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- *Nuclear power should be an important option to help meet long-term global energy needs and can be made consistent with a stronger non-proliferation regime based on the NPT.*

- *Major long-term RD&D efforts are needed to improve the economics, safety, proliferation resistance, and risk performance of nuclear power.*

- *Advances in fuel cycle technology may hold the promise of improving management of nuclear wastes and increasing the proliferation resistance of nuclear power.*

- *The U.N. Security Council should vigorously support compliance with non-proliferation obligations.*

Proliferation and the Future of Nuclear Power

Can the promise of nuclear power in helping resolve the world's growing demand for energy be reconciled with the increasing concern about the spread of nuclear weapons and the weaknesses of the current non-proliferation regime? If so, what existing or prospective nuclear power technologies will be best suited to help resolve these issues and what changes, institutional or legal, may be needed to accommodate a substantially larger nuclear power sector?

Recent events, both in energy development and the ongoing international campaign against nuclear proliferation have sharpened these questions. In the hope of generating ideas helpful to policymakers who are grappling with these questions, and in the context of the ongoing study and action plan undertaken by the directors of the U.S. national labortories, the Atlantic Council convened a seminar[1] on the relationship between proliferation and the future of nuclear power on October 29-30, 2003. The seminar participants concluded that, with the proper institutional support and appropriate nuclear energy technologies, nuclear power can play a significant role in meeting energy demands within the framework of a reinforced non-proliferation regime.

Several new institutional and policy measures would allow nuclear power to expand, with U.S. encouragement, under conditions that are consistent with fostering U.S. non-proliferation objectives.

The Outlook for Nuclear Power

- *The Prospects.* There is growing appreciation and perception that the growth of nuclear power should be encouraged to help meet anticipated long-term global energy needs. The achievement of this objective will be dependent upon continued evidence that nuclear power is economically competi-

[1]A list of the participants, observers and guest speakers is included at the end of this bulletin.

tive, that nuclear power will benefit the environment, that nuclear plants can continue to be operated very safely and with high capacity factors, that it is possible to license and construct new plants on a timely basis, and that the growth of nuclear power can take place in a fashion that is fully compatible with non-proliferation objectives. Greater public support of the nuclear option also will be required.

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The World Energy Council [2], for example, forecasts that energy use will double by 2050 and that about one-third of this growth will occur in developing countries. As one-third of the world presently has no access to electricity, growth in electricity demand will be especially great (tripling by 2050). The WEC "stresses that the nuclear option should be kept open" with emphasis on research and development (R&D) on medium and large size nuclear power plants as well as "new innovative small size designs."

A study released by MIT on July 29, 2003[3] postulates a greatly expanded nuclear power sector, growing to a capacity of 1000 GW by mid-century, from a current base of 300 GW. The driving force for this recommendation is that "[t]he nuclear option should be retained precisely because it is an important carbon-free source of power."

At present, there are 440 licensed power reactors in operation in the world, 103 of which are in the United States. As of January 1st, 2004, 29 nuclear power reactors were under construction in ten countries (India: eight, Russia: six, Japan: three, People's Republic of China: three, Ukraine: two, others: seven).

- *Activities of the Six DOE National Laboratories.* A group of six Department of Energy (DOE) national laboratories[4] responsible for R&D on nuclear power and related proliferation issues have developed an action plan and common strategy to help ensure the timely growth and use of nuclear power. Their recommendations are fully consistent with a major new fuel cycle initiative conducted for several years by DOE with the strong support of the Congress. The goals of the laboratory group are to:

The recommendations provided by the laboratory group are fully consistent with a major DOE new fuel cycle initiative and strongly supported by Congress.

1. Reduce air pollution and climate change risks and improve energy security by meeting an increasing fraction of future U.S. and world energy needs through safe and economic nuclear energy solutions.

2. Reduce the threat of nuclear weapons proliferation, by enhancing safeguards and security for all elements of the fuel cycle.

3. Minimize reactor waste requiring repository disposal by reducing significantly the amount of uranium, plutonium, and minor actinides in waste. In this regard, like DOE, the laboratories have recommended that the United States should promptly investigate new and more proliferation resistant

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[2] www.worldenergy.org/wec-geis/publications/reports/ser/nuclear/nuclear.asp

[3] MIT, *The Future of Nuclear Power*, July 2003.

[4] Argonne National Laboratory, Idaho National Engineering and Environmental Laboratory, Lawrence Livermore National Laboratory, Los Alamos National Laboratory, Oak Ridge National Laboratory, and Sandia National Laboratory.

technologies for application in current and emerging nuclear fuel cycles. The laboratories believe advanced nuclear fuel cycles, under prudent conditions, could be important in helping ensure the long-term sustainability of nuclear power, in more effectively managing nuclear waste, and in reducing the dangers of nuclear proliferation. Some also believe that the advanced fuel cycles will be needed to offset the depleting global uranium resource base as nuclear power expands in the coming decades.

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◆ *Initiatives of the Department of Energy.* Both the U.S. government and industry agree that it is desirable to deploy nuclear power plants based on proven technologies. The first step toward the achievement of this goal is the DOE Nuclear Power 2010 Initiative, a government and industry cost-shared effort.[5]

The goal of an additional DOE effort, the Generation IV Initiative, is defined as follows: "Design one or more nuclear power systems that can be licensed, constructed, and operated in a manner that will provide a competitively priced supply of electricity while satisfactorily addressing the nuclear safety, waste, proliferation, and public perception concerns of the countries in which it is deployed."[6]

The member countries of the Generation IV International Forum[7] have selected six next-generation nuclear energy systems concepts. The concepts include a sodium liquid metal-cooled reactor, very high temperature reactor, supercritical water-cooled reactor, lead alloy-cooled reactor, gas-cooled fast reactor, and molten salt reactor.[8]

Participants in the Atlantic Council seminar strongly support the proposition that R&D on advanced fuel cycles must be vigorously pursued if nuclear power is to help meet global energy needs on a sustained and efficient basis. It is essential for the United States to be active in such work if it hopes to play an influential and constructive role in shaping both the future of nuclear power and the nuclear non-proliferation regime.

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[5] A Roadmap to Deploy New Nuclear Power Plants in the United States by 2010, DOE-NE and its Nuclear Energy Research Advisory Committee, October 31, 2001.

[6] Discussion on Goals for Generation IV Nuclear Power Systems, DOE, July 31, 2000.

[7] The ten members are: Argentina, Brazil, Canada, France, Japan, Republic of Korea, South Africa, Switzerland, the United States and the United Kingdom.

[8] Generation IV International Forum, "Update," September 20, 2002.

Cost Comparison

The following chart[9] presents a comparison of the estimated costs of nuclear, coal, and gas, taking into account the costs of handling used fuel or the sequestration of CO_2 produced in power generation by gas and coal. This comparison indicates favorable performance by nuclear power.

Power Costs (cents per KWh)

	Nuclear	Coal	Gas
Capital and Operating Cost	4.1-6.6	4.2	3.8-5.6
Waste Sequestration	0.1	2-3	1-1.5
Total	4.2-6.7	6.2-7.2	4.8-7.1

[9] Steyn, Julian, "Nuclear Power Economics," October 29, 2003.

◆ *Economics of Nuclear Power*. Based on European studies, a comparison of turbine generating costs estimated for the period 1997-2003 show nuclear power costs of 2.4-3.9 Euros/KWh and 3.1-9.2 for gas.

Participants in the seminar agreed that it is desirable and possible to reduce the capital and operating costs of new nuclear power plants as well as the costs of handling used nuclear fuels. In addition to interest rates, the costs of capital can be dramatically affected by the amount of time required for siting and licensing. The Generation IV Initiative is aimed at addressing these and other issues.

◆ *Environmental Issues.* A recent paper by Angelina Howard[10] of the Nuclear Energy Institute illustrates some environmental benefits of nuclear power. Between 1995 and 2002, nuclear energy in the United States avoided 30.9 million short tons (MMst) of SO_2, 13.54 MMst of NOx and 441.7 million metric tons of carbon. The magnitude of such avoidance demonstrates a significant advantage for nuclear power when considering factors such as environmental pollution and global climate change.

As noted above, a recent study by an MIT group strongly supports a significant increase in nuclear power by mid-century to "avoid 1.8 billion tons of carbon emissions annually from coal plants."

There are many political, economic, and technical obstacles to the establishment of nuclear repositories.

◆ *Repositories and Fuel Cycle Initiatives*. Discussions regarding the Yucca Mountain repository for spent nuclear fuel illustrate that there are many political, economic, and technical obstacles to the establishment of nuclear repositories. Until Yucca Mountain becomes available, nuclear power plants across the country must store spent fuel on-site at their facilities. Major concerns regarding repositories include long-term security (thousands of years), safety, access to nuclear materials that can be converted into weapons, and potential environmental impacts. The transport of used fuel to a repository has also posed a number of questions regarding safety and security. The State of Nevada has filed several law suits against DOE plans to establish a repository at Yucca Mountain, including suits about the program decision procedure and the constitutionality of the selection process. Future repository projects could face similar opposition.

The United States should be open to periodic evaluation of the merits of both open and closed fuel cycles.

Closed fuel cycles are now used in some Western European countries, in Russia and in Japan. These countries, and some in the United States, wish to recycle nuclear fuels because they believe it is essential to the long-term stability of nuclear power, will lead to better ways to manage radioactive waste, and will ultimately lead to the best way to handle plutonium now building up in spent fuel. Others believe that utilization of a once-through fuel cycle is preferable for the foreseeable future on both economic and non-proliferation grounds. There is, however, widespread agreement that, in conducting its advanced nuclear R&D program, the United States should be open to periodic evaluation of the merits of both open and closed fuel cycles.

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[10]Howard, Angelina S., "Nuclear Power's Role in Reducing Emissions," October 29, 2003.

Some believe that the UREX initiative, which involves the separation of uranium and is part of the Advanced Fuel Cycle Initiative, exhibits some proliferation-resistant characteristics since it does not involve the separation of plutonium and the minor actinides.

- *Conversion of Nuclear Weapons Materials Into Civilian Reactor Fuel*. During the past several years a very significant cooperative program between the United States and Russia has resulted in the elimination of 7,500 nuclear warheads. Over 190 metric tons of highly enriched uranium from the dismantlement of Russian nuclear warheads has been blended into low enriched nuclear fuel, which is being used in commercial nuclear power reactors throughout the world. This "Megatons to Megawatts" program now provides 10 percent of the U.S. electric supply. The United States and Russia have also each agreed to dispose of 34 tons of excess weapons grade plutonium. The United States is working to eliminate legal, financial and political barriers to enhanced cooperation in the area of plutonium disposition.

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- *Public Perception.* A recent paper by James Flynn[11] of Decision Research discussed the issue of public perception, stressing in particular the need for more effective communications regarding the future of nuclear power. Perceptions about the relative risks and benefits of nuclear power depend on the paradigm through which people view such issues. Nuclear power advocates have been ineffective in altering the risk oriented paradigm now held by the U.S. public. Flynn notes that "[t]he basic requirement is to understand how evidence is viewed in the real social world, what cognitive options people have to make sense of what they hear, see, and feel. Only when new levels of insight into the world of stakeholder ideas and expressions are achieved will risk communications be equipped to understand the issue of nuclear stigma and address the needs for public support of future nuclear power projects." Flynn suggests that Federal support should be provided for risk communication research to increase understanding between expert and public positions on nuclear and other advanced science technologies.

It is vital that the growth of nuclear power take place under terms that are fully supportive of the achievement of non-proliferation objectives.

Non-Proliferation Implications

No one questions that the growth of nuclear power should only take place under terms that are fully supportive of the achievement of non-proliferation objectives. One source of confidence that this goal can be realized is that in general, the safeguarded nuclear fuel cycle has not been the avenue of choice for nations or groups intent on acquiring nuclear weapons. Nevertheless, serious new challenges are being posed by the diffusion of nuclear technology and sensitive materials, and some states are electing to act in apparent disregard of their non-proliferation responsibili-

[11]Flynn, James, "Public Opinion and the Future of Nuclear Power in the United States," October 29, 2003.

ties and obligations under the Non-Proliferation Treaty. It is important that the United States be open to the consideration of new institutional and technological modalities that may serve to strengthen the global non-proliferation regime. At the same time, it is crucial that the United States avoid taking any steps that will serve to undermine the strength of the NPT or the broad reach and effectiveness of the IAEA safeguards regime.

It is crucial for the United States to avoid steps that will undermine the strength of the NPT or the IAEA safeguards regime.

- *Iran and North Korea.* While the current multilateral approaches for addressing the nuclear weapons programs of Iran and North Korea are welcome, these countries present two critical tests on which the future of the nuclear non-proliferation regime will depend heavily. The resolution on Iran adopted by the IAEA Board of Governors on November 26, 2003 deploring Iran's past failures to comply with its non-proliferation obligations while deferring for now the question of sending the Iran issue to the UN Security Council, should provide strong incentives for Iran to abide by its commitments to cooperate fully and transparently with the IAEA, to sign and implement faithfully the Additional Protocol, and to suspend all enrichment-related and reprocessing activities. These Iranian commitments are important steps, but doubts remain as to whether the Iranian leadership has yet made the fundamental decision to give up its nuclear weapons ambitions. Persuading Iran to do so will require sustained pressure and unity on the part of the United States, Europe, Russia, and the IAEA in the months and perhaps even years ahead. A durable solution to the nuclear issue would include Iran's permanent renunciation of national fuel cycle capabilities, in exchange for which Iran might be provided a multilateral assurance that it would receive reliable fuel cycle services on a commercial basis for any power reactors it acquires.

While it is unclear whether the Democratic People's Republic of Korea (DPRK) is genuinely prepared to give up its nuclear weapons program, the Beijing-hosted six-party process is the most effective way of testing the DPRK's intentions and possibly resolving the current nuclear crisis. Seminar participants support the framework currently being considered for a negotiated solution – a multilateral security assurance to Pyongyang in exchange for the complete and verifiable termination of North Korea's nuclear weapons programs. Assistance in addressing North Korea's pressing energy requirements is also likely to be an important element of any deal. However, the United States and other participants in the Korean Peninsula Energy Development Organization have announced a one-year suspension, beginning December 1st, 2003 of the light water reactor (LWR) project in North Korea. Whether political conditions will permit a revival of the LWR project under any negotiated solution to the North Korea issue remains doubtful, but if it were to be revived, it would have to be under much more rigorous standards than those of the 1994 Agreed Framework (e.g., intrusive monitoring, no retention of used fuel in the DPRK).

The group supports a multilateral security assurance to Pyongyang in exchange for the complete and verifiable termination of North Korea's nuclear weapons programs.

- *Proposals of the IAEA Director General.* The Director General of the IAEA, Dr. Mohamed El Baradei, published an article in the October 16,

2003 issue of the *Economist* presenting his views on reducing global proliferation risks. They included the need to revisit the limitations of the 1970 Treaty on the Non-Proliferation of Nuclear Weapons, to strengthen inspections by the IAEA, and to consider a "multinational approach to the management and disposal of spent fuel and radioactive waste." More specifically, El Baradei proposes a framework to overcome the deficiencies of the non-proliferation regime:

1. Limit the processing of weapon-usable material in civilian nuclear programs, as well as the production of new material through reprocessing and enrichment, by agreeing to restrict these operations exclusively to facilities under multinational control.

2. Deploy nuclear energy systems that, by design, avoid the use of materials that may be applied directly to making nuclear weapons.

3. Consider multinational approaches to the management and disposal of spent fuel and radioactive waste.

While the Atlantic Council's seminar participants believe that the United States should be open to such new ideas, some have expressed doubts about the feasibility and real non-proliferation value of aiming to operate facilities under multinational control. Rather than trying to adopt a "top down" new approach in this regard, a more practical approach, in their view, would be for commercially oriented consortia to offer fuel cycle services (e.g. provision of finished reactor fuel, take back of used fuel) to countries wishing to pursue nuclear power programs. Others, however, point out that multinational approaches could offer some benefits, as noted in earlier IAEA studies and the studies of the Pacific Basin Fuel Strategic Concept. There was broad agreement that more analysis needs to be devoted to these approaches. The participants at the seminar strongly supported the second recommendation of the Director General, on the merits of designing and developing possible new nuclear systems that avoid the presence of separated weapons-usable materials. This would provide powerful incentives for countries to forego independent national fuel cycle capabilities.

Seminar participants strongly supported the IAEA Director General's recommendation on designing and developing new nuclear systems that avoid the presence of weapons-usable materials.

- *Ensuring Compliance with Non-proliferation Norms.* The international community, especially the United Nations Security Council, should play a more vigorous role in enforcing compliance with the NPT, particularly in responding strongly and with unanimity to the violation or abrogation of NPT obligations. NPT parties, and the Security Council iself, should give serious consideration to addressing one of the NPT's major weaknesses: the ability of a party legally to acquire the infrastructure for a nuclear weapons capability under the guise of a peaceful nuclear energy program and then to withdraw from the treaty with only 90-days' notice and embark on an overt nuclear weapons program with that infrastructure intact. At a minimum a state should not be allowed to withdraw legally from a treaty that it has been violating (e.g., North Korea). In addition, the Security Council might decide that, especially in certain circumstances, a country's with-

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Update

Since the convening of the Atlantic Council workshop in October 2003, and the subsequent development of this report, the president of the United States announced a set of significant measures to help counter the threat of weapons of mass destruction. Many of these measures are directly relevant to curbing the latent nuclear proliferation threat inherent in the global use of nuclear power, and directly parallel several key recommendations presented here.

drawal from the NPT – even if done legally – would constitute a threat to international peace and security and would require an appropriately firm response.

Conclusions

Participants in the Atlantic Council seminar reached the following conclusions:

- Nuclear power should be *an important option* to help meet long-term global energy needs while contributing to energy security. Nuclear power can also contribute significantly to the reduction of greenhouse gases and air pollutants such as SO_2 and NOx.
- The *Non-Proliferation Treaty* and the broad international application of *IAEA safeguards*, including adherence to the IAEA additional safeguards protocol, should be strongly supported. The IAEA safeguards system should receive adequate financial, technical and political support. Additive measures, such as the U.S. Proliferation Security Initiative, will be needed to supplement the NPT to discourage states from undertaking nuclear weapons programs. These measures should reinforce the integrity of the NPT.
- Ensuring *strict compliance* with the letter and spirit of the NPT, including its safeguards obligations, should be given the highest priority. The U.N. Security Council should vigorously enforce compliance with non-proliferation obligations.
- Priority should be given to ensuring *adequate physical protection* of nuclear materials and facilities in all countries with nuclear programs.
- Major *long-term RD&D efforts*, as exemplified by the DOE Advanced Fuel Cycle Initiative, and the international effort on Generation IV reactors, are needed to improve the economics, safety, proliferation resistance, and risk performance of nuclear power. A basic objective should be to insure that the safeguarded civilian nuclear fuel cycle continues to remain an unattractive route to pursue for nations interested in acquiring nuclear weapons. As part of this effort, the United States should be open to exploring the implications and feasibility of new ways to *improve both open and closed nuclear fuel cycles* as well as options for making nuclear power more readily available to developing nations. The successful pursuit of these goals will require the availability of more adequate financial resources and the adoption of a more stable Federal R&D program that will enjoy broad bipartisan political support. The ability of the United States to assert a continued leadership voice in shaping the future development of nuclear power and the nature of the non-proliferation regime will require the preservation of a strong and vigorous nuclear infrastructure within the United States.
- *Cooperative international efforts* in the area of nuclear R&D have many foreign policy and technical benefits in advancing the status of cooperating countries and the strength of the global non-proliferation regime.
- *Advances in fuel cycle technology* may hold the promise of

improving the management of nuclear wastes, in enhancing the sustainability and in increasing the proliferation resistance of nuclear power. However, the implications still need to be evaluated, and much work will be required to bring them to the point of practical and economic application.

- The U.S. government and U.S. business sector should strive to play a more *significant role in global and domestic activities* concerning the enhancement of nuclear power and achievement of non-proliferation objectives. This will require a revitalization of technical and managerial competence in this area. It may also require closer *government-business partnerships* to develop specific options designed to harness the power of the commercial market for nuclear energy to advance non-proliferation aims. ■

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