

Internationalizing the Nuclear Fuel Cycle

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Summary

Where we are right now. The Bush administration has tried to persuade the Nuclear Suppliers Group (NSG) not to sell technology and equipment for enrichment and reprocessing to any state that does not already possess full-scale, functioning plants of this type. The proposal was rejected, even by close friends of the United States. The United States is now trying to accommodate its policy to a “criteria-based” approach proposed by France and other NSG members. Efforts to block the spread of enrichment and reprocessing capabilities have fallen short for four main reasons: (1) access to the base technologies required for entry into the field is relatively easy; (2) several states were determined to acquire their own enrichment and/or reprocessing capabilities for various reasons, e.g., to reduce energy dependence, conserve energy resources or to manage nuclear wastes; (3) no combination of incentives and threats short of military action have sufficed to dissuade nations intent on acquiring a nuclear weapons capability from exploiting these technologies; and (4) many nations that have no current intention of building nuclear weapons and no special animosity towards the United States reject the idea of a two-tier system as regards possession of enrichment and reprocessing facilities, believing they have every right to develop all aspects of a civil nuclear power program. Stopping the further proliferation of nuclear weapons will depend on developing policies that deal effectively with these four factors.

Key Issues.

1. Would it be useful to take credible steps to eliminate the “two-tier” system, both in civil nuclear power and in nuclear weapons?
2. Can equal rights to fuel cycle services be satisfied through assurances of reliable access at reasonable cost to fuel for civilian reactors?
3. Could a stronger effort to internationalize the fuel cycle help to limit the spread of technology and facilities?
4. Would it be feasible to create an international norm requiring that sensitive nuclear fuel cycle facilities be placed under some form of multinational control?
5. Are there criteria beyond (1) multinational ownership and management and (2) IAEA safeguards, which could gain international acceptance as a means to limit the number of uranium enrichment facilities in the world and prevent the spread of enrichment technologies?
6. How could agreements to internationalize nuclear fuel cycle services be enforced?

Conclusions and Recommendations.

1. It should be U.S. policy to work, step-by-step, toward the goal of a world free of nuclear weapons. In this framework, the credibility of actions to remove the “two-tier” stigma from the arena of fuel cycle service would be enhanced and efforts to block the spread of technology and equipment that can be used to build atomic bombs are likely to be more successful.
2. Current programs and proposals advanced by several nations to assure reliable supplies of nuclear fuel at reasonable costs to states with responsible nonproliferation records should be supported, while recognizing that these programs are not a complete answer to demands for an end to the “two-tier” system. One of these programs, the Bush administration’s Global Nuclear Energy Partnership (GNEP) should include a wider array of technical options than it currently does, especially ones that do not require more emphasis on reprocessing with existing technology to produce mixed oxide (MOX) fuel. The Partnership also should make infrastructure development, including internationalization of the nuclear fuel cycle, one of its priority goals.
3. Priority attention should be given to establishing uranium enrichment facilities under multinational control. The United States should take the lead in proposing that: (1) as of a given date all plans for new commercial uranium enrichment facilities should be based on the presumption that the facilities will be multinationally owned and their operations safeguarded under conditions approved by the Nuclear Suppliers Group (NSG). After that date, the NSG should give preference to such facilities when considering selling enrichment equipment and technology; (2) existing commercial facilities or those under construction that are not already multinationally owned should be encouraged to convert to multinational ownership, with their operations similarly safeguarded.
4. Models of multinational enrichment facilities include:
 - Urenco, a multinational board of directors with plants in Germany, The Netherlands, and the United Kingdom. Major policy committees, plant management, and operating staff includes nationals of the three founding countries. Technology is shared among these countries but not with others. Urenco shares are not for sale.
 - Eurodif, owned by Areva, has a plant located in France, managed and run by French personnel. Areva is a multinational corporation dominated by French interests. Technology is not shared. Angarsk, a Russian enrichment facility partly owned by Kazakhstan, apparently will follow the Eurodif model. GE Hitachi may adopt this pattern as well.
 - A generic model in which the board, senior management and operating staff is multinational, and includes consumer states. Access to sensitive technology would be limited to participants who already possess such technology.
5. U.S. policy should continue to seek to limit the number of uranium enrichment facilities in the world and to limit the spread of sensitive enrichment technology.

In addition to conditions imposed by U.S. laws and policies, NSG conditions for transfers of enrichment technology and equipment should include the following:

- A recipient of enrichment equipment or technology must be a member in good standing of the NPT and have an IAEA “Additional Protocol”, in effect or in the process of being put into effect;
 - Proposals for new enrichment facilities should be based on sufficient domestic demand or in cases where the export market is a consideration exports of enriched uranium must be in compliance with NSG Guidelines;
 - Protecting sensitive technology must be a priority objective, including “black box” arrangements for uranium facilities;
 - All exporters of enriched uranium fuel assemblies, including the nuclear weapon states, must support an increase in the IAEA safeguards budget sufficient to provide for the actual application of IAEA safeguards using Limited Frequency Unannounced Access (LFUA) at their uranium enrichment facilities;
6. The most difficult question is whether multinational enrichment facilities should be encouraged in potentially unstable areas in return for rolling back incipient nuclear weapons programs. The test case is Iran. The Iranian government stated on May 8, 2008 that it is ready to consider “establishing enrichment and nuclear fuel production consortiums in different parts of the world – including in Iran.” This should be explored in appropriate channels. A requirement for international staffing should be a part of the agreement in cases like Iran where regional security considerations are a factor.
 7. Enforcement mechanisms should be devised in case of violations of NPT/IAEA agreements, enabling the UN Security Council to establish a “response mechanism,” including a series of pre-agreed incremental sanctions.
 8. Ideally, the presidents of the United States and Russia should launch a nonproliferation initiative by declaring, early in 2009, that their mutual intention is to work toward a world without nuclear weapons. Tangible evidence of this would be their agreement to reduce the numbers of warheads in the 2002 Strategic Offensive Reductions Treaty from 1700-2200 to 1000 and to add to that treaty verification provisions drawn from START.
 9. In any case, the United States should begin consultations with other countries at an early date (1) to make the elimination of nuclear weapons a truly global enterprise and (2) to ensure that all states in compliance with their nonproliferation obligations have access to the benefits of peaceful nuclear energy, including reliable fuel supplies and, if desired, the possibility of ownership of multinational uranium enrichment facilities.
 10. The United States should consider opening domestic uranium enrichment facilities to joint ownership and co-management with entities of other nations, under conditions approved by the NSG. The goal would be to make safeguarded multinational uranium enrichment the normal way of doing business and to make substantial progress toward that goal not later than the 2010 Review Meeting of the Nonproliferation Treaty.

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Internationalizing the Nuclear Fuel Cycle

Nuclear Dilemmas

The fact that nuclear energy can be exploited both for weapons and for civil purposes has presented a dilemma which has been managed but never resolved in over six decades. Uranium and plutonium can provide abundant, carbon-free energy but also the means for producing the most destructive weapons ever invented. Enriching natural uranium is useful for producing nuclear fuel for reactors, and for bomb-making. Removing pure plutonium from spent fuel produces material from which a bomb can be made. In his “Atoms for Peace” speech of December 8, 1953, Dwight Eisenhower put it this way: “...if the fearful trend of atomic military build up can be reversed, this greatest of destructive forces can be developed into a great boon, for the benefit of all mankind.” This dilemma has never been satisfactorily resolved. In the context of a serious international commitment to work for the goal of a world without nuclear weapons, perhaps it can be.

Two interconnected concepts that might resolve the dilemma were advanced in the Acheson-Lilienthal Report not long after Hiroshima and Nagasaki. The ideas were to eliminate nuclear weapons and to create an international authority to manage the peaceful uses of nuclear energy. Eliminating the very few nuclear weapons that existed in the late 1940s would have been relatively easy to do as a technical matter. Conflicting national objectives at the time made the task impossible. Today, in contrast, eliminating nuclear weapons is a more complex task, as a technical matter. But the national objectives of the major nations may be more in alignment, as they consider the threat posed by nuclear weapons.

As in 1946, establishing some form of international authority over the most dangerous aspects of the nuclear fuel cycle is likely to be the most effective long-term remedy for the proliferation problem. And, as in 1946, the key to success is to carry out the process of internationalizing the nuclear fuel cycle in parallel with the process of eliminating nuclear weapons. Decisions to act cooperatively in this sensitive area were impossible for the major governments in the 1940s and 1950s. Cooperation on nuclear energy will be politically difficult, but perhaps not impossible, in the 2010s. In contrast to 1946, an incentive-driven, “bottom up” approach may augment public policies and this combination could lead, over time, to an international authority of limited scope.

The goal of a world without nuclear weapons should serve as a compass to guide public policy in the here and now, not in some distant future. Nowhere is such a policy framework more necessary than in decisions concerning the nuclear fuel cycle. The end of the Cold War, the globalization of the economy, and deadly challenges posed to all states by non-state organizations, have created an environment that should make the need for international cooperation more apparent. The level of cooperation that would insulate the nuclear fuel cycle from potential misuse is on a lesser scale than the authority

envisaged in the Acheson-Lilienthal Report. The technical/material obstacles confronting the task of eliminating nuclear weapons are formidable, but probably can be overcome if the task is addressed carefully and incrementally. Progress in escaping from the nuclear deterrence trap altogether is dependent on significant improvements in the relations among the major nations but progress in one should breed progress in the other.

The Nuclear Renaissance

One solution to the nuclear dilemma would be to phase out nuclear reactors, which is precisely what some people advocate, but even a world without nuclear weapons is not likely to be a world without civil nuclear power plants.¹ The rising demand for energy, especially in Asia, has made it all but inevitable that a surge in the construction of new reactors will occur over the next two decades. That will pose issues regarding the building of new uranium enrichment facilities and of reprocessing facilities, or the expansion of existing facilities. The question of assured nuclear fuel supply already is on the table, as are the perennial questions of what to do with spent fuel and whether to exploit for power generation purposes the plutonium that is contained in the spent fuel. Getting the answers right will be a crucial test for public policies, in the United States, and elsewhere.

Growing energy demands and the need to curb greenhouse gases have created the much publicized “renaissance” in proposals for new nuclear reactors. Many projects have reached the advanced planning stage or are already being constructed. Centrifuge technology for enriching uranium also has made significant advances and the cost of separative work has been reduced. The cost will drop further as the transition to centrifuge technology from gaseous diffusion technology continues. The base technology is spreading. There may be exaggerated expectations associated with the renaissance and the time frame for its full flowering is likely to be very long, but new reactors are being planned on a scale unseen in recent years. All that remains uncertain is the *rate* of nuclear power growth.

Assumptions suggesting that nuclear power growth will be slow depend primarily upon some level of stability in the Middle East so that oil supplies from there are not interrupted, and on there being no rapid and major change in the earth’s climate. If these conditions changed, or if dependence on oil from unstable regions simply becomes too risky for major oil exporters to tolerate, the world could decide to make a transition to a heavy dependence on nuclear power. If the example of France is a guide, it could do so on a global scale in 25 years.² On the other hand, if there were another Chernobyl-like accident or some dramatic diversion of nuclear materials from civil power programs to a nuclear bomb, the predicted expansion of dependence on nuclear power might be slowed down or even stopped.³ On balance, the best bet is that nuclear power plants will become a larger part of the energy mix, which means that managing the nuclear fuel cycle will present “front burner” issues for governments. In the United States, these issues come in the form of a transition to centrifuge-based enrichment technology and possibly to laser-based enrichment, persisting problems regarding storage of nuclear waste material, and whether to begin encouraging the use of plutonium as a reactor fuel.

Rejection of a Two-tier World

In addition to uncertainties about the rate of growth of nuclear power generation, there are very strong political currents in the world that distort the picture provided by objective economic analyses. One of these is the view held by many nations that a “two-tier” world is unacceptable, that it is not right that some nations are allowed to have enrichment and reprocessing facilities for peaceful nuclear energy programs, while others are forbidden to have that infrastructure. Very few nations would willingly be caught on the inferior side in a permanent “two-tier” system where some nations are entitled to the infrastructure for a civil nuclear power industry, and others are not. Assurances of reliable, uninterrupted supply of nuclear fuel, while removing some incentives, do not respond to the “entitlement” motivation. To address that, a mechanism that gives any nation that wants it at least some form of vested interest in one or more major elements of fuel cycle services is required.

Another powerful determinant of national policies is the desire to have an option to acquire nuclear weapons. This consideration has played a major role in several national decisions to build uranium enrichment facilities. To address this motivation, expectations about the future have to be changed. Nations have to become convinced that global trends are in the direction of less dependence on nuclear weapons for security, and that there are better alternatives. Otherwise, they will try to keep the nuclear weapons option and will build the infrastructure needed to do so.

The Bush administration has tried valiantly to make a two-tier system work, offering assurances of reliable supplies of nuclear fuel as an incentive. A notable example of this was the president’s speech at the National Defense University, in Washington D.C., on February 11, 2004, perhaps his most comprehensive policy statement on nuclear proliferation. He proposed seven steps to block nuclear proliferation. One of them was:

The world’s leading nuclear exporters should ensure that states have reliable access at reasonable cost to fuel for civilian reactors, so long as those states renounce enrichment and reprocessing...the 40 [now 45] nations of the Nuclear Suppliers Group should refuse to sell enrichment and reprocessing equipment and technologies to any state that does not already possess full-scale, functioning enrichment and reprocessing plants.

The administration tried to obtain the agreement of the members of the Nuclear Suppliers Group to this new rule but ran into strong opposition from states, including Canada, that insist on maintaining the option to develop their own fuel cycle capabilities. Non-nuclear weapons states parties to the Nonproliferation Treaty (NPT) believe that Article IV of the treaty gives them the right to participate fully in the peaceful uses of nuclear energy.⁴ Currently, the administration has modified its policies to fit with a “criteria-based” approach proposed in the Nuclear Suppliers Group by France and accepted by all others. This would permit transfers of enrichment technology and equipment under certain specified conditions.

On a case-by-case basis, the administration also has sought to reinforce a “two-tier” rule with sanctions, but these have been aimed only at countries deemed to be unfriendly, like Saddam Hussein’s Iraq, Iran and North Korea, not friendly nations like Brazil, India, or Pakistan.

Most of the nations that are interested in acquiring energy from nuclear sources are not presently contemplating the building of a nuclear arsenal. Presently, the demand for small, nationally-controlled enrichment facilities is fairly limited but high prices for uranium, as well as uncertainties about supply may be enough to encourage some countries to build enrichment facilities just on economic grounds. Thus, the current economic situation may not act as a sufficient economic disincentive to the building of small-scale enrichment facilities.⁵

Most nations in this category are opposed to the acquisition of nuclear weapons by Iran and North Korea. But still they are not comfortable with a two-tier system. This attitude was captured in a statement made by the IAEA director-general, Mohamed ElBaradei, at the Oslo Conference on “Achieving the Vision of a World Free of Nuclear Weapons”, on February 26, 2008:

...we must develop a new framework for the utilization of nuclear energy. As I continue to advocate, a multilateral approach would ensure security of supply of nuclear fuel, while reducing the risk of proliferation. A number of proposals have been made, including a fuel bank under IAEA auspices and multinational enrichment facilities. The ultimate goal in my view should be to bring the entire fuel cycle, including waste disposal, under multinational control, so that no one country has the exclusive capability to produce the material for nuclear weapons. I do not believe that any country will give up its right to engage in fuel cycle activities unless the multinational framework is based on equal rights and obligations for *all* participants.

Thus, added to the economic and technical dimensions of nuclear energy is the imperative identified by Dr. ElBaradei: the need to create a level playing field through a new framework that is based on equal rights and obligations.

Back to the Future?

A new framework for the peaceful uses of nuclear energy must also prevent the proliferation of facilities useful for manufacturing nuclear weapons. A tall order? Yes, and the magnitude of the challenge can be appreciated by recalling the solution to the same problem offered by the authors of the Acheson-Lilienthal Report, in 1946.⁶ The Acheson-Lilienthal Report was written in a world free of nuclear weapons, or very close to it, and its authors tried to imagine how to keep it that way. Faced with this challenge, the authors proposed the creation of an Atomic Development Authority, which would own and operate the basic means of producing materials that could either fuel power plants or be used to build an atom bomb. Access to uranium and plutonium was regarded

as a key choke-point in preventing nuclear weapons development. The Acheson-Lilienthal Report specifically left in national hands the construction and operation of energy-producing nuclear reactors, provided there was some oversight of reactor design, construction, and operation.

That report was amended by the Truman administration in ways that made it less acceptable to other nations, and specifically to the Soviet Union. It was then presented to the United Nations by Bernard Baruch on behalf of the United States government, and became known as the Baruch Plan. After years of futile debate in the depths of the Cold War, the proposal was withdrawn, long after it had ceased being a topic of international negotiation. The vision of a world free of nuclear weapons was not discussed seriously again by American leaders until 1986, when President Ronald Reagan and Soviet General Secretary Mikhail Gorbachev met at Reykjavik. They failed there to reach an accord on total elimination of nuclear weapons, but they did succeed in launching a trend toward many fewer warheads in the U.S. and Soviet/Russian stockpiles.

In 2006, on the 20th anniversary of the Reykjavik meeting, Reagan's Secretary of State, George P. Shultz, and Dr. Sidney Drell convened a meeting at Stanford University's Hoover Institution for the purpose of discussing whether Reagan's hopes could be rekindled. That meeting of knowledgeable people from around the country led to an extremely influential article published in *The Wall Street Journal* on January 4, 2007, signed by Shultz, former Secretary of State Henry A. Kissinger, former Secretary of Defense William Perry, and former Chair of the Senate Armed Services Committee, Sam Nunn. It endorsed "setting the goal of a world free of nuclear weapons and working energetically on the actions required to achieve that goal."

Another conference held a year later, sponsored by the Hoover Institution and the Nuclear Threat Initiative, resulted in a second article by the same four authors. It reaffirmed the vision of moving toward zero nuclear weapons and called for "developing an international system to manage the risks of the nuclear fuel cycle." And so today, in 2008, the dilemma faced by the authors of the Acheson-Lilienthal Report in 1946 has resurfaced, again in the context of a world free of nuclear weapons. The Acheson-Lilienthal recommendations would have required sweeping political changes that were not possible in the 1940s. Even in 1986 the world was not ready for such a dramatic shift in policies and public attitudes. Today, the attitude is more like: "Why has it taken so long?" And nearly everyone who has thought about the dilemma now believes that if a world free of nuclear weapons is to be achieved, international authorities of *limited* scope, on a more modest scale than the one proposed in the Acheson-Lilienthal Report, will become necessary at some point in the process.

A Goal and a Compass

If that is the case, then policies in the United States and elsewhere should begin laying the foundation for an international authority, recognizing that steps in that direction will have to be incremental, building on what exists today. Examples of international authorities of limited scope exist today in the nuclear field, and while they

are much less ambitious in their reach than the authority envisaged in the Acheson-Lilienthal Report, they are multinational. Some provide for joint ownership and operations of key functions of the power industry, specifically uranium enrichment.

The process of institution-building in the nuclear field may come to resemble the function-oriented process advocated by Jean Monnet as he imagined how a united Europe could be created. Monnet's scheme started with a Coal and Steel Community, although his longer-term vision was to re-create the political structure of Europe. Similarly, the creation of an international authority to manage civilian nuclear power could begin with multinational organizations of fairly limited scope which later might coalesce.⁷ Economic incentives, not top-down directives, can provide much of the motivation for progress in this direction. But a clear and convincing U.S. policy framework is needed to chart the course.

The past history of efforts to internationalize the nuclear fuel cycle does not give grounds for optimism about current efforts – but times have changed. The anticipated surge in construction of nuclear power reactors may create a steeply rising demand for nuclear fuel services, including enrichment of uranium. Four new enrichment facilities now are being planned or actually being built in the United States alone.

A second factor is the growing realization among nations that present trends in the nuclear arena court disaster. The two *Wall Street Journal* articles by Shultz, Kissinger, Perry, and Nunn received enormous public attention around the world. Their warning that the world is at a tipping point in terms of nuclear proliferation resonated strongly. As states such as Iran and North Korea have acquired the means of enriching uranium and to separate plutonium and as the clandestine network operated by A.Q. Khan has shown the ease with which technology can be transferred to such states as Iran, Libya, and North Korea the proliferation of the infrastructure for bomb-making has become a pressing concern. Instability and terrorist activities in Pakistan suggest that nuclear programs there also must be considered a potential crisis.

On the positive side, the rise of the global economy has created economic and political conditions that are more receptive to multinational cooperation, including the nuclear fuel cycle.

First Priority to the Front End of the Fuel Cycle

Construction of new nuclear reactors is a slow process and this affords time for deliberation and for building a consensus regarding appropriate multilateral responses to the anticipated demand for enriched uranium. A successful effort to internationalize the nuclear fuel cycle is likely to be an incremental process and so a basic policy question arises: should the process take place across the spectrum of fuel cycle operations or on a sector-by-sector basis?

The main sectors are 1) uranium mining, 2) uranium enrichment, 3) fuel fabrication and supply to recipient countries, and 4) reprocessing or storing spent fuel and

storing waste material. Three types of fuel cycle facilities entail high capital costs and large economies of scale: uranium enrichment, reprocessing, and storage of waste and spent fuel. These economies of scale can be used to support nonproliferation policies.⁸ It appears that uranium enrichment could be the spearhead in the process of internationalizing the fuel cycle. The lower costs of nuclear fuel provided by large, modern centrifuge facilities should help to discourage, on economic grounds, the building of small, high-cost enrichment facilities. It would be far less expensive for nations and companies to take part ownership in a multinationally-owned facility, perhaps using leased centrifuge machines under “black box” conditions, than to build their own. But the case for this choice of priority is based not only on economics but also on the fact that centrifuge technology is becoming more efficient, less expensive to operate, and more widely available. The transition from gaseous diffusion to centrifuge and laser technology means that plans have been developed to build new enrichment facilities in the United States, which makes the political and economic dynamics more favorable for multinational ownership than in the past. Furthermore, there is considerable experience in managing multinationally owned enrichment facilities. And interest has been expressed by the Permanent Members of the U.N. Security Council, among others, in a multinational mechanism as a viable alternative to indigenous development of nuclear fuel services.

A few large enrichment facilities, as opposed to many smaller facilities around the world, should help to contain the spread of national capabilities for constructing nuclear weapons.⁹ The participation of several nations in ownership management, and, in some cases, in plant operations should help to deter cheating. ***It must be recognized that for this plan to work, some jointly owned and managed enrichment facilities must be open to participation by those nations that are the consumers of enriched uranium supplied by multinational facilities. One of the principal purposes of encouraging multinational enrichment facilities is to give consumers a stake and a say in the running of such facilities so that they have fewer legitimate incentives to build their own facilities.***

Multinationally owned and managed uranium enrichment facilities situated in various regions of the world should develop common ground rules for supplying nuclear fuel. They should agree on effective approaches for safeguarding the plants to prevent diversion of enriched uranium to non-civil purposes and to ensure that enrichment does not proceed beyond a certain level. They should work closely with the IAEA to develop effective safeguards to detect and deter the construction of separate clandestine enrichment facilities. Such multinational facilities, some of which would be quite small to begin with, would have the potential to evolve into the sole lawful suppliers of enriched uranium, fulfilling one element of ElBaradei’s vision.

If the United States takes the lead in encouraging for multinational facilities, fuel centers might be developed in the following locations:

- a. Brazil, based on the Resende uranium enrichment facility. Argentina already is associated with Brazilian nuclear activities.¹⁰
- b. Russia, based on the Angarsk facility.

- c. Iran, if that proves to be feasible or, if not, another Middle East-dedicated facility outside the region as proposed by the Saudis.
- d. The United States/Canada.
- e. China and/or Japan.

A Different Solution for the Back End of the Fuel Cycle

The proposition that reprocessing facilities should be established on a multinational basis has been the subject of discussion for many years. The proliferation potential of nationally-owned facilities, which produce plutonium useable for nuclear weapons, is the basis for this interest. A thorough analysis of this idea was conducted as early as 1976 by private-sector experts, most of whom considered that it was feasible and had nonproliferation advantages.¹¹ This was at a time when it was also thought that reprocessing spent fuel and burning MOX was going to be economically beneficial. This has not been the experience with existing technology.

The very few commercial reprocessing facilities that exist today perform all the services required by nations that want pure plutonium for manufacturing fuel for civil nuclear reactors, either as mixed uranium and plutonium oxides (MOX).

The basic issue is whether to encourage the nuclear power industry to move on a large scale into building reactors that burn plutonium as fuel. The proliferation potential of such a move has made the United States and some other governments hesitant, until recently. Currently proposed technical solutions have not answered the concerns that many still have. It still makes sense, at this time, for the United States to be skeptical about the widespread use of plutonium as a fuel and to discourage the building of reprocessing facilities. Burning already separated plutonium as a means of disposing of it, however, is another matter.

There are three uses for plutonium separation facilities: for weapons, for waste management, and for producing plutonium for use as fuel in reactors, now or in the future. Plutonium is being used as a fuel today, as MOX. In a pure form it can be “burned” in fast neutron reactors, as a form of waste management and power generation. Exploiting plutonium as a reactor fuel may, with improving technology, grow to the point where a multinational approach to reprocessing would be justified, because of economies of scale. France and Japan already are exploiting MOX fuel as a very high-cost energy source as are some other nations. Japan and France already have MOX fuel fabrication facilities and related reprocessing plants. India has plans to follow suit on a large scale.

The rate of growth of energy production from plutonium-based fuel (primarily MOX) over the next two decades is not likely to be on a scale that would justify large multinational facilities. The costs are very high and current reserves of uranium are adequate to provide fuel for reactors for a long time to come. If that picture changes, perhaps due to rising costs of uranium, then expansion of the plutonium-based reactor economy could proceed more rapidly than now anticipated.¹² But for now, it appears that there is no need to move to MOX-based reactor fuel except to perhaps eliminate existing

stocks of separated plutonium (in particular in the UK).¹³ In the future, nationally-controlled MOX fuel centers in Europe or Asia might be considered as candidates for multilateralization, perhaps as “energy parks”¹⁴.

Spent Fuel Storage

A more urgent near-term need is an international used nuclear fuel storage center. Storage of spent fuel is a valid interim or even long-term procedure. The technology exists, the costs are low, it could be done quickly, and the benefits are large. An international used nuclear fuel storage center would encourage supply policies that provide for spent fuel to be returned to the supplier, since the question of where to put waste material would be easier to answer. This option deserves serious attention as a prime candidate for multinational cooperation.

Implications for U.S. Policy

One of the first concerns of U.S. policy should be to deal equitably with those states that believe they have the right, as a matter of principle, endorsed by the Nonproliferation Treaty (NPT) itself, to own facilities essential to a nuclear power program, including uranium enrichment facilities. Such states may find multinationally owned enrichment facilities attractive, because of (1) the economic advantages over creating and operating their own infrastructure and (2) a strong commitment by the United States and other nuclear-armed states to work seriously for a world without nuclear weapons. In that case, the very small number of states that insist on having their own facilities, for military purposes, can be more easily isolated. Their decisions can possibly be reversed. Iran and North Korea already have been influenced by international pressure, and this should have even more effect in the framework of ending the “two-tier” system.

How to proceed? The United States should propose that: (1) as of a given date all plans for new commercial uranium enrichment facilities should be based on the presumption that the facilities will be multinationally owned with their operations subject to effective safeguards. After that date, the Nuclear Suppliers Group should give preference to such facilities when considering selling enrichment equipment and technology; (2) existing commercial facilities or those under construction that are not already multinationally owned should be encouraged to convert to multinational ownership, with their operations similarly safeguarded.

The former proposal is a variation on one already advanced by the Bush administration. The second would require a new decision, taken jointly by government and private industry. It would mean that the U.S. Enrichment Corporation would create a joint venture out of its planned new enrichment facility near Portsmouth, Ohio.

Another U.S.-based enrichment facility under construction in New Mexico already is owned by a multinational entity, Urenco. Such a decision might also mean that the French-based multinational corporation, Areva, should be encouraged to enlarge its

plans for an enrichment facility in Idaho to include part ownership by American and Canadian entities, and others. GE Hitachi, another multinational corporation, is planning another enrichment facility in North Carolina. The Canadian firm Cameco has taken a 24% stake in GLE, the company created by GE Hitachi.

The possibility of participating in some way in a multinational facility is the key to discouraging totally national enrichment facilities for nations that are consumers of enriched uranium. Many of these nations may be satisfied with assurances of reliable fuel supplies at reasonable costs. For those that are not, the multinational option should be available. The case for relying for enrichment services on a few large enrichment facilities (roughly, one for each continent), is persuasive economically if properly designed, and can provide major nonproliferation benefits. That case may not be accepted, however, unless it is seen in the context of a new deal between the current possessors of advanced nuclear technologies, including weapons capabilities, and those nations that are still considering their nuclear options. USEC's new facility is the only one in the United States that does not have international partners. A move to internationalize USEC's new Portsmouth facility would help to convince other nations that a new deal is in the making. Furthermore, opening the facility to participation by consumer-states may be a more practical proposition than in the other three enrichment facilities. USEC's Congressional mandate (Privatization Legislation) stipulates that there is a public interest in domestic enrichment facilities but there is nothing in the mandate that suggests that the public interest would not be met by a multinational facility on U.S. soil.¹⁵

An equally important component of this course of action would be a U.S.-led effort to encourage China, Japan, and Brazil to open their enrichment facilities to multinational ownership and management, not an easy task. But Russia has already embarked on this course in its Angarsk facility and has advocated a network of multinational enrichment facilities. China has worked closely with Russia on enrichment services. During President Medvedev's May 2008 visit to China, Russia signed a new agreement with China whereby Russia will help to build a fourth stage of a Chinese enrichment facility. China might see commercial advantages in replicating Russia's Angarsk initiative, also as part of a network of multinational enrichment facilities. Japanese firms have many joint ventures with U.S. and European companies in the nuclear field, including the GE Hitachi enrichment project. Brazil and Argentina already are engaged in a modest degree of nuclear cooperation; the question is whether to deepen it and open it to other nations, especially in Latin America. It should be noted that the Japanese and Brazilian facilities are quite small, not oriented presently toward export.

A political impulse will have to be provided by high-level governmental leaders if a program of internationalizing the nuclear fuel cycle is to gain any traction. Nations that have nuclear weapons and those that do not should join in making this program a truly joint enterprise.

Complementary Policies

Commercial markets have generally worked satisfactorily in terms of assurance of nuclear fuel supply. But energy security, naturally, is a matter of prime concern for any nation and the high costs of building a nuclear power industry cause governments to be extra wary about the reliabilities of fuel supplies. Several plans already have been advanced by the United States, Britain, Japan and other nations to provide assurances of reliable fuel supply. These should be encouraged and should be developed further.¹⁶ These may not meet perceived requirements for a level playing field, but they weaken one argument for developing indigenous fuel cycle services. They may well satisfy the economic and political interests of most consumer-nations. Each of the proposals has the advantage that it adds to the diversity of suppliers, which is one of the most effective guarantees of uninterrupted supply of nuclear fuel. This also is true, of course, of multinational enrichment facilities, provided that the geographic distribution and the political complexion of the owners/managers are diversified.¹⁷

The nuclear fuel bank option, advanced by the Nuclear Threat Initiative (NTI) and endorsed by many others, should be an excellent form of assurance, depending on conditions of supply set by the IAEA, and the nation supplying the fuel. The fuel bank is both multilateral, in the sense that the IAEA supervises it, and responsive to demands for equality. Dr. Pierre Goldschmidt, former deputy director general of the IAEA, has suggested that

an IAEA low enriched fuel reserve should, for practical reasons, be physically located (in the form of UF₆) at the sites of all commercial enrichment plants. In addition, the Agency should conclude contracts with all manufacturers of fuel assemblies, whereby it would have the assurance to have access, in case of necessity, to some fabrication capacity.¹⁸

The Global Nuclear Energy Partnership

The Global Nuclear Energy Partnership (GNEP) is one of the Bush administration's efforts to answer concerns about reliability of fuel supply. The Department of Energy's research and development under GNEP currently is predicated on the concept of a U.S.-developed reactor (most likely a sodium-cooled fast reactor) that will use "recycled" fuel, but this is still in the early stages of development. The Department of Energy also is investigating a more proliferation-resistant separation process (UREX+1 and UREX+1a). GNEP's current focus appears to be too narrow at this point in time. A broader array of technology options could be added to its programs.

Precedents and Possibilities for Multinational Enrichment Facilities

Gaining control of the nuclear fuel cycle through internationalizing it could help to turn governments away from acquiring the complete nuclear fuel cycle. Private-sector initiatives within a policy framework established by governments and backed by

government support could play a major role. In contrast to the “top down” approach of the Acheson-Lilienthal Report, a mixed approach, relying in part on private-sector initiatives could become a major motivator.

But the utility of economic incentives in this field has to be understood in the context of the three multinational uranium enrichment facilities being planned for construction in the United States. They are multibillion dollar enterprises with multibillion dollar investments in proprietary technology developed over decades. They operate in a business that has very high barriers to entry and complex risk/reward calculations. One, located in Lea County, New Mexico, is being built by LES, which is owned by Urenco. It will be on-line in 2009 as the first centrifuge plant in the United States. A second, to be built 18 miles west of Idaho Falls, Idaho, will be owned by the multinational French-based firm, Areva. It also will use centrifuge technology. Technology will be protected in these two cases by “black boxes.” The third, using laser technology, is planned by the U.S.-Japan joint venture GE Hitachi Nuclear Energy and its subsidiary, Global Laser Enrichment (GLE). The technology was developed by Silex Systems Limited of Australia. The plant will be built at Wilmington, North Carolina and is expected to be in operation on a commercial scale in 2012. Cameco, a Canada-based uranium producing company, recently has brought a 24% stake in GLE.

A fourth new plant will be built by the U.S. Enrichment Corporation. USEC is planning to operate its centrifuge plant at Piketon, Ohio on a commercial scale in late 2009 and will have 11,500 machines deployed in 2012. It will use American technology, the only plant in the United States to do so.

Urenco is a particularly interesting model of a multinational facility but it may also be unique because of its membership. It is a multinationally owned and operated facility in which technology is shared among the founding participants. The United States will have access to the technology only to the extent necessary to grant licenses. Urenco was established by the Treaty of Almelo, signed March 4, 1970, by Great Britain, Germany, and The Netherlands. The treaty entered into force in 1971. Urenco, as of 2007, had 23% of the world’s market share for enriched uranium.¹⁹ All three founding countries are close allies and share basic values so decision-making, which is based on unanimity, has not been a problem. Urenco was the source of A.Q. Khan’s blueprints for an advanced centrifuge which later became the basis for Pakistan’s uranium-based nuclear weapons program, which is an obvious blight on its record. The overall experience shows that, among like-minded states, with resources available for large-scale investments, multinational facilities are practical and commercially viable

Areva and GE Hitachi are more in the mold of classic multinational corporations, which means that many nations potentially could become shareholders, if not real managers of operations. Management and staff operations have been limited to nationals of the nations whose companies dominate these multinationals.

Iran

The most difficult question about multinational enrichment facilities is whether they should be encouraged in unstable areas in return for rolling back incipient nuclear weapons programs. The test case is Iran, where a study by John Thomson and Geoffrey Forden, of MIT, suggests that measures can be taken to prevent the expropriation of a multinational facility by the Iranian government and that the likelihood of discovery of any concealed enrichment facility in Iran would be enhanced by establishing such a facility.²⁰

They have postulated a multinationally owned and operated enrichment facility located in Iran, using Urenco or Russian centrifuges, which would supplant Iran's nationally operated enrichment facility. In their analysis they describe legal, organizational, and technological barriers to nuclear proliferation, as well as barriers to nationalization. They point out that increased potential for detection of overt enrichment facilities could result from this arrangement, based on UNMOVIC and UNSCOM experience in Iraq. This is an example of the model where consumer countries would be heavily involved in ownership and management, although the technology would be "black-boxed". It is a model that may answer the level playing field arguments but, as should be expected in violence-prone regions, has proliferation risks of its own. An alternative that should be explored is a Saudi proposal for a multinational enrichment facility to supply reactors located in the Middle East, including Iran. The facility would be located outside the region, possibly in Switzerland.

Forden and Thomson report that Iranians with whom they have talked have expressed an interest in involving India and South Africa in such a facility. In a letter dated May 8, 2008 to the UN Secretary General from the Foreign Minister of Iran, it was stated that the government of Iran is ready to consider "establishing enrichment and nuclear fuel production consortiums in different parts of the world – including in Iran." The letter also spoke of "nuclear disarmament."²¹

Preventing the spread of advanced centrifuge or laser uranium enrichment technology would be a matter of concern in any multinational enterprise, even if the partners were on good terms. The technology is sensitive, and in cases of multinationally owned and managed facilities where the partners may not be equally advanced in enrichment technology, or even on very good terms with each other, that technology will not be shared among all the owners and managers, or with IAEA inspectors. This problem has been resolved in the past by the "black-box" approach to protecting technology and an on-site inspection system developed for the Urenco situation known as "Limited Frequency Unannounced Access." This gives inspectors unannounced access to the cascade hall under specified conditions. This system should be adopted by all states involved in a multinational enrichment enterprise. The question of conditions is common to all fuel supply options but applies with special force in unstable regions. Treaties or contracts should include provisions for: (1) enforcing Nuclear Supplier Group conditions for supply of fresh fuel; (2) safeguards against the host nation's seizing unilateral control of the enrichment facility; (3) a method of preventing the transfer of sensitive nuclear

technology to participants in a plant who did not previously have access to that technology, in accordance with NPT and Nuclear Suppliers Group rules.

Asia

Asia presents special complications. India, Pakistan, China, and Japan each have enrichment facilities ranging from pilot plants in the case of India to full-scale production facilities in the other countries. Japan has a commercial uranium enrichment facility (Rokkasho) and China has two, Lanzhou 2 and Shaanxi. China also has a gaseous diffusion plant for production of highly-enriched uranium. Pakistan has a centrifuge facility at Kahuta and probably one at Golra Sharif, as well. India has two pilot-scale uranium enrichment facilities.

China's commercial enrichment facilities use Russian technology, apparently under "black box" conditions and are under IAEA safeguards. Russia and China are cooperating actively in uranium enrichment services and nuclear fuel transfers. **With Russia now strongly promoting a network of international uranium centers, it is conceivable that China might agree, if only for its own commercial interests, also to open one or more of its enrichment facilities to international ownership and joint management.** It certainly should be asked, perhaps by Russia.

Japan and the United States signed a Joint Nuclear Energy Action Plan on April 18, 2007. One of its four main areas of cooperation is "establishment of a nuclear fuel supply assurance mechanism."²² In the meantime Japan's strategy has been to form joint ventures with companies operating in the nuclear field. This includes GE and Hitachi, Areva and Mitsubishi, and Toshiba's acquisition of Westinghouse.²³ The purpose is to capture part of the market for building new reactors. Japan Nuclear Fuel Limited (JNFL), owned largely by Japanese electric companies, controls the nuclear fuel cycle in Japan, including the Rokkasho uranium enrichment plant and a new mixed oxides (MOX) fabrication plant. A reprocessing plant is now under construction. *Consultations with Japan should start soon, aimed at investigating the possibilities for transforming the Rokkasho enrichment facility into a multinationally owned joint venture in parallel with a similar development in the United States.*

Pakistan and India require special consideration as non-members of the nonproliferation treaty who have also tested nuclear weapons. There is a great deal of well-documented sensitivity in both countries about rights to fuel cycle technologies. Each nation also has growing needs for energy. Nuclear power plants clearly will figure importantly in the mix of electric power-generating capacity in the subcontinent in the decades ahead.

In the near-term there is little chance either India or Pakistan will give up its enrichment facilities and each will retain an interest in domestic reprocessing facilities, most of which are involved in their weapons programs. But two developments might change this outlook over the mid-term: First, a growing coalition of the nuclear weapons states and others to move towards a world without nuclear weapons, a movement that

would change current expectations about the future salience of nuclear weapons in defense strategies; second, a global movement towards multinationally owned and operated enrichment facilities in which the United States, Canada, Russia, China, Western Europe, Japan and other nations are involved.²⁴ **A policy of relying on a few multinationally owned and operated enrichment facilities for the supply of fuel for reactors can become a serious possibility even in India and Pakistan if the goal of a world without nuclear weapons is generally adopted and if multinational enrichment facilities become the norm.** In fact, if India succeeds in its current plans to develop and build a large number of breeder reactors, India's requirements for enriched uranium may not grow at the same pace as its nuclear power program. A Fissile Material Cutoff Treaty would also help, as could the Iran international enrichment facility advocated by Forden and Thomson.

The major challenge to nonproliferation policies lies in the arc of uncertainty from South Africa, through the Middle East, to South Asia, and on to Australia. South Africa and Australia both appear to be considering their indigenous enrichment options. There are opportunities for cooperation in this area, since several nations are well disposed to the idea of preventing the proliferation of nuclear weapons. But there are also serious obstacles.

Enforcement

Although this paper focuses as a first priority on internationalizing facilities for enriching uranium, several other actions must be taken to prevent nuclear weapons proliferation. They include:

- Limiting the spread of reprocessing facilities and technology
- Controlling exports of nuclear materials and technology;
- Removing high-enriched uranium from exposed locations to secure storage facilities.

All of these actions, as well as the effort to ensure that uranium enrichment is used only for peaceful purposes, will be successful only if the international community is willing to take enforcement actions in cases of violations of NPT or IAEA obligations. This requires an international consensus, or something close to it, that violations of nuclear-related norms and agreements present a serious challenge to international peace and security. This consensus has been impossible, thus far, to achieve. Unless that problem can be effectively addressed, nuclear proliferation will proceed and the vision of a world without nuclear weapons will not be realized.

An international review, perhaps sponsored by the UN Security Council, should be conducted as to whether enforcement mechanisms could be devised that could be put into practice in case of violations of agreements. The issue of enforcement is fundamental and has never been satisfactorily resolved in nuclear matters. It needs a thorough airing in international arenas, and discussions by the UN Security Council. UNSC Resolution 1540 might be a suitable base for exploring what the Council could agree to, in advance, to deal with non-compliance.

Dr. Mohamed ElBaradei has drawn attention to this problem and to the need for the UN Security Council to have a “response mechanism”.²⁵ Several levels of sanctions agreed in advance should be identified, for example: removal of nuclear-related equipment supplied to a nation that withdraws from the NPT; an embargo on all future nuclear-related transfers; mandatory transparency measures; financial and commercial restrictions; and disabling of key nuclear facilities. If military action is necessary, it should focus on compliance issues, and hold the non-compliant regime to account for correcting any violations.²⁶

Military actions obviously would be warranted only by an apparent and imminent threat to international peace and security, but a Statement of the UN Security Council President on January 31, 1992 would seem to support that interpretation in most cases of a nation’s withdrawal from the NPT. A scenario involving the use of force might include limited naval or air forces in an intercept mission similar to those for which the Proliferation Security Initiative (PSI) was created. Aerial surveillance, such as was carried out in Iraq during the years prior to the invasion in 2003 is another possible scenario. An idea that might represent a “last resort” in an escalating situation was advanced by Dr. Jessica Mathews, president of the Carnegie Endowment for International Peace in 2002.²⁷ It was a plan for “coercive inspections”. Her proposal dealt with the issue of UN inspections in Iraq, but it is an enforcement mechanism which could have relevance in other dire situations. Dr. Mathews suggested that the UN Security Council might adopt a resolution authorizing multinational enforcement action to enable inspectors to carry out their UNSC mandate. She envisaged that the Security Council would authorize the creation of an “Inspections Implementation Force” to act as an enforcement arm for IAEA. The IAEA inspection team would be “*accompanied by a military arm strong enough to force immediate entry into any site at any time with complete security for the inspections team.*” (italics added) Dr. Mathews made it clear that the “military arm” would be a very powerful force consisting of air and armored cavalry units with substantial air support. “Use of all necessary means” would be the next step beyond the use of an Inspections Implementation Force.

A World Without Nuclear Weapons: Relating the Vision to the Steps

In any estimate of the current nuclear situation, it is impossible to ignore the core problem. This is the general assumption, shared alike by nuclear-armed nations and by those nations that have forgone nuclear weapons that the development and acquisition of nuclear weapons will proceed, that a nuclear-armed world is here to stay. That assumption has to be changed, for assurances of fuel supply by any imaginable means will not be sufficient indefinitely to block the gradual spread of nuclear-armed states. Eliminating the two-tier system of nuclear and non-nuclear armed states must go hand in hand with eliminating the two-tier system in civil nuclear power because otherwise, slowly but surely, more states will become capable of making nuclear weapons and those states will have at least the option of starting a weapons program.

A basic proposition of this paper is that a solution to the fuel cycle problem depends on embedding it in a broad commitment to a world free of nuclear weapons and

vice versa. The way to move forward is, first, to engage the United States and Russia in a commitment, at the highest levels, to work jointly toward a world free of nuclear weapons. The leaders of the two countries should follow this up with specific programs to reduce their strategic nuclear forces below the levels specified in the May 24, 2002 Treaty of Moscow. While implementing this commitment, and others, the presidents of the United States and Russia should invite other nations to join their two countries in working toward a world free of nuclear weapons. Each nation would be asked to commit to achieving a world without nuclear weapons and also to make a contribution to this goal, according to its special circumstances. A commitment to multinationally owned and managed nuclear fuel centers should be a key part of this program.

Unless impending decisions in several countries regarding the fuel cycle are made in a coherent way, with a view to how they contribute to the achievement of a world without nuclear weapons, these decisions will instead contribute to the spread of nuclear weapons capabilities. Conversely, if the goal of a world free of nuclear weapons is accepted by the international community and actions regarding the fuel cycle are consistent with that goal, it should be easier to expand the use of nuclear power without running the risk of nuclear weapons proliferation. The two have to be linked, not in lock-step, but in a way that permits each track to proceed as rapidly as events permit. Progress in one area should encourage progress in the other but, conversely, sensible progress in one area should not be delayed while waiting for progress in the other. The basic condition for success in escaping from the world's nuclear dilemma lies, as it did at the beginning of the nuclear age, in broad acceptance of the goal of a world without nuclear weapons.

¹ Helen Caldicott, Nuclear Power is Not the Answer (The New Press, 2006)

² Dr. Charles W. Forsberg, Executive Director, MIT Nuclear Fuel Cycle Study, private communication. Dr. Forsberg notes that oil hit \$133/barrel on May 21, 2008 and “that is over \$3.00 per gallon for gasoline in just the oil costs. It implies that about two trillion dollars per year is being transferred primarily to five oil exporters: Saudi Arabia, Iran, Iraq, Kuwait, and Venezuela. It is the largest and fastest transfer of wealth in the history of mankind. If it continues for a decade, much of the U.S. economy will be owned by these countries. That is noteworthy because it’s tough to argue with your banker about nonproliferation.”

³ Dr. Henry Rowen, Stanford University, private communication.

⁴ Earlier in 2008 Canada told the United States that it would no longer support the G-8 moratorium on not transferring technology to any state that does not already possess enrichment or reprocessing capabilities. This led the U.S. to shift its position at the Nuclear Suppliers Group (NSG) away from a moratorium and toward the inclusion of criteria in the NSG Guidelines. For background see http://www.armscontrol.org/act/2008_05/NuclearExport.asp and http://ap.google.com/article/ALeqM5ipQB9GzyPIIY_UCu2oLvVfTgyA4wD90719A00

⁵ This point has been developed by Dr. Geoffrey Rothwell, Department of Economics, Stanford University. See presentation by Dr. Rothwell, “The Economics of International Supplier States and Recipient State Regimes for Worldwide Nuclear Fuel Services”, presented at the Howard Baker Jr. Center for Public Policy, October 3, 2007. Rothwell believes that market intervention to stabilize prices near reasonable cost, as mentioned by President Bush on February 11, 2004, may become necessary.

⁶ <http://www.learnworld.com/ZNW/LWText.Acheson-Lilienthal.html> A ground-breaking work in this field was written by Dr. Lawrence Scheinman in 1981. Published originally in International Organization, as “Multilateral Alternatives and Nuclear Nonproliferation”, it was republished under the title “The Nuclear

Fuel Cycle: A Challenge for Nonproliferation” in Disarmament Diplomacy, No. 76, March/April 2004, The Acronym Institute.

⁷ Many scholars, particularly those adhering to the “constructivist” school of international relations, have written about international institutions as they have developed in the era of globalization. These institutions, such as the World Trade Organization, can have supranational characteristics in the specialized field in which they function. Professor Amitai Etzioni has written cogently about emerging global governance through the new institutions for transnational cooperation that have been created incrementally without benefit of a single overarching organization. As an example, Etzioni points to international cooperation in the field of counterterrorism and counterproliferation. He regards the Bush administration’s Proliferation Security Initiative as a nascent enforcement mechanism for such an authority. See “Genocide Prevention in the New Global Architecture.” The British Journal of Politics and International Relations, 2005 Vol. 7, 469-484. He also envisages a branch of the “Global Safety Authority” that would deal with what he calls “deproliferation”. For a comprehensive analysis, see his From Empire to Community: A New Approach to International Relations (Palgrave Macmillan, 2004). The informal accumulation of responsibilities by an international authority acting on behalf of national governments is a process that could occur in the fuel cycle area.

⁸ As is stressed by Charles W. Forsberg in a private communication and elsewhere.

⁹ According to the IAEA, uranium enrichment facilities exist in Argentina, Brazil, China, France, Germany, India, Iran, Japan, The Netherlands, Pakistan, Russia, the United Kingdom, and the United States. Some of these are quite small and some already are multinationally owned and operated. It has been estimated that existing uranium enrichment facilities are capable of supplying all the reactors on line or expected to come on line in the next decade or so with the type of enriched uranium useful for reactors. But a transition from high-cost gaseous diffusion technology to less expensive centrifuge technology is underway and the rate of growth of reliance on nuclear power is uncertain. See the IAEA’s INFCIRC/640.

¹⁰ Irma Arguello, “Confidence Building in Regional Conflicts Involving Nuclear Dangers”, presented at the Oslo Conference, February 26, 2006. A new Brazil-Argentinian company that will engage in nuclear enterprises, including enrichment, has been created.

¹¹ Abram Chayes and W. Bennett Lewis, International Arrangements for Nuclear Fuel Reprocessing (Ballinger Publishing Company, 1977)

¹² According to the World Nuclear Association, more than 30 reactors use MOX fuel in Europe (Switzerland, Germany, and France) while about 40 reactors are licensed to do so. In Belgium all the plutonium recovered from the reprocessing of 670 tonnes of spent fuel has been recycled as MOX fuel in two nuclear power plants. Japan also has a plant to use MOX fuel in about 20 of its reactors. Most reactors today accept 50% MOX assemblies. (www.world-nuclear.org/info/inf29.html). India is planning to embark on a very ambitious breeder reactor program.

¹³ Burton Richter states that while “MOX fuel has become a standard product...there is no real necessity for its use now.” “Nuclear Power and Proliferation of Nuclear Weapons”, Stanford University, February 22, 2008.

¹⁴ See Lawrence Scheinman’s, “Safeguarding Reprocessing Facilities: The Impact of Multinationalization”, International Arrangements for Nuclear Fuel Reprocessing edited by Abram Chayes and W. Bennett Lewis, (Ballinger Publishing Company, 1977). Also see, pg. 4 “The Future of Nuclear Power”, MIT interdisciplinary study, July 2003, <http://web.mit.edu/nuclearpower/>. “Energy parks” are proposed. Charles Forsberg notes that energy parks present two challenges. If electricity is the product, there are many transmission lines to the customers. The longer the electric transmission lines, the greater are the electrical losses. Second, all power systems require cooling water. That can be a limitation to the power output of the energy park. If the energy park is producing a fuel such as hydrogen, the energy transport problem disappears, because a relatively small pipeline moves far more energy than many power lines. Private communication.

¹⁵ Laura Holgate, NTI, has suggested the possibility of Canadian participation in the new Areva facility. Private communication. Areva is a public multinational conglomerate based in France which was formed by merging two French companies. Siemens is a large shareholder.

¹⁶ See Chaim Braun, “Nuclear Fuel Supply Assurance” (unpublished draft) for a comprehensive review and assessment of these plans. Another excellent review is a Congressional Research Service Report for Congress, “Managing the Nuclear Fuel Cycle: Policy Implications of Expanding Global Access to Nuclear

Power”, updated January 30, 2008, by Mary Beth Nikitin, Jill Marie Parillo, Sharon Squassoni, Anthony Andrews, and Mark Holt.

¹⁷ Charles W. Forsberg puts it well: “...there have to be multiple enrichment suppliers that do not have strong political ties to each other, and preferably, dislike each other.”

¹⁸ Dr. Pierre Goldschmidt, lecture at the 24th Conference of the Nuclear Societies, Israel, February 19-21, 2008

¹⁹ <http://www.urenco.com/>

²⁰ <http://mit.edu/stgs/irancrisis.html>

²¹ The text of the nuclear section of the Iranian proposal is as follows:

“ C – The Nuclear Issue:

With regard to the nuclear issue, Iran is ready- in a comprehensive manner, and as an active and influential member of the NPT and the IAEA- to consider the following issues:

1. Obtaining a further assurance about the non-diversion of the nuclear activities of different countries.
2. Establishing enrichment and nuclear fuel production consortiums in different parts of the world- including Iran.
3. Cooperation to access and utilize peaceful nuclear technology and facilitating its usage by all states.
4. Nuclear disarmament and establishment of a follow up committee.
5. Improved supervision by the IAEA over the nuclear activities of different states.
6. Joint collaboration over nuclear safety and physical protection.
7. An effort to encourage other states to control the export of nuclear material and equipment.”

²² U.S. DOE press release, April 25, 2007

²³ “GE, Hitachi to join nuclear-power businesses”, Reuters, November 13, 2006.

²⁴ Judgments regarding India and Pakistan are derived in part from Subrata Ghoshroy, MIT, in a private communication.

²⁵ In a discussion at the Council on Foreign Relations in New York on May 14, 2004, Dr. Elbaradei remarked that the French foreign minister had told him that “maybe you have to have an agreed system of sanction, agreed in advance in the case of a country’s withdrawal, so you would know the cost in advance before you decide to withdraw.”

²⁶ The IAEA’s “Report of the Commission of Eminent Persons on the Future of the Agency”, released on May 23, 2008 recommends that

The UN Security Council should go beyond its Resolution 1540 by: passing a new resolution making clear that the proliferation of nuclear weapons is a threat to international peace and security; legally prohibiting any state that withdraws from the Nonproliferation Treaty from using for military purposes any nuclear facility, materials, or technologies that it received for peaceful purposes while a party to the NPT; and legally imposing safeguards obligations, going well beyond the Additional Protocol, on any state that substantially violates its safeguards obligations.

Dr. Goldschmidt has written extensively on this subject. He has recommended that the UN Security Council should adopt a generic and legally binding resolution stating that if a state withdraws from the NPT (an undisputed right under its Article X) after being found by the IAEA to be in non-compliance with its safeguards undertakings, then such withdrawal constitutes a threat to international peace and security as defined under Article 39 of the UN Charter. He suggests that it would be logical and legitimate for the Security Council to pre-agree that, in these circumstances, all military cooperation with the non-compliant state would be suspended. Also, “all materials and equipment made available to such a state or resulting from the assistance provided to it under a Comprehensive Safeguards Agreement would have to be forthwith removed from that state under IAEA supervision and remain under Agency’s Safeguards”

Dr. Goldschmidt also proposed several ways in which enforcement could be mandated by the UN Security Council. He has suggested, for example, that in cases of a state’s noncompliance with safeguards agreements:

- “the non-compliant state [must] provide the Agency with the necessary additional verification authority...prompt access to persons, broader and prompter access to locations, in site access to

original documents and copies thereof, broader and faster access to information, and the lifting of other types of restrictions which experience has shown can be employed as obstructive tactics.” See his “Mechanisms to Increase Nuclear Fuel Supply Guarantees”, Pierre Goldschmidt, Carnegie International Non-Proliferation Conference, Washington DC, November 7-8, 2005 and lecture at the 24th Conference of the Nuclear Societies, Israel, February 19-21, 2008.

²⁷ “Iraq: A New Approach”, August 2002, Carnegie Endowment for International Peace.