shared view among respondents was that multinational fuel-cycle facilities could provide the benefit of cost-effectiveness and economies of scale thereby reducing financial burdens on individual participants. It was noted, however, that current proposals focusing on the front end of the fuel cycle and on emergency supplies would have actually little, if any, impact on reducing the costs of introducing and maintaining nuclear power production.

Along with that, some respondents expressed concern that multilateral approaches could result in higher costs for nuclear energy compared to current market prices, because multilateralization would impose more control on the nuclear fuel cycle and impose further restrictions on states' right to use nuclear energy peacefully.

5. A majority of respondents share the view that regional multilateral approaches could be effective in reducing the threat of nuclear proliferation and consider regional multilateral approaches to the nuclear fuel cycle as being more feasible than global approaches. But it was emphasized that the feasibility of a regional multilateral approach heavily depends on the political and historical context. In some regions, where states have accumulated enough experience in multilateral cooperation, agreement on multilateral fuel-cycle mechanisms could be relatively easy to achieve. However, in other regions cooperation may not be as feasible due to a

lack of trust among states. In this case, states might prefer to cooperate with like-minded states within global fuel-cycle frameworks rather than within regional arrangements.

6. A majority of respondents hold that the implementation of regional multilateral fuel-cycle approaches in Eastern and South-Eastern Asia is feasible. However, it was noted that the following obstacles may hamper implementation: (1) the lack of experience in regional cooperation; (2) historical animosities and the lack of trust among states in the region; (3) the gap in economic development and the use of nuclear energy among states in the region; (4) the unresolved nuclear issue of the Democratic People's Republic of Korea.

It was also noted that the feasibility of regional approaches may depend on the positions of states outside the region, for example the United States, which has bilateral nuclear cooperation agreements with many states in the region, prohibiting them from participating in certain fuel-cycle activities.

7. Among the models of multilateral approaches addressed in the survey, respondents gave the highest ratings in terms of non-proliferation effectiveness, economic benefits and feasibility to the proposal on nuclear fuel leasing and take-back offers by multilaterally organized suppliers. It was noted that such mechanisms could have the potential to significantly reduce operating costs as individual states would not have to build national spent fuel storage/disposal facilities.

8. Respondents also considered global and regional multilateral interim storage and long-term disposal facilities for spent fuel and radioactive waste to be of value in terms of non-proliferation and economic benefit. At the same time they expressed doubts on the feasibility of these projects.

A regional interim storage facility in Eastern and South-Eastern Asia could be an important practical step towards a multilateral back-end approach. Such a facility could provide additional opportunities for states having problems with storage and disposal of spent nuclear fuel, as well as allow time for further scientific and technological advances in managing spent fuel and radioactive wastes.

9. Respondents expressed almost unanimous support for the idea of comprehensive multilateralization of the nuclear fuel cycle, including

the conversion of existing enrichment and reprocessing facilities to multilateral operations. Such approaches were judged positively in terms of non-proliferation and economic benefit, but respondents diverged in assessing the feasibility. It should be noted no respondent (excluding Japan) has domestic enrichment and reprocessing facilities. Japan rated comprehensive multilateralization negatively in all categories.

ANNEX A

THE CURRENT PROPOSALS FOR MULTILATERAL APPROACHES

ASSURANCE OF FUEL SUPPLY: SUPPLIER GUARANTEES

World Nuclear Association Proposal (May 2006)
The World Nuclear Association promotes nuclear power and supports the many companies that comprise the global nuclear industry. Their 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.[1] The second level would be triggered only in the event of a disruption of normal commercial supplies. If one supplier cannot meet its contractual obligations due to political pressure from its government, then all suppliers party to the agreement would fill the gap with their own resources in equal shares under terms specified between the IAEA and the suppliers. This guarantee would be given to all non-supplier states contracting to obtain enrichment services from any supplier party to the agreement. If that network then fails, the third tier of supply assurance, represented by stocks of enriched uranium product held by governments, could be used as a last resort.

The initial proposal set an explicit requirement for customer states "to forego the development of, or the building or operation of, enrichment facilities" to be eligible to participate in the mechanism. But in March 2009 the World Nuclear Association stated during the International Nuclear Fuel Supply Conference in London[2] that it had decided to remove that requirement from their proposal.

Six-Country Concept (June 2006)
The six enrichment-service supplier states—France, Germany, the Netherlands, the Russian Federation, the United Kingdom and the United States—have proposed a modified version of the World Nuclear Association

proposal that offers two additional levels of assurance of enrichment services beyond normal market mechanisms.[3] At the "basic assurances" level, suppliers of enriched uranium would agree, with the support of the IAEA, to substitute for each other in the case of supply interruptions, for reasons other than non-proliferation obligations, that cannot be restored through normal commercial processes. At the "reserves" level, participating governments could provide reserves of LEU that would be made available if the basic assurances were to fail. The right to use these LEU reserves could formally be transferred to the IAEA to provide greater assurance of supply.

Non-supplier states would be eligible to use the backup mechanism if they have "chosen to obtain supplies on the international market and not to pursue sensitive fuel cycle activities". The IAEA would be responsible for making judgments on whether non-supplier states meet the eligibility conditions of access to the backup mechanism.

IAEA Standby Arrangements System (September 2006)
Japan has proposed the establishment of a database, as a complement to the Six-Country Concept, to help prevent interruptions in nuclear fuel supplies.[4] The system, to be administered by the IAEA, would disseminate information contributed voluntarily by IAEA member states on their national capacities for uranium ore supply, uranium reserves supply, uranium conversion services, uranium enrichment services 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 (September 2006)
The United Kingdom has proposed a "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 to non-supplier states, and provide prior consent for export assurances.[5] A Nuclear Fuel Assurance would be a formal agreement between a supplier state and a non-supplier state, to be overseen by the IAEA. The agreement would provide political assurances that commercial nuclear supplies would not be cut off for reasons other than the non-supplier state's non-compliance with their international non-proliferation and safeguards obligations. The agreement enables the IAEA to act as an independent advisor, and also as co-signatory of

agreements between supplier and non-supplier states. Such agreements would be available to all states provided they meet their international non-proliferation commitments.

The mechanism would be used to assure the supply of LEU, but could also cover fuel fabrication. This is an important characteristic of this proposed mechanism, because having guaranteed access to LEU will not necessarily help non-supplier states as they require a reliable supply of fabricated fuel assemblies.

On 10 March 2011 the IAEA Board of Governors voted in favour of the Nuclear Fuel Assurance proposal.

ASSURANCE OF FUEL SUPPLY: LOW-ENRICHED URANIUM RESERVES

US LEU Reserve (September 2005)
The United States has committed to down-blend 17.4t of high-enriched uranium (HEU), currently excess to national security needs, to LEU so as to support "assurances of reliable fuel supplies for states that forego enrichment and reprocessing".[6] The 17.4t of HEU would produce about 300t of LEU. The down-blending of HEU was completed in 2010.

The resulting LEU would remain under US control and be subject to obligations attached to US-origin nuclear material, including safeguards in perpetuity, prior consent for enrichment and reprocessing, and the right of return should a non-nuclear-weapon state detonate a nuclear explosive device. The precise terms and conditions governing the release of the fuel and its potential recipients have not yet been determined.

IAEA LEU Bank (September 2006)
The Nuclear Threat Initiative offered to contribute US$ 50 million to the IAEA to help create an LEU stockpile owned and managed by the Agency that would be made accessible on a non-discriminatory, non-political basis should other supply arrangements be disrupted.[7] The offer was contingent on the conditions that one or more IAEA member states contribute an additional US$ 100 million in funding or an equivalent value of LEU, and that the IAEA and its member states take the necessary actions to approve

the establishment of the reserve and decide on every other element of the stockpile—its location, structure, eligibility criteria, uranium pricing, etc.

In March 2009 the IAEA LEU bank finally secured voluntary financial pledges from states to make up the additional US$ 100 million (Norway pledged US$ 5 million, the United States US$ 49.5 million, the United Arab Emirates US$ 10 million, the European Union up to €25 million and Kuwait US$ 10 million).

On 3 December 2010 the IAEA Board of Governors adopted a resolution authorizing the IAEA Director General to establish an IAEA LEU bank to be owned and managed by the IAEA "to serve as a mechanism of last resort to back up the commercial market without distorting the market, in the event that a Member State's supply of LEU is disrupted and cannot be restored by commercial means and that such State fulfils the eligibility criteria".[8] According to these criteria, LEU from the bank can be supplied to an IAEA member state that "has brought into force a comprehensive safeguards agreement requiring the application of safeguards to all its peaceful nuclear activities" and "with respect to which the Agency has drawn the conclusion in the most recent Safeguards Implementation Report (SIR) that there has been no diversion of declared nuclear material and no issues relating to safeguards implementation in that Member State are under consideration by the Board of Governors".[9]

Having the right to receive LEU from the IAEA LEU bank will not "require giving up the right to establish or further develop a national fuel cycle or have any impact on it".[10]

The IAEA LEU bank will keep approximately 60t of LEU, which would be enough to meet the fuel needs for one full core load of a typical electricity-generating reactor—a light water reactor with a generating capacity of about 1 GW(e). The IAEA LEU bank will be located in one or more IAEA member states prepared to act as host state. A location has not yet been identified, although Kazakhstan has offered to be host state and bear relevant storage costs.[11]

The Board of Governors "request[ed] the Director General to consider proposals from any Member State interested to act as a Host State for the IAEA LEU bank … and to negotiate with it a draft Host State Agreement",[12] which has to ensure "the application of IAEA safeguards to the LEU

in the IAEA LEU bank, as well as the application of the safety standards and measures, and the physical protection measures by the Host State or States".[13] For effective operation of the LEU bank, a host state or states should preferably have a developed nuclear infrastructure.

At the end of May 2011 the IAEA began circulating a document soliciting a host for the IAEA LEU bank. The document outlines the requirements identified by the Secretariat for the selection of a host state. It also includes guidance for the submission by interested IAEA member states of "Expressions of Interest" to serve as host state.[14]

Russian LEU Reserve Proposal (June 2007)
As part of its initiative to establish the IUEC, the Russian Federation proposed the creation of a guaranteed reserve of 120t of LEU in the form of uranium hexafluoride (UF_6) enriched from 2.0 per cent to 4.95 per cent U-235. This enrichment would provide the required flexibility for meeting requirements for subsequent fuel fabrication, as the LEU supplied from the reserve would need to be fabricated into fuel assemblies before it could be loaded into a nuclear power reactor core.

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 a reserve of for supply to the IAEA for its member states to be located in Angarsk.[15]

Upon notification from the IAEA Director General, the Russian Federation would deliver the requested amount of LEU from the guaranteed reserve to the IAEA with all the necessary export licenses and authorizations required under Russian law. The IAEA would then supply the LEU to the requesting IAEA member state "with respect to which the IAEA has drawn the conclusion that there has been no diversion of declared nuclear material and concerning which no issues are under consideration by the IAEA Board of Governors relating to the application of IAEA safeguards".[16] 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"[17] but only if "the receiving State has brought into force an agreement with the IAEA requiring the application of safeguards on

all its peaceful nuclear activities".[18] Notably, "having the right to receive LEU from the guaranteed reserve would not require giving up the right to establish or further develop a national fuel cycle".[19]

The Russian Federation will bear all expenses relating to the establishment, storage, maintenance and security of the LEU reserve, as well as the application of IAEA safeguards.

On 1 December 2010 the Russian state-owned corporation ROSATOM announced that the accumulation of the 120t of LEU had been completed.[20] After IAEA inspectors completed their first inspection of the LEU reserve, on 1 December 2010 the world's first multilateral LEU reserve was officially inaugurated.[21]

MULTILATERAL URANIUM ENRICHMENT FACILITIES

Russian International Uranium Enrichment Centre (January 2007)
As a first practical step towards the creation of the "global nuclear power infrastructure" proposed in 2006 by then President Vladimir Putin, the Russian Federation established the International Uranium Enrichment Centre in the town of Angarsk "to provide IUEC participating organizations with guaranteed access to uranium enrichment capabilities".[22] The Centre was formally brought into existence with the signing of an intergovernmental agreement between Kazakhstan and the Russian Federation on 10 May 2007. Today Kazakhstan, the Russian Federation and Ukraine are IUEC stockholders. Armenia should become a full IUEC member after buying a share in the Centre in 2011, and other states may join as long as they have met their commitments under the NPT and share the objectives of the IUEC. (The Russian Federation has discussed possible participation in the IUEC with Jordan, Mongolia and Viet Nam.) Participation in the Centre does not impose any restrictions on the right of members to develop national enrichment capabilities.

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 profits. Kazakhstan and Ukraine now own a 10 per cent stake each, which guarantees them an

annual supply of uranium enrichment services to the amount of 60,000 separative work units (SWU).[23]

German Multilateral Enrichment Sanctuary Project (May 2007)
Germany has proposed the creation of a multilateral enrichment facility established by a group of interested states in a special extraterritorial area called the Multilateral Enrichment Sanctuary, supervised by the IAEA.[24] A group of interested states would 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 sanctuary and act as the nuclear regulator and supervisor for the operation of the enrichment facility, hence taking on 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]".[25]

The German proposal is envisioned to provide an opportunity for interested states not holding the relevant technology to have access to uranium enrichment capacities. As a further assurance of supply, the multinational enrichment company could establish and maintain a buffer stock or a physical reserve of LEU available to the IAEA Director General on conditions established by the IAEA Board of Governors.[26]

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.[27] Participants in the consortium would forgo developing or completing national nuclear programmes on their own territories, and instead rely on guaranteed supply from the consortium without having access to enrichment technology (the supplier of the black-box technology was not specified).

Specifically, Iran was invited to join the effort, instead of pursuing its national enrichment activities. Unfortunately, Iran rejected the invitation and this initiative, the only multilateral proposal originating from non-supplier states, has not been developed further.

GLOBAL MULTILATERAL INFRASTRUCTURE

Russian Global Nuclear Power Infrastructure (January 2006)
The Russian Federation has 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 centres 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.[28] As a first step in the creation of the proposed global nuclear power infrastructure, the Russian Federation established the IUEC in Angarsk.

Many details of the Russian initiative have yet to be fully defined. It does not explicitly mention comprehensive multilateralization of the whole nuclear fuel cycle or of its components. But the creation of the proposed global infrastructure, consisting of a network of international centres providing both front-end and back-end services, is an idea worth pursuing as it could help to limit national fuel-cycle activities around the globe.

Austrian Proposal on Multilateralization of the Nuclear Fuel Cycle (May 2007)
Austria has proposed comprehensive 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.[29] The second track would focus on eventual multilateralization of fuel-cycle facilities worldwide through progressive steps leading to "a legally binding international instrument [that] would limit the production or reprocessing of all nuclear material for civilian nuclear programmes to facilities under multilateral control".[30] The Austrian proposal 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 roadmap towards full multilateralization of the fuel cycle, even if many practical details of this plan are still to be defined.

US Global Nuclear Energy Partnership (February 2006)
The US Global Nuclear Energy Partnership was set up as both a research and technology development initiative and an international policy initiative. It sought to address the questions of how to limit the spread of sensitive nuclear technologies, and how to manage and recycle nuclear wastes more effectively and securely.[31] The proposal at first sought to create a global supply framework including two categories of states: states with full nuclear fuel cycles ("fuel-cycle states" according to the initial language) and states utilizing nuclear energy but not having enrichment and reprocessing facilities ("reactor states"). The Partnership promoted a consortium of fuel-cycle states that would provide "reliable fuel services", including uranium enrichment, spent fuel reprocessing and waste disposal, to reactor states. In essence, the Partnership offered outsourcing of front-end and back-end fuel-cycle services to reactor states.

In 2009 the US Department of Energy announced that it had cancelled the domestic component of Partnership.[32] The international component was refocused on collaboration to make nuclear energy more widely accessible in accordance with safety, security and non-proliferation objectives, as an effective measure to counter global warming, and to improve global energy security. In June 2010 the name of the partnership was changed to the International Framework for Nuclear Energy Cooperation. Its mission is to provide "a forum for cooperation among participating states to explore mutually beneficial approaches to ensure the use of nuclear energy for peaceful purposes proceeds in a manner that is efficient and meets the highest standards of safety, security and non-proliferation. Participating states would not give up any rights and voluntarily engage to share the effort and gain the benefits of economical, peaceful nuclear energy".[33]

ANNEX B

QUESTIONNAIRE ON MULTILATERALIZATION OF THE NUCLEAR FUEL CYCLE

PART I

1. What are currently the biggest proliferation risks?

_____

_____

	Yes	No
2. Is the projected expansion of civilian nuclear power a potential threat in terms of nuclear proliferation?	☐	☐

_____

_____

	Yes	No
3. Can multilateral approaches to the nuclear fuel cycle reduce the threat of nuclear proliferation? To what extent? What other factors are important?	☐	☐

_____

_____

	Yes	No
4. Would multilateralization of the nuclear fuel cycle facilitate the peaceful use of nuclear energy and contribute to economic development?	☐	☐

_____

_____

	Yes	No
5. Would multilateralization of the nuclear fuel cycle reduce the costs of nuclear energy?	☐	☐

	Yes	No
6. Can regional multinational approaches to the nuclear fuel cycle reduce the threat of nuclear proliferation?	☐	☐

	Yes	No
7. Is the implementation of regional multinational approaches more feasible than that of corresponding global approaches? Why or why not?	☐	☐

	Yes	No
8. Are regional multinational approaches more efficient in reducing the proliferation risk than corresponding global approaches? Why or why not?	☐	☐

	Yes	No
9. Do regional multinational approaches correspond to the interests of your state?	☐	☐
Better than global approaches?	☐	☐

_____

_____

	Yes	No
10. Do regional multinational approaches correspond to the interests of Eastern and South-Eastern Asia?	☐	☐
Better than global approaches?	☐	☐

_____

_____

	Yes	No
11. Is the implementation of regional approaches to the nuclear fuel cycle feasible in your region? If not, what are the obstacles?	☐	☐

_____

_____

12. Which states in your region do you consider potential partners for these projects?

_____

_____

13. What are the key reasons for non-nuclear-weapon states to develop domestic enrichment and reprocessing facilities?

	Multiple choices possible
Energy security	☐
Economic development	☐
Reduction of the cost of domestic nuclear energy production	☐
National prestige	☐
Creation of nuclear "hedge" capabilities against future security threats	☐

PART II

Below you find a list of possible multilateral approaches to the nuclear fuel cycle. Please rate the proposals' **feasibility** and their **effectiveness** in terms of the prevention of nuclear proliferation. The option **benefit** specifically refers to your state's economic and development interests, while **support** indicates whether your state would generally support the proposals with all factors taken into account.

Please use the following scale:

Feasibility, rated from 1 (very infeasible) to 5 (very feasible).

Effectiveness, in terms of the prevention of nuclear proliferation, rated from 1 (very ineffective) to 5 (very effective).

Benefit, in terms of economic and nuclear development, rated from 1 (very disadvantageous) to 5 (very advantageous).

The level of **support** to be expected, all things considered, rated from 1 (strong opposition) to 5 (strong support).

Proposals for multilateral approaches to the nuclear fuel cycle	**Feasibility**	**Effectiveness**	**Benefit**	**Support**
1. An IAEA-administered, nationally owned and operated LEU bank accessible to all IAEA member states				
2. An IAEA-owned and -operated international LEU bank accessible to all IAEA member states				
3. An IAEA-administered, nationally owned and operated LEU bank accessible to all states in good standing with their NPT obligations				
4. An IAEA-owned and -operated international LEU bank accessible to all states in good standing with their NPT obligations				
5. Internationally supervised additional guarantees of nuclear fuel outside the LEU banks provided by the existing suppliers to states that forswear enrichment and reprocessing				
6. Internationally supervised additional guarantees of nuclear fuel outside the LEU banks provided by the existing suppliers to states that do not forswear enrichment and reprocessing				
7. IAEA-administered multinational enrichment centers located in an extraterritorial area				
8. IAEA-administered multinational reprocessing facilities located in an extraterritorial area				
9. Regional multinational enrichment centers with “black-boxed” enrichment technology provided by a well-known supplier				
10. Regional multinational enrichment centers with all partners having equal access to enrichment technology				
11. Regional multinational reprocessing facilities				
12. Fuel leasing and take-back offers by multilaterally organized suppliers				

Proposals for multilateral approaches to the nuclear fuel cycle	**Feasibility**	**Effectiveness**	**Benefit**	**Support**
13. Global multinational interim storage of spent fuel and nuclear waste				
14. Global multinational long-term geological repositories for spent fuel and nuclear waste				
15. Regional multinational interim storage of spent fuel and nuclear waste				
16. Regional multinational long-term geological repositories for spent fuel and nuclear waste				
17. Limitation of all future nuclear enrichment and reprocessing facilities to multilateral facilities under IAEA safeguards				
18. Conversion of all existing nuclear enrichment and reprocessing facilities currently under national control and into multinational facilities under IAEA safeguards				

ANNEX C

EXISTING AND PROJECTED STATE NUCLEAR POWER PROGRAMMES IN EASTERN AND SOUTH-EASTERN ASIA

Cambodia

The Cambodian government announced in September 2008 and reiterated in August 2010 its aspirations to build the state's first nuclear power plant.[34] There is no nuclear infrastructure to date, and there is no feasibility study or project proposal for a nuclear power plant yet available. According to officials, a nuclear power plant will not be built anytime soon. The construction of hydropower plants is currently the priority.[35]

China

China operates 14 commercial reactors at four different sites (Guangdong, Lingao, Qinshan, Tianwan), with a combined capacity of 11,058 MW(e).[36] Twenty-seven power reactors, with a combined capacity of 27,230 MW(e), are currently under construction.[37] Projects for the construction of more than 50 additional reactors are under way.[38] In 2010, the Chinese government raised its initial goal of 40 GW(e) of nuclear power capacity by 2020 to 70–80 GW(e).[39] Following the Fukushima Daiichi accident, the government has suspended approval of new nuclear power projects until safety regulations have been updated.[40]

There are a number of uranium enrichment facilities in China. The Russian-built centrifuge plant in Hanzhong, Shaanxi Province, consists of two separate modules, completed in 1996 and 1998, with a combined capacity of 500,000 SWU/year.[41] The Hanzhong plant produces LEU under IAEA safeguards.[42] A third Russian-built module is located in Lanzhou, Gansu Province. It began operation in 2005 and has a capacity of 500,000 SWU/year.[43] The plant, Lanzhou 2, replaced Lanzhou 1, a gaseous diffusion plant that operated from 1964 to 1999.[44] A fourth module supplied by the Russian Federation, with a capacity of 500,000 SWU/year and also using centrifuge technology, is currently under construction and is to be completed in late 2011.[45] Heping, Sichuan Province, is the location of an indigenously built gaseous diffusion plant with unclear operational status.[46]

Another facility, possibly serving for uranium enrichment, is located at Xi'an, Shaanxi Province.[47]

China operates a pilot reprocessing plant at Lanzhou, Gansu Province, with a capacity of approximately 50tHM/year.[48] In January 2011, reports by state media announced substantial progress by scientists in mastering the technology for reprocessing spent fuel from nuclear reactors.[49] Initial plans to expand the Lanzhou facility to a commercial reprocessing plant with a capacity of 800 to 1,000tHM/year have probably been superseded by a project for an 800tHM/year reprocessing plant in Jiayuguan, Gansu province.[50] China's National Nuclear Corporation and France's AREVA signed a preliminary agreement on this project in November 2010, described as the "final step towards a commercial contract".[51] According to the agreement, the plant will use French technology and be operated by AREVA.[52]

Democratic People's Republic of Korea

There are no commercial power reactors in the Democratic People's Republic of Korea, but there are plans to make use of nuclear energy for civil purposes. After the shutdown and partial disassembly of the experimental gas graphite reactor at the Yongbyon Nuclear Scientific Research Centre in 2007, an experimental light-water reactor with a capacity of 25–30 MW(e) is now under construction at the same site.[53]

There is also a small industrial-scale uranium enrichment facility at Yongbyon, claimed to have 2,000 domestically-manufactured centrifuges with a capacity of 8,000 SWU/year.[54] The Yongbyon reprocessing facility, built to reprocess spent fuel from the now non-operational gas graphite reactor, was mothballed as part of the 2007 Six-Party Talks agreement, although there was perhaps a temporary resumption of operations in 2009.[55]

Indonesia

A 2006 decree by the Indonesian president calls for nuclear energy to be added to the energy mix of Indonesia by 2025.[56] Discussions over the location of two planned reactors are ongoing.[57] Potential sites include the Muria Peninsula in Central Java province, Banten province in Western Java, and the Bangka-Belitung Islands province off Sumatra.[58] Feasibility

studies are yet to be conducted.[59] The Indonesian government announced in March 2011 that it will continue to pursue its nuclear energy plans despite the risks highlighted by the Fukushima Daiichi accident, pointing to the more advanced technology of Indonesia's future nuclear plants.[60]

Japan

Following the permanent shutdown of Fukushima Daiichi reactors 1 through 4, and the temporary shutdown of reactors 5 and 6, Fukushima Daini reactors 1 through 4 and Hamaoka reactors 3, 4 and 5,[61] 41 commercial nuclear reactors remain operational in Japan, with a total capacity of 34,647 MW(e).[62] Two reactors are currently under construction (Ohma and Shimane-3), with a combined capacity of 2,650 MW(e).[63] The government initially planned to build 14 additional reactors by 2030,[64] but the future of nuclear energy in Japan after the Fukushima Daiichi accident is uncertain. The Tokyo Electric Power Company, operator of Fukushima Daiichi, cancelled plans to build two additional reactors at the plant.[65] Prime Minister Naoto Kan declared in May 2011 that Japan will have to formulate a new energy policy and abandon plans to build nuclear power plants.[66]

Japan's uranium enrichment plant in Rokkasho, Aomori prefecture, began operation in 1992 using indigenously designed and built centrifuges.[67] As of 2008, the plant's capacity was 1,050,000 SWU/year.[68] The plant is currently being re-equipped with newer generation centrifuges, which will start to go online in September 2011.[69]

Commissioning of Japan's reprocessing plant in Rokkasho, which has a capacity of 800tHM/year, has been postponed several times due to technical difficulties, most recently with the vitrification unit. The plant will not start operating before October 2012 at the earliest.[70] A mixed oxide fuel fabrication plant with a capacity of 130tHM/year is also being built at Rokkasho. The expected completion date is March 2016.[71]

Lao People's Democratic Republic

There are no plans for nuclear power generation in the Lao People's Democratic Republic. The Lao government is prioritizing hydropower to meet the country's growing energy demands.[72]

Malaysia

In December 2010, Malaysia announced its intentions to build two 1,000 MW(e) nuclear power reactors, possibly by 2022.[73] The Malaysia Nuclear Power Corporation was established in January 2011 to lead the planning process.[74] It has opened a tender to conduct a feasibility study on the possible location and technology for a Malaysian nuclear power plant.[75] The Fukushima Daiichi accident has so far not affected Malaysia's priorities with respect to nuclear energy,[76] but the cabinet has yet to decide if plans to build nuclear reactors should be pursued.[77]

Mongolia

Mongolia established a nuclear energy agency in 2008 to concretize plans to make use of nuclear energy. The government's goal is to create the necessary regulatory framework by 2021 and to meet 33% of the country's energy demands with nuclear power by 2035.[78]

Myanmar

The status of Myanmar's nuclear programme is not entirely clear. The country does not have any commercial nuclear power reactors, but in 2007 an agreement was signed with Rosatom to build a 10 MW(e) light-water research reactor.[79] Construction of this reactor has not yet started

The Philippines

Given rising safety concerns after the Fukushima Daiichi accident, the Philippine government decided to discard plans to re-active the Bataan Nuclear Power Plant.[80] This 621 MW(e) plant was built between 1977 and 1984, but never went into operation due to safety concerns.[81] The government nonetheless continues to explore the option of building new nuclear power plants at other sites.[82]

Republic of Korea

Twenty-one commercial nuclear reactors with a combined capacity of 18,698 MW(e) are currently operating in the Republic of Korea. Five reactors with a total capacity of 5,560 MW(e) are under construction.[83]

There are plans to build six additional reactors,[84] but domestic concerns about the safety of nuclear energy are rising.[85]

There are currently no enrichment or reprocessing facilities in the Republic of Korea. However, given a shortage of storage space for spent nuclear fuel, plans exist to make use of reprocessing technology.[86] This would require corresponding modifications in any future follow-up agreement to the 1974 US–Republic of Korea civil nuclear cooperation agreement, which expires in 2014 and requires permission from the United States for South Korea to reprocess spent nuclear fuel.[87]

Singapore

Singapore is conducting a pre-feasibility study on the potential construction of a nuclear power plant.[88] According to the Ministry of Trade and Industry, a decision on whether Singapore will build a nuclear power plant is still far away.[89] Although safety considerations play a particularly important role given Singapore's special geographic and demographic features, the accident at Fukushima Daiichi has so far not affected the government's interest in nuclear power production.[90]

Thailand

Thailand's 2010 Power Development Plan envisages five 1,000 MW(e) nuclear power reactors to be constructed by 2027. However, the government has yet to take a formal decision on the reactors. After the Fukushima Daiichi accident, the government declared a freeze on its nuclear plans and announced that the energy strategy would be reviewed.[91]

Viet Nam

Viet Nam plans to build 14 commercial nuclear reactors over the next two decades.[92] The construction of South-Eastern Asia's first nuclear power plant by Rosatom in Ninh Thuan province, to be completed in 2020, has already been approved.[93] The government stands firm behind its ambitious nuclear aspirations despite the Fukushima Daiichi crisis, but events in Japan are likely to influence the future selection of construction sites, according to officials.[94]

Notes

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Multilateralization of the Fuel Cycle: History and Prospects

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ABBREVIATIONS

G-77	Group of 77
HEU	high-enriched uranium
IAEA	International Atomic Energy Agency
IUEC	International Uranium Enrichment Centre
LEU	low-enriched uranium
NCA	nuclear cooperation agreement
NPT	Treaty on the Non-Proliferation of Nuclear Weapons
OECD	Organization for Economic Cooperation and Development

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The world continues to wrestle with the dual nature of nuclear energy. The proliferation risks stemming from the spread of sensitive technologies point to the need for a multilateral approach to the nuclear fuel cycle. Taking the dangerous aspects of nuclear energy out of national hands and placing them in multilateral hands could strengthen the non-proliferation regime and provide states with secure and equitable access to the benefits of peaceful nuclear energy.

This book presents two studies. The first provides a historical overview of the issue of multilateralization and discusses the present situation and future prospects. The second discusses prospects for regional approaches to the nuclear fuel cycle using Eastern and South-Eastern Asia as a case study.

USD 20
ISBN 978-92-9-045201-0

9 789290 452010 52000

Designed and printed by the Publishing Service, United Nations, Geneva
GE.11-01140 — August 2011 — 1,950 — **UNIDIR/2011/5**

United Nations Publication
Sales No. GV.E.11.0.4
E-ISBN 978-92-1-055069-7