THE ATLANTIC COUNCIL

OF THE UNITED STATES

An Appropriate Role for Nuclear Power in Meeting Global Energy Needs

POLICY PAPER

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THE ATLANTIC COUNCIL OF THE UNITED STATES

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FOREWORD

In 1996, the Atlantic Council undertook a study of an appropriate role for nuclear power in meeting global energy needs. The project has two phases. The first, a policy paper *An Appropriate Role for Nuclear Energy in Asia's Power Sector*, dated December 1997, examined the role of nuclear power in the energy sectors of Asian countries. The present report addresses nuclear power in a global context.

The choice of Asia for the first part of the project was determined by the region's growing utilization of nuclear power. If present plans come to fruition, Asia's share of global nuclear capacity will rise sharply despite the economic difficulties encountered in 1997 and 1998. The fundamentals for long-term growth and prospects for the region are strong, and are likely to be translated into a sustained rapid increase in demand for electricity. Many Asian countries plan to include nuclear power along with other sources of power in their efforts to meet growing demand for electricity.

In contrast, nuclear power capacity in North America and Western Europe appears to have stalled, and it is uncertain whether additional nuclear capacity will be brought into operation in these regions over the next twenty years. Asia is therefore likely to become the locus of future nuclear power development. This development raises a variety of issues of importance both to Asia, and to the rest of the world, which are examined in the following pages.

The Atlantic Council's goal in both phases of this project was to develop analysis and recommendations, which would be useful to: policy makers with responsibility for nuclear energy issues; owners and managers of nuclear power facilities; environmentalists, opinion leaders, others interested in nuclear power issues; and the general public. The working group brought together to develop these papers therefore include individuals with broad knowledge of energy issues, nuclear energy experts, economists, environmentalists and social scientists. About half of the working group has particular expertise and interest in nuclear energy. The other participants with expertise on overall energy, economics and the social sciences have contributed significantly to broadening the perspective of the groups in discussions in Seoul in 1997 and in Cannes in May 1998, and through the exchange of papers and communication that took place during the extensive review process involved in the preparation of this report and the preceding report on Asia.

The recommendations represent the consensus views of participants in the project, all acting in their individual capacities. The weight of the recommendations lies in the expertise and experience of these participants and their ability to introduce the recommendations to decision makers in their own countries. While the working group members signed off on the present paper, each individual participant may not necessarily agree with every word. However, the extent of the working group's agreement on these recommendations is noteworthy, given the diversity of its membership and the controversial nature of the topic. Dissenting views and additional comments are presented either as footnotes or as separate comments in Annex I at the end of the paper.

We wish to thank the members of the working group for their exceptional level of commitment to this effort, their forbearance, and their high degree of collegiality. All members made substantive contributions, and many demonstrated particular dedication and involvement. We wish to thank

Donald L. Guertin for his steady guidance as project co-director. The project greatly benefited from the technical expertise and experience of its other co-director, William J. Dircks. Richard E. Balzhiser and Christian Gobert, as co-chairs of the steering committee, lent their authoritative leadership to the project. Thanks are due to Joy C. Dunkerley and Stephen P. Pettibone who acted as co-rapporteurs to the project, as well as to Eliane Lomax whose work in organization, communications, drafting, and editing was essential to the successful and timely completion of the project. In addition, we benefited from the assistance of our student interns, Jen Divis, Erik Heinle and Loretta Keith.

In closing, we wish to thank the Center for Global Partnership, the Japan Nuclear Cycle Development Institute, COGEMA, Inc., ABB-Combustion Engineering, the U.S. Department of Energy, BNFL, Inc., USEC Inc., the Nuclear Energy Institute, Los Alamos National Laboratory, Chubu Electric Power Company, Electric Power Development Company (Japan), Hitachi, Ltd., Japan Atomic Power Company, Kansai Electric Power Company, Mitsubishi Heavy Industries, Ltd., Tokyo Electric Power Company, Toshiba Corporation, Ajou University and the Korean Electric Power Company for their funding of this effort. In addition, many participants who donated time, travel and in-country expenses contributed significantly to the success of the project. Without such diverse and generous support, this work could not have been accomplished. We are deeply grateful for the opportunity to present these ideas and recommendations for open and public debate.

As always, the paper represents the views of the project task force and not necessarily the views of the funding sponsors or the Atlantic Council.

David C. Acheson
President
Atlantic Council of the United States

February 1999

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EXECUTIVE SUMMARY

Despite the recent global economic slowdown, the demand for energy services is bound to increase over the long term in order to provide improved living standards for growing populations, in particular in developing countries. In recognition of its unique characteristics, the demand for electricity will rise even faster than total energy. Several studies present scenarios that show a doubling of global installed capacity over the next twenty years.

Providing these electricity services in a manner that minimizes local, regional and global environmental impact poses major policy and operating challenges to the energy community (comprising governments, the private sector — including former government enterprises which are being privatized — and non-governmental organizations) and all others interested in the balance between economic development, energy supply/demand and the environment.

Nuclear power is a major producer of electricity, providing 18 percent of global generation, second only to coal and about the same as hydro power.[1] In recent years, however, nuclear power has encountered serious setbacks in several parts of the world, and a number of studies present scenarios that show its share of global electricity supplies declining, despite nuclear's strong advantage as a source of electricity that emits very small amounts of air pollutants and greenhouse gases.[2]

On a regional level, these studies show that the prospect for nuclear power is mixed. Substantial increases in nuclear capacity in Asia are planned, but these are expected to be offset by stagnation or declines in North America, Europe and Russia. These trends could make Asia the new center of gravity of global nuclear power development.[3]

With this background, the Atlantic Council established a working group of experts from many countries of the world drawn from the nuclear industry itself, energy policy makers, social scientists and economists to examine the appropriate role of nuclear power in meeting the burgeoning world demand for electricity in an environmentally acceptable manner.

The group made a series of recommendations that are spelled out in detail in the Overview and the body of this report. The main points are:

1. *Reactor safety* is of paramount concern. Countries must ensure the safe operation of their own nuclear plants and cooperate to harmonize strict international standards.

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1 *World Energy Outlook*, International Energy Agency, 1998.

2 For example, *Global Energy Perspectives*, IIASA/World Energy Council, 1998 (scenarios to 2050), *World Energy Outlook*, OECD/International Energy Agency, 1998 (scenarios to 2020) and the *International Energy Outlook*, US Department of Energy, Energy Information Administration. 1998 (scenarios to 2020).

3 *An Appropriate Role for Nuclear Energy in Asia's Power Sector.* Richard E. Balzhiser, Christian Gobert et al. Atlantic Council of the United States, December 1997.

2. Governments should accept overriding responsibility for management of their nations' *radioactive waste and spent fuel* and accelerate efforts in cooperation with enterprises to find solutions to the problems of both interim storage and permanent isolation.[4]

3. Governments should ensure the long term *financial integrity* of their power sectors and incorporate the full costs of all forms of electricity, including nuclear in electricity tariffs.[5] At the same time, credit should be given to nuclear power facilities and other energy sources, such as solar, for their contribution to the reduction of greenhouse gas emissions.[6,7]

4. Governments should take the lead in the strong long-term *research and development* efforts which will be needed for all energy options, and focus both domestic and international R&D efforts in the nuclear field on improving safety, reducing and managing radioactive waste and spent fuels, as well as developing proliferation-resistant technologies.[8]

5. Given concerns over the possible *dual-use of some nuclear technologies*, countries and enterprises using nuclear power should reaffirm their commitment to the weapons non-proliferation regime, and stand ready to fund any necessary expansions in international safeguards programs.

6. The nuclear industry should further enhance its efforts to improve its *public communication* by taking up more positive and open positions, and cooperating more actively with other parts of the energy community in finding ways of meeting energy needs while minimizing environmental impacts including greenhouse gas emissions.

7. *International cooperation* by both the public and private sectors should be strengthened to increase its effectiveness. International Atomic Energy Agency (IAEA) key inspection programs should be strongly supported by member countries and expanded as necessary.

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4 Sam Thompson notes that the Executive Summary/Conclusions and Recommendations call on governments to accelerate their efforts and demonstrate their determination to "find solutions" to the problems of both interim storage and disposal. Solutions for interim storage already exist and are being implemented in a number of countries. In fact, it is the existence of these solutions that has enabled governments to put off moving forward with plans for dealing with final disposal for long-lived waste. Nevertheless, as the text of the paper makes clear, technical solutions for disposal of long-lived waste have been identified (and in one case a facility has even been licensed) and what is needed is for governments to deal with the social and political aspects of waste disposal while continuing research on the technical approaches that have been identified.

5 Thomas B. Cochran suggests that rather than referring to the "full cost" of all forms of electricity, the term "full external cost" or "full marginal cost" should be used.

6 Hans Blix notes that the reference to the use of non-fossil fuels for generating electricity is too broad. Wind, solar and biomass can be *very* useful in *some* regions to generate electricity, but they are almost invariably subsidized. Hydropower and nuclear power are normally not subsidized, and the cost of generating electricity by these sources is not *very* different from using fossil fuels.

7 Thomas B. Cochran notes that the term "consideration" would be more appropriate than "credit."

8 Thomas B. Cochran notes that more government research into the reduction of the volume of nuclear waste is not necessary. See also Recommendation 2, under Recommendations on Nuclear R&D.

In summary, the working group recommends that, if countries wish nuclear power to play an appropriate role in their energy portfolios, they should take steps to develop a nuclear policy that supports a viable commercial sector, ensures a sufficient skilled manpower resource, accepts responsibility for the safe management of nuclear waste and spent fuel, and funds adequate R&D to continue improvements in all these areas.

Overview

There is a need for wide recognition that the world must now actively address major issues relating to energy use for sustainable, sound long-term economic development. While energy use in the developed economies will continue to grow relatively slowly, the greatest economic growth, with attendant increases in energy use and environmental pollution, is forecast to occur in developing countries. In some cases, as in China and India, for example, energy use is forecast to more than double between now and 2020.

Providing energy to meet economic growth needs, while satisfying environmental goals, will depend both on increasing the efficiency and effectiveness of energy systems and developing a wide range of energy resources to meet industrial, commercial, residential, and transportation needs. Electricity, by virtue of its flexibility, versatility, and ability to provide irreplaceable services, occupies a unique role in the energy sector, growing much more rapidly than consumption of other forms of energy.

Long-term forecasts of energy and electricity consumption indicate that although renewables other than hydropower will play an increasing role, fossil fuels will continue to dominate global energy supplies for many years to come.[9] However, the evolving structure of energy supplies will require continuing efforts to assure that a wide range of energy technologies will be available in the long-term future.

The mix of energy resources will vary from country to country, depending on many factors: availability of indigenous energy resources; the costs of developing and using various energy sources; governmental views on energy security; environmental impacts; ability to finance major projects; the availability of skilled engineers and support personnel; the extent of competition in the energy sector in the country in question; and the overall regulatory environment, including energy pricing, taxation and ownership regimes. The energy mix will also depend on public acceptance of different sources of power generation in each country.

Given this complex, long-term setting, the Atlantic Council convened a working group to examine an appropriate role for nuclear power in meeting global electricity needs, taking into account the need to balance economic growth, energy supply/demand and environmental issues, including global warming. This paper presents a number of consensus conclusions and recommendations addressing the long-range outlook for nuclear power. The group includes individuals with broad knowledge of energy issues, nuclear energy experts, economists and social scientists. The mixed composition of the group enhances the credibility of this paper. The group's aim is to contribute constructively to the continuing dialogue on economic growth, energy use and the environment.

The working group brought together to discuss the global future of nuclear power wishes to note several points in particular, which should be borne when mind in considering the long-term role of nuclear power:

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[9] See footnote 2.

1. A broad range of energy options, including nuclear power, renewables, energy efficiency and conservation, will be necessary to meet the world's economic development needs in a sustainable manner for present and future generations.[10]

2. Relatively cheap fossil fuels will be available in the global market for the foreseeable future. Non-fossil-fuel electric generation technologies, ranging from renewables (such as wind, solar, and biomass) to hydro and nuclear power, are at present competitive in some regions where fossil fuel costs are high. Moreover, it is expected that the costs of fossil fuels will increase over the long-run, thereby improving the competitive positions of other energy sources.

3. The choice of energy systems has inherently long-term implications. Changes in energy systems normally take place over extended periods of time. The elapsed time from initial demonstration of a new energy technology in a laboratory to its wide-scale introduction typically takes decades. Some critical considerations involved in adopting new technology into general use include: economic viability of the option, reliability and availability of services, as well as support infrastructure. Furthermore, changes in energy systems are capital intensive. The oil sector, for example, was expected to invest $94 billion globally in 1998,[11] and major investment projects such as pipelines can take many years to complete. Financial commitments on this scale require long lead times.

4. The world will devote increased efforts to reducing pollution and greenhouse gas emissions associated with energy use. Widespread interest in the reduction of greenhouse gases is exemplified by the Kyoto Protocol, in which representatives of developed countries, recently joined by Argentina and Kazakhstan, agreed, subject to ratification by their respective governments, to lower their emissions of six greenhouse gases by an average of 5.2 percent compared with 1990 levels.[12] Nuclear power, more efficient burning of coal and other fuels, fuel cells, natural gas, carbon sequestration, and several renewable energy sources, can help reduce some forms of air pollution, and each has advantages in reducing the emissions of the six greenhouse gases noted in the Kyoto Protocol.[13]

5. Increased competition in electric utility operation, either through privatization or deregulation, is a growing trend around the world, and will affect all aspects of the electricity sector, including investment choices and innovation.

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[10] Richard E. Balzhiser notes that nuclear is a key option in assuring a sustainable energy supply which complements the variabilities of renewable energy sources in the post fossil fuel period. This requires that we address both safety and fuel cycle considerations that utilize fully the uranium and thorium resources, including plutonium, in preserving the nuclear option for future deployments.

[11] Brocato, B. "Report of Salomon Smith Barney's Survey of 202 Oil and Gas Companies." *Oil and Gas Journal*, 23 March 1998.

[12] In Annex B of the Kyoto Protocol, certain countries agreed to various emission limits of the six gases. The gases are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6).

[13] In the view of Hans Blix, this and other references to carbon sequestration should have made clear that the approach — described in the first paragraph of the section on Global Climate Change — so far is theoretical. Decarbonization also would require much energy to "reform" methane. One way of doing it would be to use a nuclear power reactor.

6. Various studies suggest that in the next twenty years, while electricity use globally will double, global nuclear electricity generation could remain constant.[14] Substantial increases in nuclear capacity in Asia are planned, but these are expected to be offset by stagnation or decline in North America, Europe and Russia.

7. Given the limited near-term prospects for nuclear power in many of the traditional centers of nuclear development in North America and Europe, R&D and nuclear technology training are lagging in those regions, raising questions about how to ensure adequate R&D and training efforts over the longer term.

8. Public perceptions of risk will continue to be critical determinants of nuclear power development in the future. Favorable perceptions of nuclear power will be promoted by the reliable and safe operation of nuclear facilities, and an assured, safe management of nuclear waste and spent fuel. Public perceptions are, however, also influenced by the level of trust in the nuclear power industry. The perceptions of the relationship between nuclear weapons and nuclear power are also factors that influence public opinion.

In short, the working group recognizes that any change in the energy sector requires both a long timeframe for action as well as consideration of the complex interactions in the economic development-energy-environment triangle. If nuclear power is to play an appropriate role in helping meet global electricity needs, it will be necessary to take these broader considerations into account, in the calculation of the pros and cons of nuclear power compared with other forms of energy. This in turn will require timely actions by both private and governmental sectors.[15] Therefore, the working group makes the following recommendations:

RECOMMENDATIONS ON REACTOR SAFETY[16]

1. All countries and enterprises engaged in nuclear power generation should recognize the paramount importance of nuclear safety, should build and maintain a strong safety culture, and should promote advanced technologies with enhanced safety features. Governments should develop and maintain reliable national safety authorities. Regulatory processes should be reformed to provide more effective, efficient and incentive-based systems.[17,18,19]

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14 *Word Energy Outlook 1998*, op. cit.

15 Richard E. Balzhiser calls attention to *The Decision Maker's Forum on a New Paradigm for Nuclear Energy*, September 14, 1998, sponsored by the Senate Nuclear Issues Caucus. This report presents high-priority recommendations for a new (U.S.) agenda for nuclear energy. Subjects addressed include: need for a viable commercial sector; construction of a monitored retrievable spent fuel storage facility; security of weapons grade plutonium and highly enriched uranium; increased R&D; and international R&D cooperation.

16 Mamoru Sueda notes that "Recommendations on Reactor Safety" is too limitied, and that "Recommendations on Nuclear Safety" would be more appropriate.

17 Richard E. Balzhiser notes that it is equally important that weapons use of plutonium arising from the nuclear fuel cycle be eliminated. Research efforts must continue internationally to assure technological and institutional safeguards.

18 Thomas B. Cochran notes that in his view, this sentence does not apply to most nations, including, nations such as China, Japan, and Cuba. In addition, he believe other reforms are more important in the United States that those noted.

19 Joe F. Colvin recommends that the term "performance-based systems" be used rather than "incentive-based

(Continued on next page)

2. Governments should strengthen cooperation on adoption and harmonization of strict international safety standards. In addition to bilateral assistance programs, governments should support existing public and private programs of international cooperation and expand them where necessary:

a. The IAEA should be permitted to increase both the coverage of nuclear facilities and the availability of experts to serve on review teams.[20] The IAEA should be encouraged to speed the implementation of the convention on nuclear safety, in order to help establish consistency and high standards in national regulatory regimes.[21]

b. The Organization for Economic Cooperation and Development/Nuclear Energy Agency (OECD/NEA) should intensify its work related to nuclear plant safety, and make its results available to countries outside the OECD region.

c. WANO[22] should be strengthened by increasing the intensity, coverage and enforcement of their review activities, notably to include management issues in their reviews and by increasing coordination with the IAEA thereby assuring complementary rather than duplicative inspection activities.

3. Efforts should be made to accelerate existing programs of technical and safety assistance to the countries of Eastern Europe and the former Soviet Union, thereby reinforcing the efforts pursued by these countries themselves.

Recommendations on Radioactive Waste and Spent Fuel Management

1. Governments should accept overriding responsibility for management of radioactive waste and spent fuel created in their countries and in cooperation with enterprises, demonstrate their determination to find satisfactory solutions to the problems of interim storage of spent fuel, retrievable spent fuel storage, and permanent isolation of high-level waste.[23]

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systems."

20 John J. Taylor notes that in order to make the best use of the resources available, the focus and priority of inspections should be placed on those plants where there is evidence of inadequate safety performance or safety culture.

21 Victor Murogov suggests that the recommendation be worded as follows: "The IAEA should be invited by governments to review more nuclear facilities and governments should make available experts to serve on review teams."

22 WANO is the World Association of Nuclear Operators. The above recommendations follow the Association's 1997 Review.

23 As defined by the U.S. Nuclear Waste Policy Act, high-level waste is (1) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including the liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations and (2) other highly radioactive material that the U.S. Nuclear Regulatory Commission, consistent with existing law, determines by rule to require permanent isolation (this includes spent fuel from nuclear reactors).

2. Efforts should be made on a regional basis to address nuclear waste and spent fuel issues, including the examination of prospects for regional waste management facilities.[24]

3. Both the IAEA and the OECD/NEA should give higher priority to their work on management of spent fuel and radioactive waste. In particular, the IAEA should actively encourage implementation of the Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management. Both agencies should consider ways of helping to make this issue better understood by government officials and the public.

RECOMMENDATIONS ON COST COMPETITIVENESS AND FINANCING OF NUCLEAR POWER

1. Governments should take steps to ensure the long-term financial integrity and credit-worthiness of their power sectors. As a priority, efforts should be made to establish economically sound tariff structures.

2. Governments of countries that are committed to privatizing and/or deregulating their power sectors should make sure that energy policy objectives, such as environmental protection and energy security, are incorporated in their new policy and market frameworks.

3. Governments should ensure that the full costs of nuclear power programs, including those costs associated with fuel cycle facilities (such as waste and spent fuel disposal, decommissioning, and monitoring) are calculated as part of the costs borne by electricity consumers. Subsidies which may be provided to the industry should be explicitly identified.[25,26,27]

4. In implementing international emission trading programs, credit should be given to nuclear power facilities for their contribution to the reduction in greenhouse gas emissions.

RECOMMENDATIONS ON NUCLEAR R&D

1. Given the rapid increase in global demand for electricity, possible long-term economic and environmental limits on the availability and use of fossil fuels, as well as concern over greenhouse gas emissions, a strong long-term R&D effort will be needed for all energy options, including

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[24] Rolland A. Langley notes that it was announced in December 1998 that Pangea Resources Inc., an organization with international investors, is exploring a concept for an international waste repository to be sited in West or South Australia. *Nuclear Fuel, Vol 23, No. 25, December 14, 1998.*

[25] Joe F. Colvin notes that this recommendation should apply to all power sources.

[26] Sam Thompson notes that it is fine for the paper to recommend that governments ensure that the full costs of nuclear power programs are calculated as part of the costs borne by electricity customers. However, the paper should call for this to be done for other power sources as well. More generally, the goal should be for cost calculations for each power source to take into account not only conventional costs, but also external costs, which are largely included in the case of nuclear power. In this connection, an effort needs to be undertaken to calculate such costs for fossil fuels. The text of the paper contains a brief but useful discussion on external costs, but the point about the need to take them into account is not made clearly in the recommendations.

[27] Mamoru Sueda notes that some of the facilities in the parenthesis may be inappropriate, particularly in the absence of "reprocessing and related services."

nuclear power, fossil fuels, renewables and energy efficiency.

2. Governments should take an active lead in these programs, particularly since a major element of such R&D must focus on the issue of nuclear fuel recycle and its implications for weapons non-proliferation. Nuclear power R&D should focus on improving safety, reducing and managing radioactive waste and spent fuel, lowering capital costs as well as developing weapons proliferation resistant technologies.

3. Given the limited R&D funds available, international coordination (under the aegis of the OECD/NEA or IAEA) should be encouraged to ensure minimal duplication. An international advisory board and program could be considered to identify technical options for innovative nuclear power reactors, including those which might be undertaken to burn weapons plutonium.[28]

4. Efforts should be made to ensure that new nuclear plants adopt advanced technology with enhanced safety features. For example, the collaborative U.S./European programs to provide advanced pressurized and boiling water designs should be available to countries considering new capacity.[29]

Recommendations on Nuclear Weapons Non-Proliferation

1. Countries that have signed treaties relating to nuclear weapons non-proliferation should reaffirm their commitments to the nuclear weapons non-proliferation regime, in particular in the area of strengthened safeguards systems, and the security of nuclear materials and facilities.

2. Those countries that have not signed or ratified the various treaties and protocols should give serious thought to the benefits of signing, including the new addendum to the Treaty on the Non-Proliferation of Nuclear Weapons.[30,31]

3. Given increased concerns over nuclear weapons proliferation, nuclear terrorism and theft of nuclear materials, countries should urge international and regional organizations involved in limiting the spread of nuclear weapons to review their activities to determine if they need to undertake additional actions to carry out their missions. The role and funding of the IAEA in weapons non-proliferation work is of crucial importance and deserves the strong financial and political support of member countries.

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[28] William J. Dircks notes that R&D cooperation will be difficult because such cooperation would invariably infringe on intellectual property rights of the enterprises involved.

[29] Kazuo Shimoda notes that this recommendation should also note Japan-U.S. collaborative programs, as a Japan-U.S. program manufactured two Advanced Boiling Water Reactors (ABWR) units, now in commercial operation, at the Kashiwazaki-Kariwa nuclear power station in Japan.

[30] Hans Blix notes that the subject of non-proliferation is examined with a Western bias. It is unrealistic to expect India and Pakistan to sign the NPT. The tests of weapons by these countries certainly raised concerns and was a set-back for non-proliferation, but the subject requires a more nuanced discussion.

[31] Victor Murogov suggests that the recommendation should encourage countries that have not signed the various treaties and protocols to give serious thought to the benefit of doing so.

4. Taking into account the continuing concern about the duality of nuclear technology[32], enterprises involved in electricity generation using nuclear power should continue their commitment to the weapons non-proliferation regime, and increase public awareness of this commitment. They should press for approval by their governments of the Additional Protocol resulting from the IAEA's 93+2 program.[33,34]

RECOMMENDATIONS ON PUBLIC COMMUNICATIONS

1. The nuclear community (industry and governments alike) should enhance its efforts to improve its image and that of nuclear power by taking up more positive and open positions. The contribution of nuclear technology, ranging from the production of electric power to medical and manufacturing uses, to national and worldwide needs should be clearly spelled out, as should the nuclear community's commitment to weapons non-proliferation.[35]

2. The nuclear community should cooperate more actively with other energy sectors and non-governmental organizations to study global long-term economic growth trends and ways of meeting energy needs through a variety of energy sources and energy efficiency, to assure sustainable levels of energy supply at a reasonable cost.

3. The International Energy Agency (IEA), OECD/NEA and the IAEA should continue to play a role in informing their member countries on the issues central to the use of nuclear power. This includes, for example, preparing reports and studies for dissemination to member country delegations, parliaments, and the general public.

RECOMMENDATION ON GLOBAL CLIMATE CHANGE

In undertaking research on how to meet the world's energy needs while taking into account concerns about climate change, intergovernmental organizations, national governments and private institutions are strongly encouraged to consider the past and future contribution that nuclear power has made and can make as a carbon avoidance generating technology. Institutions must also evaluate the economic, safety and environmental performance of nuclear power and the other generating technologies being considered.

RECOMMENDATIONS ON INTERNATIONAL COOPERATION

International cooperation should be strengthened to increase its effectiveness. More specifically:

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32 Robert H. Socolow notes that duality refers to the "civilian-military duality of nuclear technology."
33 For a description of the "Programme 93+2" and the additional protocol, please see Annex 2.
34 Victor Murogov suggests that enterprises and the public should press their governments to support the strengthened IAEA safeguards system and in particular to conclude Protocols Additional to their respective safeguards agreements. A model text of the Additional Protocol was approved by the IAEA Board of Governors in May 1997.
35 Sam Thompson questions the recommendation that the nuclear community take more "positive" positions. Has its message heretofore been negative?

1. IAEA key inspection programs in the safety and safeguards area should be strongly supported by member countries and expanded as appropriate. Individual governments should recognize the benefits of positive cooperation and the costs of lack of cooperation, and work constructively with the IAEA. In following through on these recommendations, careful attention should be given to the adequate funding of critical activities. The IAEA in turn should take steps to increase the efficiency and effectiveness of its inspection activities.

2. Governments should renew and update discussions within the IEA of the likely role of nuclear power as one of many sources to supply energy services for long-term economic growth.[36]

3. Governments should explore, through existing international organizations related to nuclear power, how regional cooperation in nuclear matters can be structured and improved. Joint projects in areas such as safety standards, or nuclear waste and spent fuel management, should be considered.

4. Should an Asia regional nuclear power association be formed,[37] the working group recommends that the association establish a senior committee to evaluate the R&D and nuclear power training needs of Asian countries and develop recommendations on addressing these needs.

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[36] Sam Thompson notes that the paper recommends that governments "renew and update" discussions within the IEA on the likely role of nuclear power. This is misleading. The fact is that, until very recently, the IEA has, for political reasons, ignored nuclear power.

[37] *An Appropriate Role for Nuclear Energy in Asia's Power Sector.* Richard E. Balzhiser, Christian Gobert et al. Atlantic Council of the United States, December 1997.

An Appropriate Role for Nuclear Power in Meeting Global Energy Needs

I. Introduction

This is the second and final report of a project devoted to discussing an appropriate role for nuclear power in the global energy sector. The first report, *An Appropriate Role for Nuclear Energy in Asia's Power Sector*, examined the issues raised by the rapid expansion in nuclear power capacity envisaged by the countries of Asia.[38,39]

The present report addresses the role of nuclear power in the global energy sector in the broader context of sustainable social and economic development. The global context introduces new challenges and opportunities, especially in the areas of safety and waste management, and economic systems and practices. It also includes a wide variety of countries, and raises new questions on the responsibilities of governments for strategic energy policy, as large elements of the energy sector are deregulated and privatized. Finally, the global approach focuses attention on the issue of how to promote a wide range of energy resources, against the time when fossil fuels become scarce or too expensive, or when governments take actions to reduce greenhouse gas emissions and limit the use of fossil fuels.

The primary lesson in this, as in the previous report, is the importance of international cooperation in solving many nuclear power-related issues. This report also draws attention to the considerable difference between regions in use and development of nuclear power, a difference which may benefit from a higher level of regional cooperation.

The report begins in Section II with a discussion of the linkages between energy, the environment and sustainable economic and social development. Section III examines the role of nuclear power in the global power sector and describes developments in each major region, with a discussion of reasons for differing patterns of nuclear power development.

With this background, Section IV discusses the issues that must be addressed if nuclear power is to continue to contribute to sustainable energy supplies. These include reactor safety, nuclear waste and spent fuel management, the costs of nuclear power compared to those of other energy sources,

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38 For general background on this section, please refer to Shimoyama, Shunji *"A Review of the Recommendations in the Council's Policy Paper on 'An Appropriate Role for Nuclear Energy in Asia's Power Sector."* presented at the Atlantic Council seminar on the global future for nuclear energy, Cannes, France, 10-12 May 1998.

39 Op. Cit

technology development, nuclear weapons non-proliferation, global climate change, and the industry's public communication. Because nuclear power is an international industry, regional and international organizations and programs are examined in Section V. Section VI offers conclusions and recommendations. These recommendations represent the consensus views of participants in the project, all acting in their individual capacities. The weight of the recommendations lies in the expertise and experience of the participants and their ability to introduce the recommendations to decision makers in their own countries.

II. SUSTAINABLE GROWTH, ENERGY AND THE ENVIRONMENT[40]

The concept of sustainability has increasingly entered into dialogues and policies relating to economic and social development. As defined by the World Commission on Environment and Development in its report *Our Common Future* (the Brundtland report), sustainable development requires that the current generation should "meet [its] needs without compromising the ability of future generations to meet their own needs."[41] It is important to realize that the concept of sustainability is essentially dynamic. To be truly sustainable, institutions, governments, cultures, economies, and energy sectors constantly adapt to new circumstances.

Converting the concept of sustainability into policy therefore raises important questions about how the global social capital should be divided between present and future generations. This capital consists of four components: manmade capital such as roads and factories; human capital, such as scientific and technical knowledge, industrial capability, management skills; natural capital such as fossil fuels and mineral deposits; and environmental capital such as clean air and water and a diverse biological base.

With regard to the first two components, historical experience suggests (at least over the past two or three centuries) that each generation will hand down to future generations an improved stock of both human and manmade capital. Some also argue that there is little reason to be concerned about society's ability to bequeath adequate stocks of many mineral resources to succeeding generations. They point to past examples of successful substitution of technology and capital for so-called "exhaustible" assets such as iron ores.

In the recent past, there has been greater concern over the sustainability of fossil fuel. Fossil fuels (coal, oil and gas) cannot be recycled. At first glance, this concern over adequacy of fossil fuel resources may appear misplaced. Since the energy crises of the early 1970s, known fossil fuel resources have increased substantially. As known reserves were reduced, improvements in extraction technology have allowed sources of fossil fuels previously considered unusable to be reclassified as known reserves. Further exploration has also uncovered previously unknown sources.

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40 For general background on this section, please refer to the following papers presented at the Atlantic Council seminar on the global future for nuclear energy, Cannes, France, May 10-12, 1998

World Energy Prospects to 2020, J.P. Ferriter, IEA
Man's Use of Energy in the Next Century, J.S. Foster
Energy Security, Munir Ahmad Khan, Ahmad Mumtaz
The Oil Reserves Question, P.R. Bauquis
Environmental Impacts of Energy Technologies, Giulia Bisconti
Environmental Impacts of Various Technologies, Katsuo Seiki
Approaches for Reducing Greenhouse Gases, Hans Blix
Fossil Carbon Sequestration: A Rival Greenhouse Mitigation Strategy, Robert H. Socolow

See Also: "The Role of Technology Transfer in the Transition to Sustainability." Alan T. Crane and Joy Dunkerley, *In Depth* , Fall 1994, Washington Institute for Values and Public Policy, Washington, DC.

41 *Our Common Future.* The World Commission on Environment and Development New York: Oxford University Press, 1987. This report has been highly influential in people's thinking on sustainability, partly because the commission represented a wide range of opinion from all parts of the world and can thus claim to represent global opinion.

The end result is there is little possibility of the world "running out" of these fuels for many years, if not centuries.

The discussion of fossil fuel resources often focuses on quantities available, as if fossil fuels will continue to be used until there are literally none left. The more likely scenario, however, is that either fossil fuels may one day become more expensive than other energy sources, or that governments might decide to reduce fossil fuel use for environmental reasons. Given the many uncertainties and possible environmental considerations facing the world, it is advisable to develop a broad portfolio of energy supply options. Such a portfolio would ensure that the risks associated with any one technology are as independent as possible from the risks of each of the other technologies in the portfolio.

Nuclear energy is an important element of that portfolio because:
1. It is currently a major technology for generating electricity worldwide (18 percent in 1996);
2. It uses a fuel source which is widely available at a modest cost;
3. It can produce baseload electric power, which will become increasingly important as the world's population concentrates in the large urban areas;[42]
4. Its wastes include limited amounts of CO_2 or other atmospheric pollutants; and
5. It has major sustainability advantages, particularly if coal use is limited by climate change concerns.

Energy is a key element in any discussion of sustainable growth because of its close links with both economic growth and the environment. World population is rising at about 1.4 percent a year — a considerable slowdown from previous decades, but still a substantial rate — which is estimated to increase population from 5.6 billion at present to just under 7 billion in 2010.[43] Longer term estimates indicate world population leveling off at 10-11 billion.[44] If living standards are to increase, world economic output must increase much faster than population. Despite progress made in improving living standards over the last generation it is estimated that over 1 billion people still live in poverty.[45]

Both historical experience and comparison among countries with different living standards attest to the close association between energy consumption and the level of gross domestic product (GDP). An increase in GDP is almost invariably associated with a rise in energy consumption, though the extent of the rise can vary considerably — sometimes it rises faster than GDP and sometimes slower, depending on a number of considerations such as the overall development of a country's economy, level of energy prices, the economic structure, and the policy environment. Most projections alreadyincorporate some element of energy conservation, as well as a shift to non-energy-intensive activities (e.g. the shift from "smoke-stack" to service industries).

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42 Richard E. Balzhiser notes that the world's uranium resource alone has an energy potential in excess of 60 times the world's estimated fossil resource, with thorium likely having a similar magnitude (John Holdren, paper distributed to the PCAST Energy Panel, October 1998).
43 Estimates of population, economic growth, energy, electricity, and nuclear power come from *The World Energy Outlook*. Paris: OECD/IEA, 1996, 1998.
44 *World Population Prospects, 1950-2050*, World Bank, Population Division, Department for Economic and Social Information and Policy Analysis, New York: 1996.
45 See "The World Bank: Now Fifty But How Fit?" Hilary French, *World Watch* Jul.-Aug. 1994.

Achieving such increases in energy supplies will prove a challenge to the world's energy industries. It also raises the question of the environmental impacts of rising energy production and use. Today, the environmental resources are taking precedence in concerns regarding sustainability, or are being weighed more heavily than before. Energy and the environment are strongly linked. Fossil fuels have significant environmental effects throughout their fuel cycle. Production can disturb surface lands and water, contaminate underground aquifers and give rise to toxic waste. But the greatest environmental impact of fossil fuels stems from the air pollution accompanying their combustion, in particular in situations where pollution control systems are not employed. The World Bank estimates that 1.3 billion people (66 percent of the global urban population) live in cities where suspended particulate matter is at unacceptable levels and 1 billion (or 40 percent) live in urban areas with unsatisfactory levels of sulfur dioxide.[46] Further, combustion of fossil fuels is the major source of energy-related carbon dioxide, a greenhouse gas. Carbon dioxide emissions from fossil fuels have doubled in the past four decades, and could double from their present level by 2025. Such increases in carbon dioxide and other greenhouse gases may have significant impacts on climate patterns, though the nature, timing and seriousness of such impacts are still uncertain.

Hydroelectric and nuclear power do not give rise to large quantities of either air pollution or carbon dioxide, but their use raises different concerns about impacts on the environment and safety. The large projects typical of past conventional hydroelectric development involved massive land disturbance and population resettlement. Dam breaks can have catastrophic results. Nuclear fuel cycles arouse concerns over nuclear safety, the disposal of spent fuel or long-lived waste, and in the case of some technologies, possible nuclear weapons proliferation.[47]

Energy efficiency and renewable energy technologies — wind power, geothermal, small hydro, sustainable biomass and solar — appear attractive because they are believed to have minimal environmental impacts. Solar, for example, is a natural complement to nuclear's base load appeal, as its availability comes during the peak periods of the load curve, albeit with variability. Its cost is still much higher than fossil alternatives, but photovoltaic systems are on a steep learning curve, with efficiencies rising and prices coming down. However, even renewables entail significant environmental uncertainties. It is not clear, for example, that a large number of small hydro plants would be less environmentally disruptive than a large one. Generation of significant quantities of electricity using solar or wind power requires very large land areas, and therefore neither solar nor wind hold much promise for providing electricity in areas of high population density where land is at a premium. In sum, it is reasonable to expect that renewables will make meaningful contributions but will not dominate in the foreseeable future.

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[46] *World Development Report*. World Bank 1992, p. 48.

[47] In the United States, low-level waste classified as greater than Class C, as defined by the U.S. Nuclear Waste Policy Act, must be stored in facilities licensed for high-level waste or in a disposal facility licensed by the Nuclear Regulatory Commission. In this instance the waste has high-levels of radiation and is long-lived; however, it is still classified as a "low-level waste."

In brief, all forms of energy have environmental impacts. Environmental policy is therefore a complex business involving the comparison of different impacts. It is within this context that the role of any one form of energy — in this case nuclear power — must be considered. No single source of energy is without its risks and uncertainties, as well as its advantages. In particular, if the greenhouse gas emissions targets agreed upon in Kyoto are implemented by governments, strenuous and comprehensive efforts would have to be made to reduce CO_2 emissions from the energy sector, in addition to developing forests to act as a carbon "sink," and new technologies for carbon dioxide separation and sequestration.[48] One fact is clear, any single approach is likely to be inadequate.

[48] Joe F. Colvin notes that the use of carbon-avoidance technologies should be encouraged.

III. GLOBAL AND REGIONAL NUCLEAR POWER SECTOR DEVELOPMENT

Electricity occupies a special role in the energy sector, growing much more rapidly than other forms of energy delivered to final consumers. In 1971, for example, electricity accounted for about 10 percent of all energy used by final consumers. By 1995 this share had risen to 16 percent and is forecast to continue rising in the future. Electricity has certain unique features not shared by other forms of energy, which account for this increase. First, as many energy sources can be used to generate electricity, it is possible (admittedly at a cost) to substitute one primary energy source for another. This provides an element of flexibility which can be of strategic as well as economic value. Second, electricity is the most versatile and controllable of any energy form. It can be provided as needed and in the quantities desired. Its use has permitted more rational organization of work process, increased productivity and greater flexibility in production methods.[49] While the superiority of electricity is well established in developed countries, the popularity of electricity among poor households in developing countries is even more dramatic. The arrival of electricity in a village can lead to higher crop yields, improved domestic water supplies, superior lighting (compared with kerosene) and a wide range of entertainment services. Television ownership in electrified Indian villages is now as high or higher than it was in Europe a generation ago.

It is often thought that in the industrialized countries, whose households already possess a wide range of appliances, demand for electricity has reached saturation levels and is not likely to increase much more rapidly than the rise in population or household formation. That has not proved to be the case in the past, nor, according to the IEA, is it likely to in the future. The IEA forecasts that demand for electricity in OECD countries, which among themselves vary greatly in electricity use, will rise by over 60 percent from 1995 to 2020. However, this substantial rate of increase could be dwarfed by the almost doubling of consumption of electricity in the other countries of the world, which would account for two-thirds of the global increase in electricity use to 2020.[50]

A. Global Trends

One of the most striking trends in the global power sector has been the rapid development of nuclear power which increased twentyfold, admittedly from a low base, between 1971 and 1995. The share of nuclear power in total electricity generation rose from 2 percent to 18 percent in that period. This rapid increase was shared by all the major industrial regions of the world, North America, Europe, the former Soviet Union and Asia.

Views of the future of nuclear power diverge widely, illustrating the uncertainties facing this sector. For example, the IEA and the U.S. Energy Information Administration (EIA) project a leveling off of nuclear power output, with global generation in 2020 about the same or a little lower as in 1995.[51]

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49 For further discussion of the role of electricity in industrial development see "The role of Electricity in Industrial Development." Nathan Rosenberg *International Association for Energy Economics, Energy Journal*, Vol 19, No. 2.

50 *World Energy Outlook*, International Energy Agency, 1998.

51 *Energy Outlook*, U.S. Energy Information Administration, 1998.

On the other hand, one of the World Energy Council (WEC) scenarios (scenario B), which closely corresponds to one of the IEA scenarios in total energy consumption, incorporates a substantial increase in nuclear power generation.[52]

Trends in global nuclear power output mask considerable regional variation. Substantial increases in nuclear capacity in Asia are planned, but these are expected to be offset by stagnation or decline of capacity in North America, Europe and Russia. An examination of the nuclear power experience and plans of the different regions can throw light on the issues to be addressed in assessing a future role of nuclear power in global energy supplies.

B. Asia

Asia presently accounts for 18 percent of the world's total nuclear power output. This share is projected to increase in future, though it is not yet clear the extent to which the recent economic downturn in Asia could impact the entire energy sector, including its nuclear component. However, if Asia recovers from its economic difficulties, as expected, the region would become the new center of gravity of the nuclear industry with major implications for technology development, supplier industries, nuclear safety, weapons non-proliferation, nuclear waste and spent fuel handling, and institutional arrangements governing the development of nuclear energy.

At present, 82 reactors are operating in Asia, with a capacity of 62 gigawatts (GW). Over two thirds of that capacity is in Japan. Taiwan and South Korea account for much of the rest. Looking forward, however, the intra-regional balance is changing. Of the 49 GW of capacity under construction or planned, South Korea accounts for the largest share (29 percent) followed by China (20 percent) then Japan (18 percent). While projections are seldom fulfilled, they make the point that many of the countries of Asia hope to expand their nuclear power sectors. Several Asian countries such as Japan and South Korea already have mature nuclear industries to serve as a basis for further expansion. China, on the other hand, plans for a major expansion in capacity from a relatively modest base.

This planned increase in nuclear capacity in Asia is driven by a number of considerations. Most are shared by all countries in the region but, reflecting the diversity of the Asian region, the weight of the different motives varies from country to country.

Common to all is the pressure to meet rapidly rising demand for electricity. Scenarios from the IEA indicate that consumption of electricity could triple between now and 2020. The Asian economic and financial crisis will dampen demand, but this may prove to be a temporary effect, in which case, electricity demand in Asia will resume its sharp upward trajectory. Many of Asia's economies are still developing, and electricity consumption in the most populous countries is still low. In China, for example, annual per capita electricity consumption is about 800 kwh, India 353, Indonesia 246, and Pakistan 254. This is a tenth or less of the level in Japan (7700) and an even smaller proportion of per capita consumption in the United States (12,797 kwh annually). Consequently, there is much room for growth in electricity consumption. Policy makers faced with the formidable tasks of

[52] *Global Energy Perspectives*, IIASA/World Energy Council 1998.

meeting this demand, which requires major baseload additions, are not inclined to dismiss out of hand any one electricity generating technology. Despite the ambitious plans for nuclear expansion in the region, nuclear power will barely maintain its present share of just over 10 percent of total electricity supplies.

A powerful reason for the interest in nuclear power in Asia is Asian concern about energy security. Two OECD countries in the region, Japan and South Korea, have few domestic energy resources and depend on imports for over 80 percent of their total energy supplies, a much higher share than most OECD countries of North America and Europe. The Philippines and Thailand are also heavily dependent on imported energy. Even countries with domestic resources are relying more and more on imports; China has become a net oil importer, as is India. For all of Asia, a large part of this imported energy consists of Middle East oil shipped through long and potentially vulnerable sea lanes.

Nuclear power, especially if the technology and civil works can be provided domestically, is seen to promote energy security through diversifying energy supplies and lessening the degree of import dependence. At present, for most countries in the region, nuclear power does not eliminate import dependence, as most Asian countries need to import uranium and are dependent to varying degrees on fabrication and enrichment services from abroad. However, nuclear fuels require much less shipping volume per energy unit, and can be more easily stored than oil and gas. Several countries in the region plan to increase or already have increased domestic content of the nuclear fuel cycle by developing facilities for fuel enrichment, fabrication and reprocessing, or at least spreading their risks through investing in uranium mines overseas, concluding long-term fuel enrichment contracts, and maintaining nuclear fuel inventories as a hedge against supply interruption.[53]

For several countries, nuclear power provides important logistical advantages. China and India, for example, have large coal reserves (China is the world's largest coal producer) but in both cases, coal resources are situated far from population centers. Transmission systems are limited and railway capacities already under strain from the need to haul coal for long distances. Nuclear power, which has greater locational flexibility, and is not dependent on a constant flow of high volume fuel over long distances, helps escape these logistical problems.

Nuclear power is also of interest to many Asian countries because it addresses concerns about urban air pollution in the region. Urban air pollution is dangerously high in many Asian cities, typically exceeding World Health Organization guidelines by a large margin.[54] Heavy dependence on coal in India and China, where the use of cleaning technologies is only beginning, has led to particularly acute urban air quality problems. The use of nuclear power instead of coal to produce electricity can reduce the growth in air pollution. Though urban air pollution is a growing policy concern in China, India and other developing countries, greenhouse gas emissions have not aroused similar concern, and they have not signed the Kyoto and other Protocols governing the level of greenhouse gas emissions.

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53 These countries are China, India, Japan and South Korea.

54 *Clear Water, Blue Skies.* The World Bank, 1997.

Nuclear power appeals to many countries in Asia because of its high technology content. These countries do not wish to be left behind in a technology that they believe could be of increasing importance, with major spin-offs that will promote modernization and economic development, lead to a high technology export trade and contribute to defense, as some nuclear technology can be dual-use. This includes nuclear medicine as well as the use of nuclear in manufacturing and other uses. They prize and wish to encourage the linkages between nuclear power and the development of the country's technological base, industrial infrastructure and reserves of trained manpower.

A major reason for Asia's interest and planned expansion of nuclear is the supportive role of government, and in many countries the general public. Many nuclear power programs in Asia are run by state-owned utilities and/or are led by central government agencies that coordinate policy and planning, and most important of all, provide financing. This provides a national commitment to nuclear power which permits steady development independent of economic considerations.

C. North America

In 1971, North America accounted for 41 percent of the world's nuclear power generation. By 1995 that share had fallen to 35 percent, and, despite the 125 reactors currently operating in North America, is projected to decline further in the future.

In the United States, the rapid expansion in nuclear generation occurred in the 1960s and early 1970s, at a time when electricity demand was still increasing rapidly. The regulatory regime of the time made efforts to mitigate or at least defer unanticipated capital charges. Regulations controlling the use of gas and oil for electricity generation gave a further boost to nuclear, as did clean air legislation. The United States was on the leading edge of all aspects of the nuclear fuel cycle, with world-class vendors competing successfully on a global basis.

Slowing demand for electricity in the 1970s, attributed to oil price increases and increased energy efficiency, reduced the need for new/additional baseload plants, and resulted in excess plant orders. The last new order for a nuclear plant in the United States that was not subsequently canceled was in 1973. The decline in oil and gas prices in the 1980s reduced the competitiveness of nuclear power, which was further compromised by new, low capital, gas-fueled generating technologies. The Three Mile Island incident heightened public fears about nuclear accidents. Regulatory actions, designed to improve the safety of nuclear power generation, led to costly retrofitting, substantially lengthened construction times, and increased costs for operations and maintenance. Long and contentious public hearings stretched out the licensing process and led to huge increases in capital costs. Interest rate increases boosted the capital costs of the plants much more than expected. Because of the uncertainty in demand growth, utilities either suspended construction or stretched out construction, again contributing to excessively high capital costs. At the same time, the Public Utility Regulatory Policies Act (PURPA) opened the market to independent power generators.

Many of these considerations continue to enter into play in the future role of nuclear power in the United States. The outlook for electricity demand over the next twenty years raises the question whether any new baseload plant of any sort will be needed.[55,56] There are strong reasons for continued life-extension of existing power plants to help meet rising demand (it has been noted that extending the life of existing plants could be viewed as deferral of need to build more baseload). These include what has been termed the "distinct anti-new-source bias of environmental regulation," past and prospective weakening of guaranteed capital recovery, and technological changes in monitoring, diagnostics and control which can be grafted on to existing plants.[57] Life extension can apply to nuclear plants as well as coal, but the regulatory procedures for life extension of nuclear plants has been established, and currently, two applications are being processed by the U.S. Nuclear Regulatory Commission with results expected in late 1999 or 2000. The process of deregulating the power sector that is proceeding in many states is likely to weaken guaranteed capital recovery which could diminish the attraction of nuclear power to investor-owned utilities.

On the other hand, the economics of nuclear power could be very attractive for some well run plants, given their low production costs, and some aspects of industry deregulation could also favor nuclear.[58] If, as seems likely, deregulation will be associated with consolidation and reduction in the number of generating firms, each generating firm may end up with several nuclear plants and be able to rationalize its operating procedures. At the moment, most investor-owned utilities with nuclear facilities have only one or two plants which require a highly specialized work force dedicated to them.

The general expectation is that no new nuclear plants will be ordered in the United States out to the present planning horizon, and that the actual level of output of existing plants will depend on plant retirements. The first applications for license extension (a 20-year renewal of an original 40-year license for Baltimore Gas and Electric's Calvert Cliffs plant and Duke Power Company's request for an extension of its Oconee Plant) have recently been made, and the regulatory procedure should give some indication of the conditions (and costs) to be required. Nevertheless, some observers speculate that relicensing will meet with only limited success in the United States.

Factors that could favor nuclear include an emerging concern about energy security, as in the 1970s, or a new appreciation of the environmental advantages of nuclear power which would soften public opposition to nuclear power, perhaps in response to discussions on how to fulfill U.S. obligations under the Kyoto Protocol. Some states are examining the future role of nuclear power in their energy mix, taking into account deregulation and air pollution requirements. Adherence to the Clean Air Act could help foster the prospects for nuclear power.

Canada is a major power in the world nuclear arena. Despite its relatively small population it ranks sixth in the world in terms of installed capacity. Its large uranium reserves make it by far the world's leading uranium producer. Canada has developed and uses a nuclear technology which differs from the otherwise dominant light water reactor. The CANDU reactor is moderated by heavy

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55 Joe F. Colvin notes that these economies could continue to be attractive for well-run plants.

56 Donald L. Guertin notes that this statement is only intended to raise a question and is not a forecast.

57 "Note on the Seemingly Indefinite Extension of Power Plant Lives". Denny Ellerman, *International Association for Energy Economics Energy Journal*, Vol. 19, No. 2 .

58 Joe F. Colvin notes that recent evaluations by Standard & Poor and other analysts indicate a high likelihood of license renewal for well-run plants.

rather than light water, which enables it to sustain the fission of natural uranium without enrichment. This technology has been exported to several countries.

Though Canadian nuclear technology has enjoyed a good deal of success both at home and abroad, the program has run into problems in recent years. Ontario Hydro has laid up the seven oldest of its nineteen operating units, in order to correct shortcomings in station management, rebuild depleted station staffs, and concentrate on using available resources to bring the twelve newest units back to first-class condition.

D. Western Europe

Output of nuclear power in Western Europe is at similar levels to North America. Like North America, Western Europe experienced a rapid increase in output of nuclear power, and current trends also indicate a slowing of growth in the future. But there are differences between the two regions. Although the last order of a nuclear power unit occurred in the United States in 1973, more than 70 units were ordered thereafter in Western Europe (the majority in France, Germany and the United Kingdom). In addition, some countries in Western Europe have developed the industries and the suppliers for the back-end of the fuel cycle (reprocessing of spent nuclear fuel and recycling of recovered material — uranium and plutonium — as MOX fuel). Another important difference is that nuclear power provides a much higher share of total generation in Western Europe (32 percent) compared with that in the United States (20 percent).

Within the region, there are considerable differences among individual countries. At one end of the spectrum, France, with 59 reactors, has the second largest stock of nuclear power plants after the United States. These reactors provide three quarters of France's total electricity production. France is largely self sufficient in all aspects of the nuclear fuel cycle, with exports which cover the entire gamut of nuclear goods and services as well as electricity itself. The development of nuclear power has benefited from a good deal of government and public support. The French government considers nuclear power to be a valuable high technology industry which makes an important contribution to France's energy security. France, like several of the Asian countries, has few domestic fossil fuel resources, and is therefore keenly aware of energy security considerations. Nuclear power is also valued for its contribution to the improvement of air quality and the reduction in CO_2 emissions. France is recognized as a country with exceptionally low carbon intensities of its primary energy supply, largely due to the high share of nuclear power.

At the other end of the spectrum, several European countries either have no nuclear industry (for example, Ireland, Denmark, Greece, Luxembourg, Portugal, Norway and Austria), or have shut down part or all of their nuclear power stations. In the Netherlands, one unit was shut down because it could not economically compete with other power sources. Italy, which is highly dependent on energy imports, has nevertheless shelved nuclear development. A high dependence on energy imports is often associated with the development of substantial nuclear energy programs. In Sweden, a national referendum in 1980 urged the phasing out of nuclear power. However, to date, no units have been shut down. The closing of Sweden's nuclear power plants ahead of the time when they would normally be retired will pose major problems, as nuclear power provides about half of Sweden's electricity, and Sweden's per capita output of nuclear electricity is the world's highest. A vigorous campaign to reverse the decision, led by parts of Swedish industry and Swedish labor, is currently underway. In fall 1998, Germany's new government announced that it would be closing down its nuclear power plants, accounting for one-third of the country's electricity generation, although as of this writing, the timeframe for the closure has not been determined.

Belgium, Finland, Spain and Switzerland all have substantial nuclear generation but there are no firm plans to build new units However, these countries are increasing capacity by installing new steam generators and other upgrades to the existing units. Finland has also recently undertaken an environmental assessment for a possible fifth reactor.

The United Kingdom is of particular interest because of the recent privatization of much of the nuclear generating capacity in British Energy. This offers a test case of how nuclear power might survive the discipline of the market. Experience to date in the U.K. privatization shows nuclear power to be competitive with other forms of generation. The United Kingdom, like France, is active in all stages of the nuclear fuel cycle and has been a leader in nuclear technology. British Energy has also been actively investing in nuclear plants in the United States.

Though there is considerable variation among European countries, for the region as a whole, there is little possibility of major increases in nuclear output in the near term. France is the only country that is building additional capacity, and is in the process of completing one new plant. As in the United States, plant life extensions may be a decisive factor.

There are several reasons behind the projected slowdown in Western Europe. Like the United States, Western Europe is facing a relatively slow load growth, which does not favor large baseload plants such as nuclear. At the same time, increasing gas supplies from a number of sources — Russia, North Africa, and Norway — are diminishing concerns about energy security. Public support is lagging, even hostile, in many countries, and, in the new environment of deregulation and privatization, the industry can no longer count on the degree of government support that it enjoyed during the 1960s and 1970s. The situation could, however, change because of requirements to reduce greenhouse gas emissions in accordance with the Kyoto Protocol.

E. Eastern Europe and the Former Soviet Union

This region, like North America and Western Europe, has a large and technologically self sufficient nuclear industry. Because of the structure of the Soviet nuclear industry, many of the former Eastern block countries have nuclear power plants, but enrichment, spent fuel and waste management facilities lie within the borders of Russia. Following a rapid increase in nuclear capacity, this region now accounts for about 9 percent of global nuclear power generation, and is predicted to hold this share up to 2020.

There are currently 59 reactors in this region, of which 29 are in Russia, 16 in Ukraine, six in Bulgaria, four each in Hungary, the Czech Republic and the Slovak Republic, two in Lithuania, one each in Armenia, Kazakhstan, Romania and Slovenia. The breakup of the Soviet Union resulted in a rather arbitrary partitioning of nuclear power capacity. As a result only 12 percent of Russia's total electricity supply is from nuclear, whereas 88 percent of Lithuania's electricity comes from its one nuclear plant (2 units, 1500 MW each). In many of the other countries — Bulgaria, Slovakia, Hungary, Ukraine — nuclear power is a major part of the power supply, accounting for about 40 percent.

Virtually all the reactors in Eastern Europe are Soviet designed.[59] There are two main designs, the RBMK (a light water cooled, graphite moderated reactor) and the more recent and more commonly used VVER (the Russian version of a PWR). The performance of the latest models of VVER reactors compares well with Western reactors, but according to a 1997 European Commission report, despite recent improvements, the older generation reactors continue to pose safety problems, especially in regard to containment.[60] Concern with the safety design and operation of some Soviet built reactors, as well as concern over a lack of safety research underpins the safety upgrade and assistance programs, such as the Nuclear Safety Account, initiated by the OECD Nuclear Energy Agency, the European Commission, and the G7 (part of which is administered by the European Bank for Reconstruction and Development).[61]

At the moment, this region plans to press ahead with reactor construction. Russia has four under construction, Ukraine two, Slovakia four, and the Czech Republic two. Romania also has one in operation and three units in various stages of completion, although no construction is currently underway. Even with this program, nuclear power will barely retain its share of total electricity consumption. The main motive behind the continued expansion is the use and development of a technology in which the region has extensive expertise, both for home use and export, and a very large infrastructure of trained personnel. Nuclear power provides some countries, such as Ukraine and Armenia, with a desired element of energy security. It also opens up possibilities, as interconnections between Western and Eastern Europe develop, to export electricity to neighboring countries.

There is, however, a large element of uncertainty in these plans. The economic disruption that followed the break-up of the Soviet Union reduced demand for electricity, and it may be some time before steady load growth resumes. At the same time, dislocation of the power system, as political autonomy shifted, has led to regions of surplus and shortage. It will take time for the differences in supply and demand to be sorted out. In the past, nuclear power development was financed through national budgets. Now these budgets are under strain, though in several cases (the Mochovce project in Slovakia, the Temelin project in the Czech Republic and the Cernovada project in Romania) private investors are stepping in and taking up the slack. In such an environment it is difficult to evaluate future plans. However, Eastern Europe's energy balance is more likely to approximate that of North America and Western Europe (that is a relatively small increase in nuclear generation, if any), rather than the rapid increase planned in Asia.

59 Romania has one CANDU reactor, and Westinghouse supplied one reactor to Slovenia/Croatia.

60 See *Nuclear Energy in Europe and World-Wide.* European Commission May 1997.

61 Boris A. Gabaraev notes a) that RBMK reactors alone produce more than 50 percent of the nuclear power plant electricity in Russia and 100 percent in Lithuania. As it was revealed by the TACIS "RBMK Safety Review" project, the performance of the latest generation of RBMK reactors compare well with Western reactors of the same vintage. b) The majority of VVER and RBMK reactors upgrade measures is planned and implemented in the frame of national reconstruction programs of VVER and RBMK operating countries.

F. Other Regions

Generation of electricity from nuclear power in other regions is very small, together accounting for under one percent of the global total in 1993. If present plans are fulfilled, this share could reach just over one percent by 2020, and account in most countries for a small part of total domestic electricity generation.[62]

In Latin America, Argentina has two power stations with a third due for commissioning in 1999. Brazil has one operating station with a second due for start up also in 1999. Mexico has two reactors, in service since 1990 and 1995.

In Africa, nuclear power is produced only in South Africa which has two 920 MWe reactors. South Africa has abundant uranium reserves.

Australia has no nuclear program but is a leading producer of uranium.

62 William J. Dircks notes that in addition to the countries listed below, Cuba has two reactors in stages of near-completion which have not been licensed for full operation because of technical, safety and financial concerns.

IV. THE ISSUES

All countries have a common interest in securing reliable, sustainable, low cost, flexible energy supplies with minimal impact on the environment, and therefore have an interest in considering the role of nuclear power along with all the other sources of energy and energy efficiency in fulfilling these policy objectives. A discussion of the role of nuclear power is especially topical following the agreement within the Kyoto Protocol among the developed countries to hold carbon dioxide emissions below 1990 levels in the 2008-2012 period. The example of France shows how nuclear power can dramatically reduce the carbon dioxide intensity of energy supplies.

Despite the regional differences in nuclear development plans described in section III, a number of questions arise which are of common interest to all countries, and which require resolution if nuclear power is to maintain or increase its role as a source of energy that contributes to sustainable economic and social growth. Left unaddressed, these problems are likely to inhibit the development of nuclear power. And if, for one reason or another, plans for nuclear power are cut back, many of these questions will still need to be addressed. The safety of nuclear plants will remain an international obligation and issue as long as nuclear plants are in operation. Even if nuclear power generation stopped tomorrow, spent fuel and waste management issues would still have to be solved.

These questions include: What needs to be done to design, build and operate plants in an acceptably safe and reliable manner? How to implement an appropriate nuclear waste and spent fuel strategy? How will nuclear power compete in privatized markets and what financing mechanism will need to be developed to attract private capital investment for large scale energy projects in a liberalized and deregulated market? How can technological progress be assured? Are additional measures required to ensure that civilian nuclear power does not contribute to weapons proliferation? What changes are needed in international and national regulatory regimes to ensure safe and sustainable supplies of nuclear power?

A. Reactor Safety[63]

The erosion of public support for nuclear power following the accidents at the nuclear plants at Three Mile Island and Chernobyl demonstrate the fact that a nuclear plant accident anywhere is a nuclear accident everywhere. Even the perception of danger can sway public support; although there was no unacceptable release of radiation beyond the plant from the accident at Three Mile Island, public support for nuclear power worldwide fell significantly. The issue of safety was dealt with at length in an earlier report.[64] The main conclusions of that report were:

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63 For general background on this section, please refer to *Rethinking Nuclear Safety.* Klaus B. Stadie, and *Nuclear Energy for Sustainable Development.* E.O. Adamov, B.A. Gabaraev, V.V. Orlov, presented at the Atlantic Council seminar on the global future for nuclear energy, Cannes, France, May 10-12, 1998.

64 *An Appropriate Role for Nuclear Energy in Asia's Power Sector* op. cit.

1. Safety issues are of universal importance in the sense that the future of nuclear power depends on the safe operation of all nuclear power plants, no matter where they are situated.
2. Concern for safety pervades the entire nuclear power sector, including the design and construction stage as well as operation. High level safety procedures and technologies are available, and in use today, and methods of transferring and implementing such technologies and procedures should be explored.[65]
3. Most accidents occur because of improper operational practices and inadequate maintenance. Experience with operational plants and resultant feedback can be expected to reduce design and material deficiencies.[66]
4. The human factor is critical in ensuring the safe and sound plant management necessary to develop a robust "safety culture".
5. Reactor safety is closely related to the independence and credibility of the regulatory regime.

These conclusions apply with great force in the broad context of the global nuclear power industry. On the global level, a wide range of operating conditions prevail, which not only pose a threat to the global industry, but also a challenge to the industry and governments to help bring low-safety plants up to the highest levels. In recognition of the imperative of maintaining a strong safety culture, the private and governmental sectors have taken many actions at the enterprise, national, bilateral and multi-lateral levels.

Operator-level efforts in addition to in-house efforts have included the formation of the World Association of Nuclear Operators (WANO). This organization, formed in 1989, works to enhance safety and performance of nuclear power plants through discussions on operator training, dissemination of information, and reviews of plant operations. WANO now plans to have peer review teams visit half of all nuclear power stations by September 1999. Areas of review include: policies; procedures; determining root causes of equipment failure; fire protection; radiation protection procedures; and training.

The international community has also recognized the critical importance of safety, and has developed a number of international agreements covering nuclear safety, accidents, transportation of nuclear materials, handling of nuclear waste and spent fuel, and related issues implemented through international organizations, such as the OECD/NEA and IAEA.[67] These agreements, which express the basic international safety rules to be followed by all, and provide an international legal infrastructure for nuclear power, are supportive of national efforts. They are noted in Tables 1 and 2 below, and described briefly in Annex II. The related question of liability is also addressed in a number of international agreements (Table 2 and Annex II, see section V for further discussion). They collectively represent an approach to dealing with issues relating to nuclear safety and liability. The working group believes that governments and enterprises should increase their efforts to work

65 Sam Thompson notes that the transfer of considerable information on safety procedures and technologies has already taken, and is taking place.

66 Sam Thompson notes that this reference to accidents is misleading. First, the use of the term "accidents" conjures up images of major releases of radioactivity, whereas the fact is that a large portion of so-called accidents are really incidents with very minor implications. Second, most such incidents are caused by human error (i.e. not because of improper operational practices, but improper *implementation* of practices and procedures).

67 At the international level, both the IAEA and the OECD/NEA are active in the safety area. The IAEA now has 128 member states. The OECD/NEA has 27 member countries (85 percent of the world's installed nuclear capacity).

with the IAEA and OECD/NEA to further strengthen these treaties and conventions. It is vital that a strong and indigenous safety culture be present at all levels of the nuclear community.

Work undertaken by a number of institutions in support of nuclear power operators in the former Soviet Union further illustrates the dedication to a strong safety culture. Several assistance programs have already been developed to complement and support the work done by countries themselves. The aim is to make nuclear power plants in the former Soviet Union compatible with modern international safety requirements. International programs include those developed by Japan, the United States, the IAEA and the European Commission (TACIS and PHARE).[68] WANO contributes technical assistance and the OECD/NEA plays a major role in coordinating assistance. The G7, acting as a multilateral group, have set up a Nuclear Safety Account, part of which is operated through the European Bank for Reconstruction and Development. Loans from the account, governed by EBRD requirements, can cover either safety improvements to existing plants or plant closure, with preference in a number of cases for the latter. However, this program has encountered difficulties. Loans can only be made on the understanding that the project is based on a study showing that the actions proposed are the "least cost" solution to providing energy services. These studies take time to prepare, are contentious when they have been completed, and often run counter to the priorities of prospective grant recipients. In the words of one source "when it comes to choosing between living with the possibility of a major accident or the certainty of no heating next winter, experience in Ukraine has shown that few of the public will choose the latter".[69] In addition, Western companies have been reluctant to undertake work in these countries under both bilateral and multilateral grants, because of unsatisfactory or developing third party liability arrangements. Companies fear this lack of protection will expose them to litigation in the event of an accident at the plant where they carried out work and which caused damage or injury. This issue has been addressed by both the IAEA and the OECD/NEA.

The continuing emphasis on safety in the nuclear industries of Asia, North America and Western Europe is further illustrated by discussions on the key issue of the actual or prospective shortage of skilled manpower, including engineers, managers and craftsmen. The human factor is critical in a robust "safety culture." In many of the countries of these regions, the slowing or stagnation of nuclear programs is discouraging new entrants into the industry. The existing work force is aging and is not easily replaced by sufficient new entrants with the requisite skills. In other countries, such as China, the planned rapid build-up of the industry may strain existing resources of skilled manpower at all levels. It is estimated, for example, that if Asian countries expand their use of nuclear as planned, they will require 400,000 to 500,000 trained individuals. In contrast, Eastern Europe and the countries of the former Soviet Union have a large stock, even a surplus, of technically trained manpower. This global imbalance offers the potential for international cooperation in human resource development. This has been illustrated by the setting-up of the

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68 TACIS (Technical Assistance to the New Independent States and Mongolia) was set up in 1991 to support the process of reform and economic development in those countries. The objective of the nuclear safety program was to take immediate action to remedy urgent shortcomings through short-term assistance measures with a view to then drawing up longer-term projects to improve the safety of more recently designed reactors. A number of bodies were set up to provide technical know-how, including the electric utilities, the engineer/architect companies, nuclear fuel cycle operators, safety authorities, and bodies that manage radioactive waste.

69 *World Wide Prospects for Nuclear Energy*. World Commission on Nuclear Energy London. Chatham House, page 6.

Table 1

International Nuclear Agreements on Accidents, Safety, Transportation and Waste

Treaty/Agreement	**Status**	**Areas Addressed**
Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management	• opened for signing 1997 • 37 signatories • 5 parties	• international framework for safe management of spent fuel, waste • minimal facility standards • establish national regulatory agencies
Convention on Nuclear Safety	• entered into force 1996 • 49 parties • first review meeting begins 12 April 1999	• adherence to fundamental safe principles • regular meetings • peer review
Code of Practice on the International Transboundary Movement of Radioactive Waste	• passed by resolution 1990	• international standards for transport, protection • consent of receiving country required • international cooperation and IAEA clearinghouse for information
Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency	• entered into force 1987 • 75 parties	• international framework for cooperation • IAEA to serve as clearinghouse for equipment, experts, materials
Convention on Physical Protection of Nuclear Material	• entered into force 1987 • 60 parties	• requires states to protect nuclear material being transported • international framework for cooperation in protection, recovery, return • sanctions for criminal acts involving nuclear material
Convention on Early Notification of a Nuclear Accident	• entered into force 1986 • 80 parties	• notification of any civilian accident • reporting of time, location, radiation release • nuclear weapon states report weapons accidents • fosters strong national regulation and its supporting legislation for nuclear power facilities
"London Convention" on the Prevention of Marine Pollution by Dumping of Waste and Other Material	• entered into force 1975 • 80 parties	• prohibits dumping radioactive waste • IMO charged with training, monitoring • states must work toward eliminating existing waste • funding for elimination of waste, through polluter pays principal

Table 2

International Nuclear Agreements on Civil Liability for Nuclear Damage

Treaty / Agreement	**Status**	**Areas Addressed**
Protocol to Amend the Vienna Convention	• adopted 1997	• broadens definition of damage to include economic, environment and preventive damage • broadens liability to include transport • compensation raised to 300M SDR[70] • time frame for action extended to 30 years
Convention on Supplementary Compensation	• opened for signing September 1997	• establishes formula to make international public funds available for compensation
Joint Protocol of Paris and Vienna Conventions	• entered into force 1992 • 20 parties	• brings conventions into collaborative force, combining geographic coverage
Vienna Convention	• entered into force 1977 • 28 parties	• establishes IAEA framework for civil action caused by nuclear accident • absolute liability rests with the operator • maximum liability U.S. $5M • operators must carry insurance to cover liability • action must be brought within ten years • jurisdiction lies in state where accident occurred
Paris Convention	• Approved 1960, entered into force 1968 • parties are OECD members • amended by protocol 1964, 1982	• establishes framework for civil action caused by nuclear accident • absolute liability rests with the operator • maximum liability 15M SDR • operators must carry insurance to cover liability • action must be brought within ten years • jurisdiction lies in state where accident occurred
Brussels Convention	• entered into force 1968 • supplementary to the Paris Convention	• raises maximum liability to 300M SDR • establishes formula where compensation is split between operator, the state where the accident occurred and common international fund

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70 SDR, or Special Drawing Rights is a unit of currency used by the International Monetary Fund. The value as of 8 February 1999 is US $1.389.

International Science and Technology Centre (ISTC) in Moscow, and the Science and Technology Centre in Ukraine (SCTU), both with the aim of facilitating the conversion to civilian programs of scientists and engineers previously involved in nuclear weapons.

Nuclear experts agree that reactor safety is also critically dependent on national regulatory regimes, and they recognize that the creation of competent and credible regulatory regimes is a complex affair, in which one model does not fit all cases. Countries differ greatly in their form of government and degree of centralization/decentralization, and the regulatory system must be consistent with the existing governmental structure. However, certain principles of regulation seem to apply universally. These include: a clear focus on the purposes of regulation to protect public health and safety; the independence of the regulatory authority; the separation of the licensing and operating authorities; transparency and promptness in decision-making; impartial and predictable enforcement; and a process that permits effective public involvement. Regulatory regimes in place differ from country to country, so that standardization of regulatory requirements and procedures could offer the opportunity for all countries to re-evaluate their systems and ensure that the safety of their nuclear power sector is reinforced by strong and effective regulatory regimes. The regulatory regime of a country is an effective method of setting standards that will define the strong safety culture necessary for the safe and reliable operation of a nuclear power plant.

B. Management and Transportation of Radioactive Waste and Spent Fuel[71,72]

Management of nuclear waste and spent fuel has proved to be one of the most visible and pressing global issues of nuclear power. While a number of technical solutions have been proposed, their utilization requires difficult political choices, taking into account local, national and international considerations. The issue could potentially inhibit further development of nuclear power unless the public is convinced that it is satisfactorily being addressed.

Volumes of radioactive waste and spent fuel are rising.[73] The great majority of waste is intermediate and low-level, of which about half is generated from nuclear reactors and half from other activities, largely related to medical and research applications. The technical consensus is that intermediate and low-level waste disposed of in properly licensed sites can be safely managed without risk to future generations. There are a number of these sites already operating in the United States and

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71 For general background on this section, please refer to *Transport of Nuclear Materials.* M. Nakajima, presented at the Atlantic Council seminar on the global future for nuclear energy, Cannes, France, May 10-12, 1998.

72 Richard E. Balzhiser notes that spent of used nuclear fuel contains an enormous future energy potential in the form of uranium and plutonium as well as other highly radioactive isotopes, the latter having no apparent commercial value. Interim, not permanent, storage is required if uranium's full energy potential is to be realized. Governments working with the IAEA must assume the responsibility for safe and secure management of this material. Specific proposals deserving serious consideration have been made by W. Häfele and C. Starr ("International Spent Fuel Storage: Concepts, Issues and Options", Lewis Dunn and Stephen Carey, eds., *Science Applications International*, February 25, 1998), and K. Tomabeichi and E.P. Velikov ("The World Needs an International Nuclear Fuel Bank", *Proceedings of the 17th Congress of the World Energy Council*, Houston, September 13-18, 1998).

73 Joe F. Colvin notes that while the volume of spent fuel from commercial nuclear power plants increases with the increased production of electricity from these facilities, the spent fuel is completely controlled and fully managed, with no releases to the environment. The spent fuel will ultimately be disposed of in an engineered and analyzed facility such as a deep geologic repository.

Western Europe and Asia, though the main issue remains obtaining local public acceptance for any new site — as illustrated by the difficulties in gaining approval for agreements in the United States, under which regional sites for waste disposal would be established.[74]

The management of high-level and long-lived waste and spent fuel, has raised more questions.[75,76] Technical solutions to the disposal of nuclear waste have been identified and are being implemented in one case (e.g. the Waste Isolation Plant in the United States). According to a European Commission report, "a worldwide consensus is beginning to emerge, based on extensive R&D programs carried out in a number of countries, that such waste when properly conditioned can safely be disposed of in repositories deep underground."[77,78,79] A "collective opinion" produced by the OECD/NEA in 1995 reached a similar conclusions taking into account ethical considerations arising from intergenerational obligations.

Some countries currently use the "once through" cycle in which all spent fuel is considered as waste even though it contains re-usable uranium and plutonium.[80] Current storage procedures for "once through" reactor spent fuel is to store spent fuel assemblies *temporarily* at the reactor site in specially designed water filled pools. These pools were originally designed for short term storage, but due to problems that have arisen in selecting permanent disposal sites in most countries of the world, they are now providing long-term storage. The capacity of the pools has been increased by re-racking or packing the rods more efficiently. After a period of time, the heat generated by the rods diminishes, allowing storage outside of the pools. On-site spent fuel storage capacity has been further enlarged by storing the older spent fuel assemblies outside the pools in containers such as metal or concrete storage casks. Though these procedures buy time, they represent a temporary solution to the storage problems until permanent disposal facilities have been developed.[81]

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74 As specified in the Low-Level Radioactive Waste Policy Amendments Act of 1985 (Public Law 99-240), low-level waste is radioactive waste not classified as high-level waste, spent nuclear fuel, or by-product material specified as uranium or thorium tailings and waste.

75 U.S. Department of Energy, Energy Information Agency. *World Nuclear Outlook,* Washington DC. Oct. 1995 p. 40.

76 Robert H. Socolow notes that the World Nuclear Outlook estimates cumulative discharge of spent fuel from world nuclear power plants at 32,000 metric tons in 1997, but these data start only at 1995. If the waste from previous years is included the cumulative discharge would be nearer 100,000 tons. High-level wastes are expected to rise by about 10,000 tons annually.

77 *Nuclear Energy in Europe and World-Wide.* European Commission, May 1997.

78 Richard E. Balzhiser notes that high-level wastes should be concentrated, vitrified or otherwise consolidated before they are isolated permanently. Government repositories should be provided for final disposal.

79 Joe F. Colvin notes that since the 1950s, scientific organizations around the world have examined the issues of radioactive waste management. Most organizations— from the National Academy of Sciences and the Office of Technology Assessment in the United States, to the International Atomic Energy Agency and the Organization for Economic Cooperation and Development's Nuclear Energy Agency have reached the same conclusion. They believe that the best and safest long-term option for dealing with high-level radioactive waste is deep geologic disposal.

80 Canada, Finland, Sweden and the United States have chosen the once-through fuel cycle.

81 Thomas B. Cochran notes that this paragraph does not mention the higher cost of a "twice through" cycle compared to a "once through" cycle. The closed fuel cycle, with rare exceptions, will not be pursued beyond one recycle. About 97 percent of spent fuel content is recovered during reprocessing, but it is not all recycled in reactors. Much of the uranium will end up as enrichment tailings, which is waste for all practical purposes.

Therefore, it is important to take into account the amount of uranium and plutonium, which is burned in the second cycle. Recycling reduces the volume of high-level waste, but not the total volume of high-level plus low-level waste. Moreover, more radioactivity is routinely retraced to the environment in the case of the twice through cycle. The volume of high-level waste is not natural to the size and cost of geological disposal, which is a function of the heat

(Continued on next page)

The other option takes the spent fuel from reactors and extracts the remaining uranium and plutonium. The residual waste is prepared for deep storage as in the case of the "once through" cycle. In reprocessing, uranium and plutonium (approximately 97 percent of the spent fuel content of the fuel rods) can be recycled in nuclear reactors, thus using a much larger part of the energy originally contained in the uranium fuel rods. This in turn reduces the amount of uranium that has to be mined, milled and enriched. Second, this approach reduces volumes of waste for permanent storage, and increases its suitability for vitrification, a process which minimizes volume and probability of their reentering the environment.

Originally, the intention was to recycle the recovered plutonium in fast reactors with their higher fuel burn-up performances. However, Fast Reactor development has lagged, and has even been suspended in some countries. Thus the recovered plutonium is currently recycled in the form of MOX fuel (a **M**ixed uranium/plutonium **OX**ide fuel) in light water reactors.[82] Three MOX fuel fabrication plants, with an overall capacity of approximately 200 tons per year, are in operation in Europe and supply 30 reactors currently loaded with MOX fuel in Belgium, France, Germany and Switzerland. Japan plans to start loading MOX fuel in its LWR reactors by the turn of the century.

There are issues common to both fuel cycle approaches which need to be addressed as soon as possible. The first is to assure that the current safety requirements and practices of handling nuclear materials in spent fuel and processing plants, as well as during transports, are properly maintained.[83] A second issue is the need to develop permanent disposal facilities for high-level and long-lived waste, including spent fuel. A third issue is to develop communication plans to reassure the public as to the safety and integrity of nuclear materials transport. And finally, research into the reduction of the volume of nuclear waste and methods of storage is required. While these activities imply a strong technical and R&D component, the first two also require increased attention to public understanding. Efforts so far to establish permanent storage facilities have often met with some public hostility, which is also manifested during the transportation of nuclear fuels and waste. The key need for both energy security and environmental needs is to establish the importance of monitored retrievable storage and the politics of site location and transport.

These conclusions are broadly similar to those arrived at in the previous Atlantic Council report.[84] Extending the analysis to cover all countries of the world underscores the urgency to act. It also draws attention to the fact that the disposal of nuclear waste and spent fuel is a problem that has to be solved regardless of the future of nuclear power. Even if nuclear generation were to stop tomorrow, the disposal of large amounts of nuclear waste would still be required. This aspect of nuclear power is not optional.

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loading of the waste. Volume has economic implications, but not enough to offset the considerably higher cost of the twice through cycle.

82 Masao Kuroda notes that the use of MOX fuel in light water reactors (which is called "plu-thermal") significantly improves the efficiency of uranium utilization and it requires little additional capital investment in existing nuclear power generation facilities. Therefore, in Japan, research and development of the "plu-thermal" project has been underway from the beginning of the development of nuclear energy. In terms of promoting nuclear non-proliferation, it is also important to use plutonium at a steady pace. Such being the case, Japanese electric utility companies plan to introduce the MOX fuel utilization program to a PWR and a BWR in 1999.

83 Joe F. Colvin notes that the National Academy of Sciences in the United States has advocated that meeting the spent fuel standard would be adequate protection for the disposition of surplus weapons grade materials.

84 *An Appropriate Role for Nuclear Energy in Asia's Power Sector,* op.cit.

C. Cost Competitiveness and Financing of Nuclear Power[85]

A question of increasing prominence in discussions about nuclear power is whether its cost will be competitive with other forms of electricity. The cost competitiveness of nuclear power is likely to be greatly influenced by new market conditions in the power sectors of many countries. Until a few years ago, in most countries, the power sector was one of the "commanding heights" of the economy, recognized as being of critical national importance. Most branches of the power sector were publicly owned, though many enjoyed a good deal of operational autonomy. For many years, they operated secure in the knowledge that if necessary the government would come to their financial support. In some countries, notably the United States, Germany and Japan, the utilities were investor rather than government owned, but were highly regulated under a regime that encouraged vertical integration and protected investors against several market risks, with the *quid pro quo* that utilities would be responsible for providing a reliable electric supply.

Though this system of government regulation has been strongly criticized in recent years, its achievements should not be underestimated. It permitted the rapid increases in electricity consumption which have been a striking feature of global development since the Second World War. Many countries, including the United States for some decades, experienced "double ten" growth in which consumption doubled every ten years. However, as time passed, fiscal and performance problems emerged. In general, utilities in the OECD countries performed satisfactorily, and exercised fiscal responsibility by charging tariffs that were high enough to cover costs and finance system expansion. The experience in many developing countries was less successful. Though systems were rapidly expanded, the quality and reliability of the electricity provided was poor, and the utilities' finances seriously deficient. Their financial difficulties were not entirely of their own making. Many utilities were required by their governments to subsidize tariffs, the subsequent financial shortfall to be reimbursed by the government if and when it could. In several of the countries in transition, notably Russia and China, any profits had to be returned to the central government's treasury and (costless) capital was then allocated to each utility following some pre-determined rules.

In recent years, deregulation and privatization have been adopted as means to increase competition in the electric energy industry. In some cases, as in the United Kingdom, the entire power sector was privatized, including most of the nuclear plants. In other cases, the vertical structure of the sector was broken up into its constituent parts and deregulated. In the United States, many utilities have sold their generating facilities and concentrated on the transmission and distribution ends of the industry. These and other utilities have invested in regions outside their franchises, acting as Independent Power Producers (IPPs). Several developing countries, though keeping the traditional

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85 For general background on this section, please refer to the following papers, presented at the Atlantic Council seminar on the global future for nuclear energy, Cannes, France, May 10-12, 1998.

Economic Implications of Electric Industry Restructuring, Linda C. Taliaferro;

Comparative Costs of Power Generation Using Various Technologies, John J. Easton, Jr.;

Also: *Strategic Thinking About Nuclear Energy: Implications of the Emerging Market Structure in Electric Generation*, David L. Bodde.

structure intact, opened up their power sectors to private, domestic and foreign investment through IPPs. The purpose in all cases was to provide a new market-oriented operating environment.

The movement towards greater market orientation, however, is uneven. Among Asian countries these moves are muted, and it appears that in most of these countries the government will continue to play the major role in the power sector, not least because of their concerns over energy security.[86] In North America and many countries of Western Europe on the other hand, movements towards privatization and deregulation are more developed. Most of the countries of Eastern Europe and the former Soviet Union have declared in principle in favor of greater market orientation in their power sectors, but progress in achieving this goal may be slow.

These developments are of importance to the future of nuclear power both in the long and short term. In the short term, the question is whether existing nuclear plants can be competitive in the new market environment. For the moment, there is limited experience. In the United Kingdom the greater part of the nuclear generating plants have been privatized as British Energy which is now the single largest supplier to the grid.

Where capital costs have been largely depreciated and high operating efficiencies maintained, nuclear power should, in principle, be highly competitive because of its low production costs (operation, maintenance and fuel). Capacity factors have been rising generally, but capital depreciation varies from plant to plant, and with differences in accounting procedures it is difficult to generalize. Life extension for nuclear plants could improve their competitiveness, depending on the costs and conditions of life extension.[87] In the case of British Energy, the recent life extensions given its plants have been reported by the company to have had a positive effect on its financial situation and prospects.

Over the longer term, decisions to build new plants will be influenced by nuclear's cost competitiveness in relation to the costs of other generation options — coal, gas, hydro, the range of renewables and energy efficiency programs. The OECD/NEA and the IEA jointly provide cost estimates on a periodic basis (levelized lifetime costs in constant money) per unit of electricity produced by nuclear and fossil fuel generators. These estimates cover all capital, fuel and operating costs, including estimates for plant decommissioning, spent fuel management, and radioactive waste disposal, and also include a specified rate of return on capital. The latest estimates suggest that nuclear power is generally at a disadvantage compared to fossil-fired alternatives. This study finds that in countries where fossil fuel prices are close to OECD averages, fossil-fired plants are the cheapest options, with gas having an advantage over coal in many cases. The study also concludes that nuclear power has the potential to be the cheapest option where its capital costs can be kept

[86] Balzhiser, Gobert et al. *Op. Cit.*

[87] Projections of U.S. nuclear generating capacity, for example, depend critically on relicensing assumptions. Department of Energy, Office of Nuclear Energy, Science and Technology.

low, and where gas and coal prices are rather high and projected to increase during the economic lifetime of the plants.[88]

Such estimates, given their long time frame, are at best approximations, and are beset with major uncertainties regarding the economics of power generation regulation and technical advances. For nuclear and coal-fired plants, total investment requirements have the most significant impact on overall economics since typically 50 percent or more of total generation cost depends on capital cost. For capital-intensive plants, the longer they operate, the better their economics, compared to less capital-intensive plants. For gas and oil-fired plants, fuel cost over the plant lifetime is the single most important variable.

Many things can happen over the lifetime of a power plant (40 years or longer) that can vastly change the comparative economics of nuclear versus other power generation options:

1. Fuel prices can change in unexpected ways. Neither nuclear nor fossil fuel prices can be predicted with certainty.
2. New generation technologies can emerge which change the relative economics of generation options. Combined cycles employing gas turbines provide a recent example.
3. Times required for plant construction and commissioning can vary according to changes in regulatory requirements, local political views, and other factors, For example, stricter environmental requirements tend to lengthen construction and licensing times for all types of plants. Builders of nuclear plants hope that streamlined licensing procedures will tend to shorten development times for nuclear plants.
4. New laws and policies can cause capital or operating costs of plants to change. Environmental and safety regulations are especially important in this regard.
5. As capital-intensive technologies, nuclear, hydro and large coal plant cost estimates are highly sensitive to the discount rate used. In the past, discount rates have been typically a low rate applied to government sponsored projects. Privatization and deregulation will push discount rates higher to the detriment of capital-intensive technologies.

Furthermore, conventional costs do not fully incorporate the "external" costs (or benefits) of electricity production, that is, those costs which are not borne by the electricity producer, but by the public at large. Much emphasis has been placed on external costs, such as impacts on public health, of electricity generation, and more research should be undertaken in this important area. A recent study concludes that the external costs associated with nuclear power generation are small in relation to other costs, and much smaller than the environmental costs associated with other forms of electricity generation such as coal.[89] This conclusion was reached even without imputing any environmental costs to greenhouse gas emissions. Technology can lower coal and oil CO_2 emissions but not eliminate them. Nuclear power's economics then could look more attractive especially as other air and water pollutant costs are rising.

Another externality that may influence decision making is security of supply. From the previous section on regional developments it was seen that perceived supply security considerations exercise

[88] "Projected Costs of Generating Electricity – Update 1998" *OECD* Paris: 1998.
[89] Resources for the Future and Oak Ridge National Laboratory.

considerable influence on decision making in Asia, where many counties are highly dependent on energy imports. In their view, nuclear power is insurance against disruptions in imported supplies, or the inability to pay for them. This view of energy security is shared by other highly import dependent countries (such as France and several emerging, landlocked countries in Eastern Europe). Other countries, notably those who have low levels of import dependency, or do not worry about them, place less value on the energy security advantages of nuclear power.

Even if nuclear power can be shown likely to be the most economical choice of generating capacity, there is still a major financing issue. With the exception of hydro, nuclear power plants are the most capital intensive of the current baseload technologies. In the past, when nuclear plants were financed directly by the public sector, or were given compensatory regulatory treatment, the high capital intensity was not a major obstacle.[90]

In those markets where power sector financing must come from the private sector, financing is likely to be more difficult, as private investors will normally be unwilling to invest in nuclear capacity where capital requirements are high and returns long delayed. Admittedly, the freeing of capital markets has meant the development of a variety of instruments for risk sharing, but these are unlikely to prove adequate if risks are much higher than in comparable projects.

For those countries that continue to maintain a strong governmental presence in energy markets, and who are committed to expanding nuclear capacity, financing arrangements will no doubt be made. Even when public funds are available for the power sector, however, there are compelling reasons for decisions to be made on a rational basis, and to establish the financial integrity of the sector — otherwise, the whole nation loses.

In those countries that have privatized to greater or lesser extent, there remains the question of what the role of government in a privatized energy market situation should be. The role for continued, or different types of regulation is readily accepted in the new market-driven environment. But the broader issue of the strategic role of government in considering the longer term, societal issues facing the energy sector has not been given sufficient attention. Issues to be discussed include: will the market result in the mix of generating capacity which is to the country's long-term advantage? If, at the moment, there appears to be little economic rationale to build new nuclear power plants, is the country willing to allow the nuclear option to disappear by default? Is the market taking into account environmental, security, technology and manpower issues in an adequate way? Is there any justification "to level playing fields" (e.g. imposing costs on emitters of greenhouse gases) in order to improve the relative financial attractiveness of hydro, renewables and nuclear compared with other forms of power generation? What will be the final costs of decommissioning and waste management?[91]

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90 Joe F. Colvin notes that the 1998 NEA/IEA publication *Projected Costs of Generating Electricity* presents comparisons of capital, operating and maintenance, and fuel costs in the OECD and non-OECD countries. This study notes, for example, that in France and China, nuclear power plants have the lowest levelized costs at both 5 and 10 percent discount rates, while nuclear power is the cheapest option in Canada, South Korea, Spain, India, and Russia at a 5 percent discount rate.

91 Recommendations relating to analyzing the economics of and financing for nuclear power were also presented in the paper on Asia nuclear power. These recommendations stressed the need for international cooperation "to develop acceptable models for determining the cost and economics of nuclear power relative to other power sources," and the

(Continued on next page)

D. Nuclear R&D[92]

During the coming century, the world will require increased energy to foster economic growth in a sustainable manner. This will be the case, even with significant increases in energy efficiency. Seeking to assure that economically viable energy resources — ranging from fossil fuels to renewables— are available will require basic research by both the private and governmental sectors.

If the nuclear power option is to be kept open against the time when fossil fuels become too scarce, too expensive to use, or are considered to have unacceptable environmental impacts, longer term and more basic research would be required.[93] Candidates for such research could be: less capital-intensive technologies; smaller reactors; increased standardization in design; and reactors that improve safety, reduce volumes of nuclear waste and spent fuel, expand fuel resources, and have anti-proliferation features. Fast-breeder technology could extend the fuel resource base, but research into this technology is at present at a low level. With current and prospective low uranium prices their "breeding capability" offers no commercial advantage, but in the long term the upward movement of uranium prices and improved reactor designs may well provide such an advantage. Another promising development is the high-temperature gas-cooled reactor, which would expand the utilization of nuclear power to a broader energy sector, including industrial heat process. In the longer term, some argue that fusion technology has major safety and waste management advantages. But there is no certainty as to when such technology may be practically available.

In the past, much of nuclear R&D took place in the United States and Europe. However, the demand for nuclear reactors on a worldwide basis has stagnated in recent years. The slowdown in orders for nuclear plant in North America and Western Europe, still the center of civilian nuclear power and accounting for over 70 percent of global capacity, means diminished incentive for either the nuclear industry or governments to undertake major research programs.[94] Government budgets are under pressure throughout the world and R&D is a particularly vulnerable area when it comes to expenditure cuts. Power sector deregulation is further reducing R&D and shifting resources to shorter-term R&D.[95]

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need to take into account "to the extent possible, the external benefits and damages of different energy forms in formulating energy policies."

The paper also recommends that countries should establish the long-term financial integrity and credit-worthiness of their power sectors "through establishment of meaningful tariff structures and domestic capital markets."

92 For general background on this section, please refer to the following papers, presented at the Atlantic Council seminar on the global future for nuclear energy, Cannes, France, May 10-12, 1998.

Nuclear Energy for Sustained World Development, E.O. Adamov, B.A. Gabaraev, V.V. Orlov;

Nuclear Energy Issues and the Role of Advanced Nuclear Reactors, V.M. Mourogov;

Proposal of Research and Development Target for Fast Breeder Reactor, Yasuo Wakabayashi;

Rethinking Nuclear Power Technology, K.B. Stadie.

93 A comprehensive list of research needs was provided by John J. Taylor in *An Appropriate Role for Nuclear Energy in Asia's Power Sector.*

94 For a discussion on nuclear technology issues in the United States, see: *Federal Energy Research and Development for the Challenges of the Twenty-First Century*, President's Council of Advisors on Science and Technology, 5 Nov. 1997, Chapter 5.

Also, *The Decision-Makers Forum on a New Paradigm for Nuclear Energy*, Idaho National Engineering and Environmental Laboratory, 14 Sep. 1998.

95 See "Unintended Consequences: Energy R&D in a de-Regulated Energy Market," J.J. Dooley, *Energy Policy*, Vol 26,

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There is a certain amount of short- and near-term R&D of an evolutionary nature which is accomplished by suppliers and utilities as part of their on-going activities to improve their product in an increasingly cost and safety conscious environment. Given the shortage of R&D funds, there is every interest to ensure that the results of such activity that do exist are widely disseminated, although it must be recognized that commercial interests of private companies may inhibit sharing some R&D efforts. In the past, governments and international organizations have taken the lead in this activity through official meetings and contacts, but now the center of activity may be passing to the private sector.

In addition, some R&D is taking place in Europe, the United States and Japan based on the evolutionary improvement of existing light water technology. The Advanced Boiling Water Reactors (ABWR) (Japan has two in operation) and the Advanced Pressurized Water Reactors (APWR) are designed to make reactors simpler, safer and more economical, including such features as prefabricated modular construction.[96] Another advanced light water reactor has been developed which substitutes powered emergency cooling systems with "passive" systems depending only on gravity or compressed gas to provide emergency cooling. The passive cooling features of the pressurized water version of this design has been successfully tested and the design has received the regulatory approval of the U.S. Nuclear Regulatory Commission. Other designs include the European pressurized water reactor developed by France and Germany, hybrid reactors that increase the destruction of long-lived waste and less powerful, integrated primary loop designs that reduce the risk of serious accidents. However, as the cost per installed kilowatt is high, commercialization is still far distant.[97,98]

Another promising direction of R&D common to all reactor types is the adaptation to nuclear power of the front-line developments in information technology. Such adaptation has been slow in nuclear power because of the low growth rate of new capacity and the constraints of regulation. By comparison, major technological gains in many other industries have been made by applying the latest developments of information technology to their business processes. Analogous applications to nuclear power could result in major improvements in its reliability and economics over the full gamut of design, construction and operation processes and their associated configuration controls.

It may be that the locus of nuclear research will increasingly migrate to those areas where demand is growing rapidly, as in Asia, or where there is a large nuclear research establishment already in

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No. 7 1998 pp. 547-555.

96 *Nuclear Energy in Europe and World-Wide.* European Commission, May 1997.

97 Richard E. Balzhiser notes that ALWR technology for both PWRs and BWRs offers improved options for near-term deployments where economical. Advanced reactor designs, incorporating high temperature coolants, offer potential efficiency and/or breeding benefits. R&D is important to assure full utilization of the uranium and thorium resource potential. International efforts such as the General Atomics/Russian collaboration should be encouraged.

Russian capabilities and interests in nuclear's future are manifested in MINATOM's activities in liquid metal and gas-cooled reactors development and demonstration programs that deserve higher visibility within the global community. MINATOM should also commit itself to assuring the safe operation of earlier reactors in FSU countries that pose potential risks to nuclear power's global future.

98 Boris A. Gabaraev notes that it is also very important to support the development of revolutionary designs using existing reactor and fuel cycle technology, e.g. such as suggested in the paper of E.O. Adamov, B.A. Gabaraev, V.V. Orlov, presented at the Atlantic Council seminar on the global future for nuclear energy, Cannes, France, May 10-12, 1998.

existence, as in Russia. These regions would naturally determine their own research agenda in accordance with their own domestic needs and capabilities, and there is no reason to believe that their R&D programs would meet the priorities of other areas or even result in an optimally balanced world menu of possible technologies.[99] Many of the areas in which R&D is needed are of general benefit, especially proliferation-resistant fuel cycles, and waste management technologies. Consideration should be given to the setting up of international consortia to develop such research.

E. Nuclear Weapons Non-Proliferation[100,101]

From the beginning of civilian nuclear power, a major concern has been its potential for dual use, and the need to ensure that it did not contribute to the proliferation of nuclear weapons. A number of public and private international agencies, groups or committees and treaties (see Table 3 and Annex II) have been created to ensure the integrity of sensitive nuclear supplies and technologies. The cornerstone of the international safeguards system is the Nuclear Non-Proliferation Treaty (NPT). The International Atomic Energy Agency (IAEA), which plays a critical role in monitoring compliance with the NPT, also has a wide range of activities aimed at ensuring the safe operation of nuclear facilities.[102] These activities are described in detail in Section V and Annex II.

In addition, the Nuclear Supplier Group (NSG), established in 1975, includes most governments with advanced nuclear fuel cycle technologies. The NSG issues guidelines for the export control of those sensitive nuclear materials, technologies, and equipment which are relevant to weapons proliferation. The operational interpretation of treaty requirements for safeguards on the exports of nuclear equipment and materials is based on the work of the Zangger Group which has compiled a trigger list of specific nuclear equipment and materials which must be controlled for export. The group is composed of major nuclear suppliers who are also NPT signatories So far, 31 countries have voluntarily committed not to export trigger list items.[103]

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99 *An Appropriate Role for Nuclear Energy in Asia's Power Sector* recognizes the critical role of R&D by recommending stronger efforts at technology diffusion for all forms of energy supply technologies and energy efficiency. The paper also recommends expanded networks to share R&D information, activities and proposals, and collaboration on R&D where possible.

100 For general background on this section, please refer to *Nuclear Weapons Proliferation: What is in Store for the Next Millennium.* Thomas B. Cochran, presented at the Atlantic Council seminar on the global future for nuclear energy, Cannes, France, May 10-12, 1998.

101 Tamàs Makray comments: "I am convinced that it is a serious omission not to address clearly the need of elimination of nuclear weapons. The trauma of nuclear weapons is hindering the public acceptance of nuclear power. The fact that nuclear weapons materials can be converted for use in commercial reactors would favor public acceptance. The reluctance of governments to reduce their nuclear arsenals is affecting their international credibility."

102 Richard E. Balzhiser notes that proliferation resistant technology for fuel reprocessing must be assured before separating plutonium from the high-level waste. Candidate cycles and reactors should be reviewed and approved by IAEA before licenses are approved.

103 Victor Murogov clarifies that countries have agreed not to export trigger list items to countries that do not have all of their nuclear installations under safeguards.

Table 3

International Nuclear Agreements on Nuclear Weapons Proliferation, Geographic Nuclear Free Zones, and Testing

Treaty/ Agreement	**Status**	**Areas Addressed**
Treaty on the Non-Proliferation of Nuclear Weapons (NPT)	• entered into force 1970 • extended indefinitely 1995 • 187 parties, plus Taiwan	• outlaws non-weapons states 'acquisition of weapons • IAEA safeguards inspections for verification • assistance to non-nuclear weapons states in area of nuclear power development • encourages free flow of civilian information/technology • weapons states must pursue disarmament
Tlatelolco Treaty	• entered into force 1968 (for the parties with a 'waiver') • 32 parties	• outlaws nuclear weapons in Latin America • does not prohibit peaceful use of nuclear power • establishes the Agency for the Prohibition of Nuclear Weapons in Latin America, cooperates with IAEA to administer controls, verification and special inspections, based in Mexico City
Rarotonga Treaty	• entered into force 1986 • 13 parties, all members of South Pacific Bureau for Economic Cooperation (SPEC)	• outlaws nuclear weapons in South Pacific • SPEC responsible for administration and monitoring
Bangkok Treaty	• entered into force 1997 • 10 parties	• outlaws nuclear weapons in Southeast Asia • does not prohibit peaceful use of nuclear power • establishes Commission of Southeast Asian Nuclear Free Zone for implementation and administering control and verification, to work through ASEAN ministerial meetings and secretariat
Pelindaba Treaty	• opened for signing 1996 • parties are on the African continent/members of the Organization of African Unity	• outlaws nuclear weapons in countries that are parties to the treaty on the African continent • does not prohibit peaceful use of nuclear power • establishes African Commission on Nuclear Energy, to meet annually and work with IAEA in verification/encouraging peaceful nuclear use
Partial Test Ban Treaty	• entered into force 1963 • 94 parties	• prohibits nuclear explosives testing in the atmosphere, outer space or underwater
Comprehensive Test Ban Treaty	• opened for signing 1996 • 151 signatories • 23 parties	• prohibits nuclear explosives testing • establishes agency for verification

While many of these initiatives are government inspired, the nuclear industry and utilities, whether private or publicly owned, already contribute by ensuring the security of any sensitive materials and technologies under their control. With regard to weapons material control, the industry is also cooperating in the disposal of highly enriched uranium and plutonium resulting from weapons disposition, as in the agreement between the United States and Russia for the purchase and transfer of Russian excess weapons material in the form of blended-down highly enriched uranium to the United States, to be used in civilian reactors. France and Germany, with the support of the industry, are also cooperating with Russia on the conversion of its weapons-grade plutonium into MOX fuels, for use in Russian civilian reactors. This is the late 20th century version of "beating their swords into plowshares and their spears into pruning hooks."

Though the system of safeguards has met with considerable success, there are still potential dangers and trouble spots, as well as issues of implementation which raise questions on how to increase the effectiveness of the non-proliferation regime.[104] Not all countries are signatories of the NPT.[105] Concerns have also been raised regarding the security of technology and nuclear materials in countries of the Former Soviet Union. One of the problems may be that the present non-proliferation regime was premised on conditions of the Cold War and was based on the political balance of that time. It must be recognized that the NPT's objectives (which do not preclude the promotion of new nuclear-weapon-free zones) are not universally accepted. The end of the Cold War permitted a major breakthrough in nuclear arms reduction between the two main nuclear weapons countries, the United States and Russia, and attention has now shifted to two areas that have existed all along, but have increased importance: the rise of other nuclear weapons states and the threat of nuclear terrorism.

Some countries with civilian nuclear power programs are considering, or developing nuclear weapons programs. Such activities raise weapons non-proliferation concerns and complicate industry activity or international cooperation to help improve the safety and operations of existing nuclear power facilities. India and Pakistan, for example, tested nuclear weapons in May 1998. These tests raised a number of serious concerns among nations that have supported civilian nuclear power while promoting weapons non-proliferation. India and Pakistan stated at the time that their tests were essential to national security.[106] The tests led to the imposition of sanctions by a number

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104 Boris A. Gabaraev notes that it is necessary not to limit ourselves to safeguards and organizational commitments of countries and enterprises to the weapons non-proliferation regime. It is also important to develop such nuclear technologies which exclude by their nature any possibility to separate plutonium. An example of that approach is described in the paper of E.O. Adoamov, B.A. Gabaraev, V.V. Orlov presented at the Atlantic Council seminar on the global future for nuclear energy, Cannes, France, May 10-12, 1998.

105 Countries that have not signed the NPT include Cuba, India, Israel and Pakistan.

106 *Evolution of India's Nuclear Policy*, tabled by the government of India to the Parliament, on May 27, 1998:

"Under such circumstances, India was left with little choice. It had to take necessary steps to ensure that the country's nuclear option, developed and safeguarded over decades, not be permitted to erode by a voluntary self-imposed restraint. Indeed, such an erosion would have had an irremediably adverse impact on our security. The government was thus faced with a difficult decision. The only touchstone that guided it was national security."

P*akistan Announces Unilateral Moratorium on Nuclear Testing.* Statement from the Information Division, Embassy of Pakistan in Washington, DC, June 11, 1998:

"The tests that were conducted on May 28 & 30, 1998 were a natural response to restore the strategic balance that had been altered by India's nuclear weaponization and subsequent provocative actions and statements against Pakistan."

of countries. As of the writing of this text, India, Pakistan and involved countries are undergoing discussions to resolve concerns raised by these tests.[107]

F. Public Communication[108]

A thread running through much of the previous discussion is the question of public acceptance and support of nuclear power. It is indeed difficult for any technology to develop and prosper today in the face of widespread public concern.

Through the 1950s, 60s and early 70s, there was generally wide public support for nuclear power as a new form of energy and for the use of nuclear energy in applications in the fields of science, industry, medicine and agriculture. This trend was probably best exemplified by President Eisenhower's "Atoms for Peace" program, paving the way for the deployment of civilian applications in a new field of science linked originally to national defense. With the increased public awareness of safety-related issues, radioactive waste and spent fuel management, and the appearance of an activist environmental movement, the development of nuclear power was met by growing opposition in some quarters, later fueled by the 1979 Three Mile Island accident in the United States, and in 1986, by the Chernobyl disaster in the former Soviet Union. In addition, concerns were also raised about weapons proliferation risks associated with the civilian uses of nuclear energy. Further, opponents of nuclear power have been effective in raising concerns about safety, handling of nuclear waste and spent fuel, and non-proliferation.

Today, there is a general perception, which is reflected in the media, that a majority of the public opposes nuclear energy. While this may be true in some countries, it is not corroborated by the results of public opinion polling data in most countries where nuclear power is already part of the energy mix. In Asia for example, public attitudes have been supportive and even enthusiastic about nuclear power, although opposition has become stronger in Japan and South Korea in recent years.

In France, a nationwide poll has been performed every year since 1992, which shows continuing acceptance of the French nuclear program. According to the December 1997 poll, 62 percent of respondents stated that nuclear energy is the "energy that will have the greatest role ten years from

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[107] Sam Thompson notes that this paragraph needs clarification. If a country is developing nuclear weapons, there will, by definition, be proliferation concerns whether or not that country has a nuclear power program. While a civilian power program, depending on the breadth of that program, can to some degree provide a cover for a nuclear weapons effort, the link between the two needs to be kept in perspective. Countries do not need civilian power programs in order to develop nuclear weapons, and, in fact, generally countries that have pursued nuclear weapons have done so through dedicated programs. Doing away with nuclear power will not eliminate the risk of further proliferation, nor will the growth of nuclear power greatly increase the risk of further proliferation, which is more related to political factors than technical factors.

[108] For general background on this section, please refer the following papers presented at the Atlantic Council seminar on the global future for nuclear energy, Cannes, France, May 10-12, 1998:

Public Acceptance of Nuclear Power in Democratic Societies, Paul Slovic;

Nuclear Risks and Environmental Risks: Problems of Communicating Risks to the Public, Yasumasa Tanaka;

Risk Perception: Analyzing Images and Fears, Y. Tanaka;

Toward a Symbolic Coexistence of Energy and People: Importance of Coordinating Institutional Arrangements and Risk Communication, Yasumasa Tanaka.

now." The results were six points higher than the year before. At the same time, however, that poll showed that the feeling of being "not enough informed" on nuclear power issues is still prevalent (60 percent). The apparent contradiction in the French polls probably lies at the heart of the public acceptance issue of nuclear power in most countries.[109]

While the nuclear power community has increased its efforts to provide real-time and hard-fact information to the general public, the perception of opacity and secrecy is still widespread, especially when incidents occur at nuclear facilities, and more generally, in the case of radioactive waste and spent fuel management. But there is growing consensus within the nuclear community that whatever has been done in the past to allay public concerns is still not enough and that new approaches are needed.

Many support the initiation of educational programs for the benefit of the younger generation at the school and college level. The advantages of such schemes are thought to be two-fold. First, the younger generation will grow up with a fuller knowledge and, it is assumed, support of nuclear power. It may also help in recruiting highly qualified personnel to the industry, which is likely to be a major issue in coming years. Others report that focused programs to explain and demonstrate aspects of nuclear power development have met with success when properly designed.

Even more radical changes in approach may be needed. In the past, it has often been assumed that public opposition was founded on ignorance, and that all that was needed to establish the public's trust was timely distribution of information and scientific data concerning nuclear power design and health consequences, couched in layman's terms. Although this remains a necessary step, there is greater realization that the issue is much more complex, and that the industry needs to make even greater efforts to establish the public's trust. A comparison of public attitudes in France and the United States is of particular interest. Public opinion polls in both countries indicate a similar level of perceived risk from nuclear power among the population at large. French respondents support nuclear power, as they consider it necessary. This verdict may reflect France's high energy import dependence, and the perception that there are few other options. The French public also has a high level of trust in the experts and engineers who build, operate and regulate nuclear power plants.[110]

The industry should debate openly the long-term need for nuclear power to help meet energy requirements and ensure sound economic growth in a sustainable environment.[111] In doing so, the

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109 Richard E. Balzhiser notes that the importance of public opinion was recently reinforced by the narrow margin of support for nuclear power in the European Parliament (225 for; 218 against). R.E. Balzhiser also notes that Hans Blix, Director General Emeritus of the International Atomic Energy Agency, offered a number of pertinent queries relating to sound safety performance, benefits of nuclear power to sustainability, economic viability of nuclear in reducing oil dependence, and nuclear's contribution to reducing greenhouse gases. (reported in *Financial Times Energy Economist*, "Nuclear Questions in a Faustian Bargain", November 1998).

110 In an opinion poll of 1,000 college graduates and registered voters in the United States, sponsored by the Nuclear Energy Institute, 73 percent of respondents supported keeping open the option of building more nuclear energy plants in the future.

111 Joe F. Colvin notes that such a debate should take into account the benefits of nuclear technologies in medicine, agriculture and other fields.

nuclear energy industry could join with the other branches of the energy industry in the search for solutions to the problem of how to assure sustainable levels of energy supply at reasonable costs.[112]

There could also be a natural alliance between nuclear power and the whole range of renewable energy, as sources of energy which are beneficial in reducing air pollution. Another example of a natural alliance is with those professions and industries outside nuclear power which utilize ionizing radiation for beneficial purposes. The ties with these professions and industries should be strengthened and joint communications should be developed. More generally, the growing world-wide concerns about the deleterious effects of climate change also require a bold new and concerted approach to public acceptance issues by the energy industry as a whole, with the nuclear energy industry having the potential of a larger role.

G. Global Climate Change

The Kyoto Protocol and continuing intergovernmental discussions on climate change demonstrate the deep international interest in reducing the level of greenhouse gases, with particular emphasis on CO_2.[113] Given the interest in this subject, ways of reducing the levels of CO_2 and other greenhouse gases emitted from the use of energy and from other human sources are being discussed. They include more efficient burning of coal, increased use of renewables, energy efficiency, and the use of nuclear power. The U.S. Department of Energy is exploring technical opportunities for decarbonization of fuels, as well as carbon sequestration, the method by which CO_2 emissions are trapped and isolated. In the decarbonization process, primary fuels, for example natural gas (primarily methane), can be reformed to produce hydrogen, a fuel that produces no carbon when burned.[114]

A number of studies in the past few years, by the President's Council of Advisors on Science and Technology, the Trilateral Commission, the IEA and the OECD/NEA conclude that nuclear power could play a significant role in reducing greenhouse gases, while meeting global power needs. The 1997 report of the President's Council of Advisors on Science and Technology notes that "as a non-greenhouse gas emitter, nuclear power can play a major role in allowing countries to meet emission goals, and "that it will be more difficult for the United States to meet emission goals

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112 Richard E. Balzhiser notes that nuclear should not be viewed as a competitor to renewable resources by its proponents. It is the ultimate complement to the variability of our solar, wind and hydro resources once fossil fuel costs or CO_2 limits establish their economic viability. Public communications programs should emphasize this point.

113 Charles R. Perry notes that while there has been much publicity and verbal support of the Kyoto Protocol, it is certainly questionable as to whether developed countries will be willing to pay the cost to meet these objectives. Most of the methods to meet these objectives represent what the developed countries should be doing anyway to conserve fossil fuels for future generations, i.e., improving fuel efficiencies, energy conservation, developing renewable energy sources that are truly economical without any subsidies, etc. Therefore, greater emphasis should be placed on energy conservation worldwide; if this is accomplished, then the reduction of emission of carbon dioxide will occur simultaneously.

114 S. T. O'Brien and R. Socolow, *Cooling the Greenhouse*. Energy, March 1998, pp 21-24 (Norwalk CN: Business Communications Co.). See also, R. Socolow, ed., *Fuels Decarbonization and Carbon Sequestration: Report of a Workshop*, PU/CEES Report No. 302, Princeton University, September 1997, available at http://www.princeton.edu/~ceesdoe .

without nuclear power."[115] The report states that "since 1973, the generation of electricity by U.S. nuclear plants has resulted in approximately 2 billion metric tons fewer carbon emissions than if the same amount of energy had been produced by coal plants."

The Trilateral Commission report *Maintaining Energy Security in a Global Context* also hopes that nuclear power's role in the OECD countries can be enlarged after 2010 to contribute to reducing greenhouse gases, as well as to national security.[116,117]

Because of the small amounts of CO_2 produced by the use of nuclear power, it is clear that expansion of nuclear power in place of fossil-burning plants would result in a smaller amount of CO_2 emitted into the atmosphere. Estimates vary, but under certain assumptions, continued growth in nuclear power could cumulatively reduce greenhouse gases by the equivalent of 55 gigatons of carbon by 2050, compared with generating the same amount of power using fossil fuels.[118,119]

An OECD/NEA report on nuclear power and climate change states that "keeping the nuclear option open... to realize this potential will require a number of actions by governments and industries in the nuclear sector." These actions include: maintaining high safety standards; implementing high-level and long-lived waste repositories; and R&D on the technical feasibility of non-electrical applications of nuclear energy (e.g. heat and hydrogen production).[120]

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115 *Federal Energy Research and Development for the Challenges of the Twenty-First Century,* President's Council of Advisors on Science and Technology, 5 Nov. 1997, Chapter 5.

116 *Maintaining Energy Security in a Global Context,* W.F. Martin et al, Trilateral Commission, Paper: 48 (1996).

117 Masao Kuroda notes that the Energy Supply and Demand Subcommittee of the Advisory Committee for Energy, an advisory organ for the Ministry of International Trade and Industry of Japan, published a report on July 11, 1998. This report suggests the efforts required to build energy supply and demand structure which can harmonize with the environment in Japan. Regarding the conversion of the energy supply structure, the report states that it is essential to promote nuclear power generation and requests that concerned individuals make their greatest efforts to achieve the goal of producing 480 million MWh of electricity by nuclear generation (approximately 300 million MWh was produced by nuclear power in 1996).

118 Development of this estimate uses the following assumptions: 200 gigatons of carbon dioxide would be emitted by 900 gigawatts of coal-fired power plants running for 50 years, assuming a) 50 percent efficiency in conversion of thermal efficiency to electricity; b) 80 percent capacity factor (the electricity actually produced in a year divided by the amount that would be produced working at full capacity the whole year); and 24 kg of carbon is emitted as carbon dioxide per GJ (gigajoule, or billion joules) of coal consumed -- a representative emission factor (44 kilograms of carbon dioxide carry along 12 kilograms of carbon). The 50 percent figure is a conservative estimate of what the efficiency will be for coal plants decades from now. The assumption that the plants replacing the nuclear plants would be coal, not natural gas, is critical also. (The carbon emissions per unit of energy for coal and natural gas are roughly in the ratio of 7:4.) The answer is not sensitive to the other assumptions. 900 GW is three times the current installed nuclear capacity.

119 Robert H. Socolow suggests an alternate calculation: Each thousand-megawatt (1 gigawatt, or 1GW) coal-fired power plant operating a few decades hence will emit 1.2 million metric tons of carbon per year, or 1.2 Mt(C)/yr, into the atmosphere as carbon dioxide, under reasonable assumptions. Assuming each coal plant were replaced with a nuclear plant of the same efficiency and capacity factor, atmospheric carbon emissions would be reduced by 1000 Mt(C)/yr (about one-sixth the rate today of global carbon emissions from fossil fuels) if roughly 800 GW of installed capacity of nuclear power plants. This analysis uses the following assumptions: 1)24 kilograms of carbon are produced from coal per billion joules of thermal energy; 2) the efficiency and the capacity factor of the future plant are 50 percent and 80 percent respectively. Roughly 0.7 Mt(C)/yr would be emitted if a similar thousand megawatt-power plants were burning natural gas.

120 *Nuclear Power and Climate Change*, OECD/Nuclear Energy Agency 1998.

An IEA presentation to the G-8 energy ministers meeting (8 March, 1998) states that "new policies will be required if nuclear power and non-hydro renewable energy sources are to help reduce the future rates of growth of fossil fuel consumption and greenhouse gas emissions. These policies would need to encourage... new designs for less costly nuclear power plants and determine the location for permanent repositories for radioactive wastes."[121]

There are other groups, however, which while recognizing that nuclear power does not result in significant greenhouse gas emissions, believe that increased energy efficiency and the use of renewables are preferable alternatives to the use of nuclear. Those adopting this position raise questions about safety and the economics of nuclear power, as well as concerns about non-proliferation and the dual civilian-military aspects of nuclear power.[122]

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121 *World Energy Prospects to 2020*, OECD/ IEA, 31 Mar. 1998.

122 A paper presented at the Cannes seminar of the working group notes that the Natural Resources Defense Council "would strongly oppose the use of nuclear power to reduce greenhouse gas emissions if the nuclear power industry intends to rely on commercial use of separated plutonium (e.g. the closed fuel cycle). Increasing the commercial use of separated plutonium to reduce CO_2 is not progress."

V. International and Regional Cooperation

While it is recognized that countries and enterprises must bear primary responsibility for safety and nuclear waste management, many of the issues discussed in this report point to the need for, and advantage of, greater regional and international cooperation. The wide variations in safety standards among countries, and the global need for the industry to improve them, points to the potential for cooperation on both the governmental and industry level. Power sector financing, previously undertaken domestically, is also becoming international, as investors seek to take advantage of the opening up of power sectors all over the world. The slowing of R&D in the OECD countries, previously the major locus of nuclear research activity, demands greater cooperation in order to use the available funds and resources as efficiently as possible. Issues of public attitudes towards nuclear power can benefit from international comparisons of experience. Finally, weapons non-proliferation issues continue to be inherently international in their focus.[123]

Many institutions and organizations from the public and private sector are already active in these areas. These include: the International Atomic Energy Agency; the World Association of Nuclear Operators; and the Nuclear Energy Agency, affiliated with the Organization for Economic Cooperation and Development.

The IAEA plays a key role in assisting countries make use of nuclear technology in a wide range of fields, such as medicine, agriculture, industrial applications, and where appropriate, power generation, in addition to its mandate regarding weapons non-proliferation. It places heavy emphasis on safety programs. Member states of the IAEA have directed the agency to carry out a broad range of programs but have failed to provide the funds to fully implement them. The IAEA's activities in these areas should be adequately financed and supported. For the past eleven years, the IAEA's budget has been adjusted for inflation, but not raised, despite a significant increase in its program responsibilities. This policy of "zero real growth" has been applied by governments to all U.N. agencies as a means of avoiding assigning priority to individual U.N. agencies. In the case of the IAEA this policy should be reviewed, as the Agency has been singled out by heads of most governments as an essential element in maintaining international peace and security, public health and safety. The IAEA could be classified as a special international agency and provided funding based on its program needs. This is especially acute in the areas of safeguards, physical protection, nuclear facility safety, spent fuel and nuclear waste management.

The IAEA safety program has developed a set of international standards for safety, applicable to all nuclear power facilities. It has also organized groups of experts from a variety of countries to serve as peer review teams to visit reactors and provide advice to operators and regulators on measures to improve operations. Governments should fully fund this program and make available experts from their national laboratories and utilities to serve on their teams. The IAEA should increase the

[123] Boris A. Gabaraev notes that it is necessary to combine the knowledge in nuclear technology that exists in developed countries with the needs of developing countries in nuclear power. Such efforts could foster international cooperation to develop innovative nuclear technologies similar to the International Thermonuclear Experimental Reactor, especially taking into account the fact that the goal of developing innovative nuclear technologies is much more practical than research and development on fusion technology.

coverage of nuclear facilities and provide objective criticism and advice on ways to maintain and operate plants to maximize safety and public health.

The international safeguards regime needs to be strengthened. The board of governors of the IAEA approved a substantially strengthened program of safeguards inspection and monitoring which will go far in reducing the probability of diverting nuclear material into illicit uses and will greatly improve the level of confidence that governments and their citizens have in the protection being provided by the IAEA.[124] But the approval process is slow because of concerns about the cost, the level of intrusiveness and possible disruption that the inspections and monitoring may entail. However, the benefits of deterring a country from violating its treaty obligations and diverting material from a civilian to military program should carry great weight in discussions of a strengthened IAEA. Many believe the long-term future for nuclear power will be greatly limited unless concerns regarding the link between civilian and military uses of nuclear reactors are strongly addressed.

The IAEA should be asked to carry out audits and peer reviews of member countries' national efforts to deal with problems of theft of nuclear materials. This action would complement the IAEA safeguards program and would make use of its expertise. In addition, proposals now before both the Physical Protection Convention and U.N. General Assembly should take advantage of IAEA expertise. Governments should support these initiatives and also provide funds for greater international cooperation in combating nuclear theft and terrorism.

The OECD/NEA provides a forum for cooperation on technical, legal, and policy issues, and helps to build consensus in the areas of nuclear safety and regulation, radioactive waste management, radiation protection, nuclear law and liability, nuclear resources, economics and the fuel cycle, as well as nuclear science. The Agency facilitates research in nuclear safety and waste management, coordinates international peer reviews of national high-level waste management programs, collects and analyses nuclear data and contributes to the modernization of the international nuclear liability regime.

WANO's activities are worldwide in scope, with regional centers in Atlanta, Moscow, Paris and Tokyo. As noted in the section on safety, WANO is strengthening its program by increasing its plant operations evaluation program. It is also committed to improving member services through an "aggressive" internet site and by providing performance statistics on CD-Rom, enabling members to compare their performance with that of other facilities.

124 Victor Murogov notes that the Board of Governors of the IAEA approved a new model protocol which will go far in reducing the probability of diverting nuclear material into illicit uses and will greatly improve the level of confidence that governments and their citizens have in the assurances provided the IAEA. Additionally, the bilateral safeguards agreements between the Agency and the NPT parties focus on "declared" nuclear materials in "declared" facilities. Under the new "Additional" Protocol, states have to provide the Agency with more information, and the Agency inspectors have much broader access. However, it will take some time before the new regime is fully functioning. The new measures have to be integrated into the present regime. Moreover, the ratification process will take time in most countries (25 states have ratified at present). All NPT parties have signed the additional Protocol, but it has only entered into force in a handful of countries.

In the next century, fast and consistent communications will be vital to all business areas of society, whether in the service of the manufacturing or nuclear industry. Further cooperation at the regional level within the nuclear industry should be the first step towards increased international cooperation. On the regional level, the European Union PHARE and TACIS programs have the stated political aim of improving nuclear safety in the Central and Eastern European countries and the former Soviet Union.

To further strengthen cooperation in Asia, the Atlantic Council's earlier policy paper[125] presents a recommendation that consideration be given to the formation of a new Asian regional nuclear association of nuclear operators and other parties interested in nuclear power. The association would be concerned with the effective and safe management of nuclear power and its fuel cycle in the broadest context. This recommendation is being considered by the Pacific Nuclear Council and other institutions in Asia.

125 *An Appropriate Role for Nuclear Energy in Asia's Power Sector*, op.cit.

VI. CONCLUSIONS AND RECOMMENDATIONS

This study examines an appropriate role for nuclear power in providing reliable, sustainable, and reasonably-priced energy to enable expanding populations to enjoy higher standards of living. It finds that all forms of energy have health and environmental impacts. These impacts differ in many dimensions: where they occur in the fuel cycle, the likelihood and extent of occurrence, and the environmental media affected. All these characteristics must be taken into account in formulating energy and environmental policy and it is within this context that the role of any one form of energy, in this case, nuclear power, must be considered.

This study finds that a number of significant developments are occurring which are greatly influencing the environment in which decisions about the role of nuclear power are being made. The economic environment that drives decisions to develop different types of power generation has changed radically in several countries in recent years. There is plenty of relatively cheap oil available. Many countries have access to pipelines with cheap and abundant natural gas. Innovative small-sized gas turbines technologies have become very competitive. Globalization has put competitive pressure on the power sector, and in associated developments, many industrial countries have moved toward deregulating and restructuring their power sectors, and opening them to foreign investment. The role of the private sector in power sector development, a theme already put into place in most OECD countries, is being reviewed and changed with an overall trend towards reduced economic regulation and increased environmental and safety regulation. This is important, as governments have a key role in determining whether nuclear power is economically competitive through regulatory policy and decisions over excess costs levied on plants and utilities (e.g. U.S. nuclear operators are required fund a "final" spent fuel repository).

The world will devote increased efforts to reducing pollution and greenhouse gas emissions associated with energy use. Widespread interest in this subject is exemplified by the Kyoto Protocol, in which representatives of developed countries, recently joined by Argentina and Kazakhstan, agreed, subject to ratification by their respective countries, to lower their emissions of six greenhouse gases by an average of 5.2 percent compared to 1990 levels in the 2008-2012.[126] Nuclear power, more efficient burning of coal, natural gas, fuel cells, carbon sequestration and renewable energy sources, such as solar, can help reduce some forms of pollution, and each has advantages in reducing the emissions of the six greenhouse gases noted in the Kyoto Protocol. It must be recognized, however, that nothing can be done to halt completely the production of carbon dioxide from the direct burning of fossil fuels, although methods of separating and sequestering carbon dioxide are being explored.

Finally, the international structure of the nuclear power industry has changed. In the past, most of the additions to nuclear power capacity and the associated technological development took place in North America, Western Europe, and the countries of Eastern Europe and the former Soviet Union. In the coming years, substantial increases in nuclear capacity in Asia are planned, but these are expected to be offset by stagnation or decline in North America, Europe and Russia. This

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126 In Annex B of the Kyoto Protocol, certain countries agreed to various emission limits of the six gases. The gases are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6).

change in geographic focus could have major implication for the development of technology, supplier industries, the handling of nuclear waste, and institutional arrangements governing the development of nuclear energy.

The study examines the future of nuclear power in the light of these changing circumstances, and identifies the issues that must be addressed if nuclear power is to play a role in providing the sustainable energy supplies needed for rising populations to gain higher living standards, and still protect the quality of the environment. The project's working group made a number of recommendations, particularly in the areas of promoting high standards of nuclear safety worldwide, nuclear waste management, development of human resources for the nuclear industry, nuclear R&D, government leadership in an age of market driven change, changing the industry's image, and strengthening international safeguard and safety regimes. These recommendations represent a consensus view of the working group on a range of controversial and important issues. Their weight lies in the expertise and experience of the working groups members who formulated them and their ability to introduce these recommendations to decision makers in their own country on an informal or formal basis.

The working group recognizes that any change in the energy sector requires a long time-frame for action and requires consideration of the complex interactions in the economic development-energy-environment triangle. To ensure that nuclear power plays an appropriate role in helping meet global energy needs, it will be necessary to take into account these considerations, as well as the pros and cons of the use of nuclear power. Timely actions by the private and governmental sectors will be required. Therefore, the group makes the following recommendations:

RECOMMENDATIONS ON REACTOR SAFETY[127]

1. All countries and enterprises engaged in nuclear power generation should recognize the paramount importance of nuclear safety, should build and maintain a strong safety culture, and should promote advanced technologies with enhanced safety features. Governments should develop and maintain reliable national safety authorities. Regulatory processes should be reformed to provide more effective, efficient and incentive-based systems.[128,129,130]

2. Governments should strengthen cooperation on adoption and harmonization of strict international safety standards. In addition to bilateral assistance programs, governments should

[127] Mamoru Sueda notes that "Recommendations on Reactor Safety" is too limited, and that "Recommendations on Nuclear Safety" would be more appropriate.

[128] Richard E. Balzhiser notes that it is equally important that weapons use of plutonium arising from the nuclear fuel cycle be eliminated. Research efforts must continue internationally to assure technological and institutional safeguards.

[129] Thomas B. Cochran notes that in his view, this sentence does not apply to most nations, including, nations such as China, Japan, and Cuba. In addition, he believe other reforms are more important in the United States that those noted.

[130] Joe F. Colvin recommends that the term "performance-based systems" be used rather than "incentive-based systems."

support existing public and private programs of international cooperation and expand them where necessary:

a. The IAEA should be permitted to increase both the coverage of nuclear facilities and the availability of experts to serve on review teams.[131] The IAEA should be encouraged to speed the implementation of the convention on nuclear safety, in order to help establish consistency and high standards in national regulatory regimes.[132]

b. The Organization for Economic Cooperation and Development/Nuclear Energy Agency (OECD/NEA) should intensify its work related to nuclear plant safety, and make its results available to countries outside the OECD region.

c. WANO[133] should be strengthened by increasing the intensity, coverage and enforcement of their review activities, notably to include management issues in their reviews and by increasing coordination with the IAEA thereby assuring complementary rather than duplicative inspection activities.

3. Efforts should be made to accelerate existing programs of technical and safety assistance to the countries of Eastern Europe and the former Soviet Union, thereby reinforcing the efforts pursued by these countries themselves.

RECOMMENDATIONS ON RADIOACTIVE WASTE AND SPENT FUEL MANAGEMENT

1. Governments should accept overriding responsibility for management of radioactive waste and spent fuel created in their countries and in cooperation with enterprises, demonstrate their determination to find satisfactory solutions to the problems of interim storage of spent fuel, retrievable spent fuel storage, and permanent isolation of high-level waste.[134]

2. Efforts should be made on a regional basis to address nuclear waste and spent fuel issues, including the examination of prospects for regional waste management facilities.[135]

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131 John J. Taylor notes that in order to make the best use of the resources available, the focus and priority of inspections should be placed on those plants where there is evidence of inadequate safety performance or safety culture.

132 Victor Murogov suggests that the recommendation be worded as follows: "The IAEA should be invited by governments to review more nuclear facilities and governments should make available experts to serve on review teams."

133 WANO is the World Association of Nuclear Operators. The above recommendations follow the Association's 1997 Review.

134 As defined by the U.S. Nuclear Waste Policy Act, high-level waste is (1) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including the liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations and (2) other highly radioactive material that the U.S. Nuclear Regulatory Commission, consistent with existing law, determines by rule to require permanent isolation (this includes spent fuel from nuclear reactors).

135 Rolland A. Langley notes that it was announced in December 1998 that Pangea Resources Inc., an organization with international investors, is exploring a concept for an international waste repository to be sited in West or South Australia. *Nuclear Fuel*, Vol 23, No. 25, December 14, 1998.

3. Both the IAEA and the OECD/NEA should give higher priority to their work on management of spent fuel and radioactive waste. In particular, the IAEA should actively encourage implementation of the Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management. Both agencies should consider ways of helping to make this issue better understood by government officials and the public.

RECOMMENDATIONS ON COST COMPETITIVENESS AND FINANCING OF NUCLEAR POWER

1. Governments should take steps to ensure the long-term financial integrity and credit-worthiness of their power sectors. As a priority, efforts should be made to establish economically sound tariff structures.

2. Governments of countries that are committed to privatizing and/or deregulating their power sectors should make sure that energy policy objectives, such as environmental protection and energy security, are incorporated in their new policy and market frameworks.

3. Governments should ensure that the full costs of nuclear power programs, including those costs associated with fuel cycle facilities (such as waste and spent fuel disposal, decommissioning, and monitoring) are calculated as part of the costs borne by electricity consumers. Subsidies which may be provided to the industry should be explicitly identified.[136,137,138]

4. In implementing international emission trading programs, credit should be given to nuclear power facilities for their contribution to the reduction in greenhouse gas emissions.

RECOMMENDATIONS ON NUCLEAR R&D

1. Given the rapid increase in global demand for electricity, possible long-term economic and environmental limits on the availability and use of fossil fuels, as well as concern over greenhouse gas emissions, a strong long-term R&D effort will be needed for all energy options, including nuclear power, fossil fuels, renewables and energy efficiency.

2. Governments should take an active lead in these programs, particularly since a major element of such R&D must focus on the issue of nuclear fuel recycle and its implications for weapons non-proliferation. Nuclear power R&D should focus on improving safety, reducing and managing

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136 Joe F. Colvin notes that this recommendation should apply to all power sources.

137 Sam Thompson notes that it is fine for the paper to recommend that governments ensure that the full costs of nuclear power programs are calculated as part of the costs borne by electricity customers. However, the paper should call for this to be done for other power sources as well. More generally, the goal should be for cost calculations for each power source to take into account not only conventional costs, but also external costs, which are largely included in the case of nuclear power. In this connection, an effort needs to be undertaken to calculate such costs for fossil fuels. The text of the paper contains a brief but useful discussion on external costs, but the point about the need to take them into account is not made clearly in the recommendations.

138 Mamoru Sueda notes that some of the facilities in the parenthesis may be inappropriate, particularly in the absence of "reprocessing and related services."

radioactive waste and spent fuel, lowering capital costs as well as developing weapons proliferation resistant technologies.

3. Given the limited R&D funds available, international coordination (under the aegis of the OECD/NEA or IAEA) should be encouraged to ensure minimal duplication. An international advisory board and program could be considered to identify technical options for innovative nuclear power reactors, including those which might be undertaken to burn weapons plutonium.[139]

4. Efforts should be made to ensure that new nuclear plants adopt advanced technology with enhanced safety features. For example, the collaborative U.S./European programs to provide advanced pressurized and boiling water designs should be available to countries considering new capacity.[140]

Recommendations on Nuclear Weapons Non-Proliferation

1. Countries that have signed treaties relating to nuclear weapons non-proliferation should reaffirm their commitments to the nuclear weapons non-proliferation regime, in particular in the area of strengthened safeguards systems, and the security of nuclear materials and facilities.

2. Those countries that have not signed or ratified the various treaties and protocols should give serious thought to the benefits of signing, including the new addendum to the Treaty on the Non-Proliferation of Nuclear Weapons.[141,142]

3. Given increased concerns over nuclear weapons proliferation, nuclear terrorism and theft of nuclear materials, countries should urge international and regional organizations involved in limiting the spread of nuclear weapons to review their activities to determine if they need to undertake additional actions to carry out their missions. The role and funding of the IAEA in weapons non-proliferation work is of crucial importance and deserves the strong financial and political support of member countries.

4. Taking into account the continuing concern about the duality of nuclear technology[143], enterprises involved in electricity generation using nuclear power should continue their commitment to the weapons non-proliferation regime, and increase public awareness of this

139 William J. Dircks notes that R&D cooperation will be difficult because such cooperation would invariably infringe on intellectual property rights of the enterprises involved.

140 Kazuo Shimoda notes that this recommendation should also note Japan-U.S. collaborative programs, as a Japan-U.S. program manufactured two Advanced Boiling Water Reactors (ABWR) units, now in commercial operation, at the Kashiwazaki-Kariwa nuclear power station in Japan.

141 Hans Blix notes that the subject of non-proliferation is examined with a Western bias. It is unrealistic to expect India and Pakistan to sign the NPT. The tests of weapons by these countries certainly raised concerns and was a set-back for non-proliferation, but the subject requires a more nuanced discussion.

142 Victor Murogov suggests that the recommendation should encourage countries that have not signed the various treaties and protocols to give serious thought to the benefit of doing so.

143 Robert H. Socolow notes that duality refers to the "civilian-military duality of nuclear technology."

5. commitment. Theyshould press for approval by their governments of the Additional Protocol resulting from the IAEA's 93+2 program.[144,145]
6. RECOMMENDATIONS ON PUBLIC COMMUNICATIONS

1. The nuclear community (industry and governments alike) should enhance its efforts to improve its image and that of nuclear power by taking up more positive and open positions. The contribution of nuclear technology, ranging from the production of electric power to medical and manufacturing uses, to national and worldwide needs should be clearly spelled out, as should the nuclear community's commitment to weapons non-proliferation.[146]

2. The nuclear community should cooperate more actively with other energy sectors and non-governmental organizations to study global long-term economic growth trends and ways of meeting energy needs through a variety of energy sources and energy efficiency, to assure sustainable levels of energy supply at a reasonable cost.

3. The International Energy Agency (IEA), OECD/NEA and the IAEA should continue to play a role in informing their member countries on the issues central to the use of nuclear power. This includes, for example, preparing reports and studies for dissemination to member country delegations, parliaments, and the general public.

RECOMMENDATION ON GLOBAL CLIMATE CHANGE

In undertaking research on how to meet the world's energy needs while taking into account concerns about climate change, intergovernmental organizations, national governments and private institutions are strongly encouraged to consider the past and future contribution that nuclear power has made and can make as a carbon avoidance generating technology. Institutions must also evaluate the economic, safety and environmental performance of nuclear power and the other generating technologies being considered.

RECOMMENDATIONS ON INTERNATIONAL COOPERATION

International cooperation should be strengthened to increase its effectiveness. More specifically:

1. IAEA key inspection programs in the safety and safeguards area should be strongly supported by member countries and expanded as appropriate. Individual governments should recognize the benefits of positive cooperation and the costs of lack of cooperation, and work constructively with the IAEA. In following through on these recommendations, careful attention should be given to the

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144 For a description of the "Programme 93+2" and the additional protocol, please see Annex 2.

145 Victor Murogov suggests that enterprises and the public should press their governments to support the strengthened IAEA safeguards system and in particular to conclude Protocols Additional to their respective safeguards agreements. A model text of the Additional Protocol was approved by the IAEA Board of Governors in May 1997.

146 Sam Thompson questions the recommendation that the nuclear community take more "positive" positions. Has its message heretofore been negative?

adequate funding of critical activities. The IAEA in turn should take steps to increase the efficiency and effectiveness of its inspection activities.

2. Governments should renew and update discussions within the IEA of the likely role of nuclear power as one of many sources to supply energy services for long-term economic growth.[147]

3. Governments should explore, through existing international organizations related to nuclear power, how regional cooperation in nuclear matters can be structured and improved. Joint projects in areas such as safety standards, or nuclear waste and spent fuel management, should be considered.

4. Should an Asia regional nuclear power association be formed[148], the working group recommends that the association establish a senior committee to evaluate the R&D and nuclear power training needs of Asian countries and develop recommendations on addressing these needs.

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[147] Sam Thompson notes that the paper recommends that governments "renew and update" discussions within the IEA on the likely role of nuclear power. This is misleading. The fact is that, until very recently, the IEA has, for political reasons, ignored nuclear power.

[148] *An Appropriate Role for Nuclear Energy in Asia's Power Sector,* op. cit.

ANNEX I
COMMENTS BY WORKING GROUP MEMBERS

Richard E. Balzhiser

A November article in the *Financial Times Energy Economist* offers, reporting on a statement by Dr. Hans Blix, a number of pertinent questions relevant to the narrow margin of support for nuclear power in Europe:

"*On safety.* Should the [European] parliament not have noted that the world's civilian nuclear power plants have logged over 8,000 years of operation without any other fatal accidents from radiation than those from the Chernobyl case and also without any significant emissions of radioactivity to the environment other than those from Chernobyl?

On sustainability. Should the parliament not have recognized that existing global uranium resources would allow even a much expanded reliance on the currently dominant types of power reactors for a long time? And that the future use of fast reactors would make the world's uranium and thorium resources a practically endless — and sustainable — source of energy?

On energy production. Should not the parliament have noted that reliance on nuclear power has proved to be an economically viable means of reducing Europe's dependence on oil? And that the turning from nuclear to gas would mean renewed increased dependence on outside fuel sources and exposure to the risk of turmoil in several regions of uncertain stability?

On climate change and the Kyoto target to reduce carbon dioxide emissions by 5 percent from 1990 levels by 2008/2010. Should the European Parliament not have noted that in France, which generates some 70 percent to 80 percent of its electricity by nuclear power, the emissions of carbon dioxide per kilowatt hour were about 64 grammes, while in the UK, which relies on an energy mix of coal, gas and a smaller amount of nuclear, the carbon dioxide emission per kilowatt hour was ten times as large? And should it not also have noted that in Sweden, where about half the electricity comes from nuclear and the other half from hydropower, the emission of carbon dioxide per kilowatt hour is 58 grammes, while in Denmark, which relies for the greater part on coal the figure is 917 grammes."

For Europe as a whole, noted Dr. Blix, nuclear power helps to avoid the emission of some 700 million tonnes of carbon dioxide a year.

Juan Eibenschutz

Nuclear power was born from nuclear weapons programs and has lived and will probably continue to do so under a spell, characterized by worries about radiation and proliferation.

This major challenge has not been recognized as shown by the lack of emphasis on the need to judge impartially. Two examples may serve to illustrate this:

Economic assessment of nuclear power considers cost externalities (decommissioning, complete fuel cycle costs, licensing etc.) whereas for other power sources, externalities are not part of cost evaluations.

The listing of international nuclear agreements and the lack of discussion of the fact that for other energy sources (also subject to accidents and the evil use of the technologies involved), there are no such international conventions and safeguards indicates the bias against nuclear.

John P. Ferriter

This document is a welcome contribution to the ongoing debate about nuclear power, both in OECD countries and throughout the world. The broad issues the paper raises, and the recommendations, capture the state of nuclear power today.

There are several areas, however, where the paper could provide, in my view, a more complete perspective or indicate the magnitude of the problems facing nuclear power. In particular:

As an issue of public communication, the difficulties facing nuclear power are understated, particularly environmental problems. This is not simply a matter of "perception," as the paper implies. In many countries, further nuclear power development will be impossible until nuclear power's real drawbacks are discussed and debated openly, so that they be weighed against nuclear power's undeniable strengths and benefits. As the paper points out, nuclear power is one of many potential energy sources, but is not a pre-ordained choice.

The use of nuclear energy is not sustainable over the long-term, using today's technology. That is because today's reactors capture only a small fraction of the energy potentially available from natural uranium. In the long term, breeder reactors must be developed. Yet the economics and feasibility of new nuclear technology cannot be taken for granted.

Governments and industry have failed, to date, to resolve the issue of what to do with high-level wastes. Although there are technical solutions, not a single country using nuclear power today has the plans, facilities, and legal structure in place to show convincingly that wastes can be safely handled for the long-term.

The economic prospects for nuclear power in the near term are poor in most countries. Unfavorable economics are a fundamental reason why nuclear power growth has stopped in all but a few OECD countries with high fossil fuel costs and strong government backing for nuclear power. While this can certainly change over time, it is for the time being a fundamental obstacle to nuclear development.

The worldwide framework to ensure non-proliferation cannot be taken for granted. Not all countries are party to non-proliferation agreements, nor are these agreements infallible.

Having said this, I support the conclusions and recommendations of the report and am pleased to be associated with it as a member of the working group.

Robert E. Newman

I would like to emphasize three important points that I believe are not properly focused in the report.

(1) Non-proliferation discussions are still a little too strong in the context of energy supply. As noted by the *International Nuclear Fuel Cycle Evaluation*, commercial nuclear technologies are already substantially proliferation-resistant by their nature. The emphasis needed to move the peaceful uses of nuclear technology forward should reside in measures that reduce the capital cost of nuclear energy plants;
(2) The "level playing field" idea for comparison of energy alternatives appears to be somewhat

misconstrued. In fact, nuclear is the only energy option where the full costs of the technology are already included in electric rates. To ensure that supply additions are decided based on a valid comparison of costs between alternatives, the full costs of the alternatives should also be included. Examples include the cost of waste disposal, emissions and land use; and,

(3) I would be a little more optimistic about the prospects for nuclear plant life extensions in the United States. The U.S. nuclear industry is aggressively pursuing this option, and the U.S. Nuclear Regulatory Commission is positive on its prospects. The success of such measures is an assumed prerequisite for success in any government initiative to mitigate atmospheric emissions of carbon dioxide and methane from the use of fossil fuels.

Takehiko Sakairi

This comment refers the Atlantic Council's paper *An Appropriate Role for Nuclear Energy in Asia's Power Sector*, which recommended that consideration be given to the formation of a new Asian regional nuclear association.* I would like to emphasize the necessity of the early establishment of such a regional association in Asia, whose main purpose would be to secure the safe and economical operation of nuclear power plants.

There have been proposals for similar Asian regional organizations in the past. However, nothing has been actually implemented to date. I believe this lack of action is because the organizations proposed to date have been suggested by individuals having academic or political backgrounds and are therefore too broad in structure and scope. We must be more realistic. There is a great need for the kind of organization proposed in the text. The early establishment of such an organization is necessary because of the rapid growth of nuclear power in Asia. The regional organizations previously proposed for Asia are little more than "thinking experiments." We should focus on the practical and what can be done.

In my view, we should take quick action and pursue the idea in a realistic manner. The first step could be the establishment of a standing committee to discuss the basic framework of this association. In parallel with that, we may need a temporary secretariat to manage this issue. The proposal of the association is a good beginning, but we should take action soon or nothing may come of it.

Paul Slovic

This report addresses public resistance to nuclear power by recommending programs that are safe, efficient, economical and well regulated along with effective efforts at public communication. However, to be effective and increase public support for nuclear power, these efforts would have to overcome the nuclear stigma that now exists in the United States and in varying degrees in countries around the world.

Selling the ideal of nuclear power to the public is often a difficult and frustrating task. Risk communication tends to present expert opinion about the relative safety the industry provides from radiation and other hazards. Public relations emphasizes the potential advantages and benefits of nuclear technologies. Government agencies conduct major programs to improve and assess the science, engineering and operations of power stations. However, over the past two decades, these efforts have not gained public approval for new nuclear power development in the United States. This condition of public aversion in the United States is clearly a reversal of the public support for nuclear technologies that existed from the 1950s to the 1970s. In addition, there is strong evidence that similar obstacles exist or are developing in other Western countries,

* This comment also appeared in Annex I of *An Appropriate Role for Nuclear Energy in Asia's Power Sector.*

with the distinct possibility that all modern societies at some point of development will recreate this nuclear cul-de-sac.

The social science literature shows that acceptance of nuclear power, if not active endorsement, has resulted from positive judgments about: 1) potential benefits, 2) assured management of the risks, and 3) necessity. Uncertainty, doubts, or adverse judgments about these key areas produce opposition, which when played up by the news media, can result in a technological stigmatization, a phenomenon of the late 20th century.* Stigma forms when the public constructs a deeply felt and widely shared aversion to activities and facilities — in this case, the industrial development of nuclear science and its technologies. The basis for the stigma is the widely-held belief that certain nuclear technologies are wrong, unnatural and even immoral. Nuclear proponents on the other hand, envision nuclear technologies as right, necessary and inevitable because they express deep scientific and human truths.

Should we consider this as a checkmate for nuclear power? Or a draw, whereby existing facilities continue until used up but nothing new is built? Risk communication, at the current time, is not capable of ameliorating the problem. Nor does government, academia, or the industry understand enough about the causes of nuclear stigma to correct the conditions producing the stigma and satisfy public concerns. So far, the response from government has been to provide funding for engineering and technical research and development without any prospect of putting these advances to work at a specific operational site. Industry for its part spends millions annually on advertising, which attempts to convince the public to disregard the stigmatization of nuclear power, but these efforts serve mainly to temporarily shore up the industry's lagging sprits with no appreciable effect on public opinion.

This leads to a new and important conclusion. The science that should be strongly called for in this report, the science most needed for the future of nuclear power, is a social science of understanding nuclear stigma and how it originates within human societies. This is truly basic science. The lack of understanding about nuclear stigma will stand as an overwhelming obstacle to the future of nuclear power for as long as it remains an unknown and potent force in shaping public opinion. We recommend serious support for the study of the social context of nuclear power. Certainly efforts well beyond anything done to date should be pursued.

Klaus B. Stadie

The most damaging outcome of the difficulties which nuclear power faces is not so much the stifled growth of its generating capacity in many OECD countries but rather the decay of a forward-looking development of this immense energy source. In fact, the widespread opposition to the production of electricity by nuclear fission increasingly spoils the prospects of attracting the intellectual and financial resources necessary to ensure further advances in nuclear science and technology.

It is evident that the public will demand further substantial improvements in nuclear safety, in proliferation-resistant fuel cycles and in radioactive waste management as a price for approving a major expansion of this fuel.

In recent years, industry in several countries has begun to develop advanced light water reactors, building on experience with operating plants. These new designs have generally a smaller output and avoid the unnecessary complexity of existing stations. Major safety research regarding severe accidents has succeeded

* Gregory, R., Flynn, J. and Slovic, P. (May/June 1995). "Technological Stigma." *American Scientist* pp. 220-224.

in lowering their probability, but has also demonstrated the limits of improvability of light water reactors to cope with these challenges. Moreover, their fuel cycles require an impervious safeguards system.

With the insights which have been gained in nuclear technology over the past four decades, novel power reactors and fuel cycles are now within the realm of possibility that totally eliminate reactor accidents with off-site consequences [which are universally feared], inherently prevent the risk of proliferation and largely, if not entirely, transmute long-lived radioactive fission products and thus greatly reduce repository requirements. These innovative concepts are untried, yet the vast promise of such a benign technology compels humankind to continue strong support of nuclear R&D in order to take full advantage of this environmentally attractive and huge resource.

While the nuclear industry is preoccupied with protecting its investment, governments must take the lead in underwriting the long-term progress of nuclear power. International pooling of talents and economic resources would be the most efficient way to attain this goal.

Helga Steeg

With reference to Chapter IV, section C, I would like to point out that the past systems of government regulations have realized achievements. However, electricity companies have enjoyed large monopoly rents in many countries. Some of which were used for cross-subsidization for non-energy objectives (eg. schools, bipartisan political projects), which veiled the real electricity costs for the electricity consumer. Furthermore, if long-term supply strategies are the responsibility of the utilities, it is in the first instance their role to stand the market test, including security of supply. But governments should monitor the long-term supply strategies and intervene if deficits are being recognized.

Mamoru Sueda

I would long for the time to come soon when everybody would readily accept the state-of-the-art uranium/plutonium nuclear fuel cycle as an indispensable approach toward sustainable, environmentally-benign, and resource-saving energy, as many of our pioneers determined and opened the way some decades ago. What is basically important in this U/Pu fuel cycle concept is to recognize that "spent fuel" is never worn-out (and therefore useless) fuel remnant, but is a sort of mine containing (and therefore usable) uranium and plutonium, and this recognition leads me to question the U.S. concept to consider "spent fuel" with "waste disposal" in the same category.

ANNEX II
INTERNATIONAL NUCLEAR AGREEMENTS

Agreements on Accidents, Safety, Transportation and Waste for Nuclear and Radioactive Material in Civilian Use

Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management

Opened for signing September 1997, this convention sets out an international framework for cooperation in the safe management of spent fuel and radioactive waste to prevent an accident and mitigate the effects should one take place. The convention focuses on removing residual heat generated during spent fuel management, minimizing waste generation, the interdependencies among the steps in spent fuel management, effective protection and defense against potential accidents, and taking into account biological and chemical hazards associated with spent fuel management. The convention sets minimal standards in siting, design and construction, safety facilities, operation and closure procedures of all existing and proposed spent fuel management and radioactive waste storage facility. The convention also calls for the establishment of national regulatory agencies to monitor the facilities and report to the IAEA on facility activities. As of June 1998 the convention has 33 signatories. The United States has signed but not ratified the convention.

Convention on Nuclear Safety

Entered into force October 1996, this convention requires states operating land-based nuclear power facilities to maintain a high level of safety by subscribing to IAEA safety fundamentals in facility siting, design, construction, operation, availability of adequate financial and human resources, assessment and verification of safety, quality assurance and emergency preparedness. The convention requires regular meetings and "peer review" of safety reports by all parties. There are no sanctions for failure to maintain safety standards; the treaty is based on the mutual interest of all parties to maintain the highest standards possible. As of May 1998, the convention has 46 parties. The United States has signed but not ratified the convention.

Code of Practice on the International Transboundary Movement of Radioactive Waste

Passed by resolution at the General Conference of the IAEA in September 1990, this code calls for the use of international standards for the safe transport and physical protection of nuclear material and radioactive waste. It affirms the right of any state to prohibit the movement of radioactive waste through its territory and calls for movement to take place only after consent has be granted and the receiving country has the appropriate administrative and technical capacity. The code calls for international cooperation to enforce accepted practices and the use of the IAEA as a clearinghouse to disseminate appropriate information.

Convention on Assistance in the Case of Nuclear Accident or Radiological Emergency

Entered into force February 1987 in response to the Chernobyl accident, this convention sets out an international framework for cooperation in the event of a nuclear accident or radiological emergency. States must notify the IAEA of available experts, equipment and materials. The IAEA serves as a clearinghouse; channeling information, supporting efforts and providing services. As of March 1998, the convention has 75 parties, including the United States.

Convention on the Physical Protection of Nuclear Material

Entered into force February 1987, this convention requires states to take actions to protect nuclear material transported through their territory or on board their ships or aircraft. The convention also sets up an international framework for cooperation in protection, recovery and return of stolen nuclear material and the application of sanctions against those who commit criminal acts involving nuclear material. The convention was unanimously supported at an October 1992 review conference. As of March 1998, the convention has 60 parties, including the United States.

Convention on Early Notification of a Nuclear Accident

Entered into force October 1986 in response to the Chernobyl accident this convention requires notification of any nuclear accident with a significant transboundary release of radiation. States must report the accident's time, location, radiation release(s) and other data essential to assessing the situation. Reporting may be done either through the IAEA or to the affected state(s) directly. All five nuclear weapons powers have declared that they will report accidents involving nuclear weapons or nuclear weapons tests. As of March 1998, the convention has 80 parties including the United States.

Convention on the Prevention of Marine Pollution by Dumping of Waste and Other Matter – "London Convention"

Entered into force August 1975, this convention prohibits the dumping of certain wastes, including radioactive wastes, and requires permission to dump other wastes in the sea. States must enact and enforce laws to punish polluters and work together, particularly in regional arrangements, to prevent pollution of the seas. The treaty charges the International Maritime Organization to train scientific and technical personnel, supply necessary equipment and facilities for research and monitoring, and assist states disposal and treatment of wastes that might otherwise be dumped. A 1995 protocol called for states not only to prevent pollution but to work to clean up previously dumped waste. The protocol calls for the enactment of the "polluter pays principal" and "reverse listing" that outlaws all dumping except those wastes clearly specified. The definition of sea was expanded to include the sea-bed and sub-soil. As of June 1998, the treaty has 80 parties, including the United States.

Agreements on Civil Liability for Nuclear Damage

Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage

Adopted September 1997, this protocol amends the Vienna Convention by broadening the definition of nuclear damage to include economic loss, environmental damage and preventive measures. Liability is broadened to included accidents that occur during transport. The minimum compensation is raised to 300 million SDR. The time that action can be brought is extended to thirty years for cases involving loss of life or personal injury.

Convention on Supplementary Compensation for Nuclear Damage

Opened for signing September 1997 as part of the measures taken to strengthen the Vienna Convention, this convention sets out a formula to make available public funds for compensation for nuclear damage. According to the convention the amount of funds available will be determined by the nuclear capacity of the state multiplied by 300 million SDR (US $416 million) per unit of installed capacity and the ratio between the party's United Nations rate of assessment and the total assessment of all parties up to 10 percent of the total nuclear capacity of all the parties multiplied by 300 million SDR. These funds will be available for all nuclear damage that is suffered in the territory of the party, on board ships or aircraft of the party, in international air or water, or in or above the exclusive economic zone of a party.

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oint Protocol Relating to the Application of the Vienna Convention and the Paris Convention

Entered into force April 1992, this convention brings the conventions of the OECD (Paris) and the IAEA (Vienna) into collaborative force. The protocol does not combine the two earlier conventions and subtle differences remain, however, the geographic area covered under the Paris and Vienna conventions is essentially combined. The protocol states that in the case of a nuclear incident the original convention to which party is contracted will apply. As of December 1996 the convention has 20 parties.

Vienna Convention on Civil Liability for Nuclear Damage

Entered into force November 1977, this convention sets out the international framework for civil action for damage caused by a nuclear accident. The convention states that absolute liability for loss of life, injury or loss or damage of property rests with the operators of nuclear facilities and nuclear material coming from or entering those facilities. Operator liability is set at a minimum of U.S. $5 million for a single accident and operators must carry insurance to cover the liability. Action against operators must be brought within ten years of the accident. Jurisdiction lies exclusively with the courts of the party to the convention where the accident happened and the courts must insure that that compensation is applied equally and without discrimination. As of March 1998 the convention has 28 parties. The United States has not signed the convention.

Convention on Third Part Liability in the Field of Nuclear Energy – "Paris Convention"

Adopted in 1960 and entered into force April 1968 this convention sets out the OECD framework for civil action for damage caused by a nuclear accident. The convention states that absolute liability for loss of life and property rests with the operators of nuclear facilities and nuclear material coming from or entering those facilities. Operator liability is set at a maximum of 15 million SDR (US $21 million) for a single accident and 5 million SDR (US $7 million) for damage to the means of transport where nuclear material was involved. Operators must carry insurance to cover the liability. Action against operators must be brought within ten years of the accident. Jurisdiction lies exclusively with the courts of the country where the accident happened and the courts must insure that that compensation is applied equally and without discrimination. The convention was amended by protocol in January 1964 and November 1982.

Convention of January 1963 Supplementary to the Paris Convention – "Brussels Convention"

Adopted in 1963 and entered into force as supplementary to the Paris Convention April 1968, this convention amends the amount of compensation that can be awarded for nuclear damage to 300 million SDR (U.S. $416 million). The 300 million SDR is to be divided up with the facility operator liable for a minimum of 5 million SDR (to be paid through required insurance), the difference up to 175 million SDR (US $243 million) to be paid for by public funds of the country party to the convention where the accident occurred, and between 175 and 300 million SDR to be paid out of a common fund from all parties. The convention establishes the formula for that common fund with each party contributing 50 percent of dues from the ratio of its GNP out of all the parties' GNP, and 50 percent from the ratio of its nuclear facilities out of all the parties' nuclear facilities.

Agreements on Nuclear Weapons Proliferation and Geographic Nuclear Free Zones

Treaty on the Non-Proliferation of Nuclear Weapons (NPT)

Entered into force March 1970, this treaty outlaws the transfer of nuclear weapons from any of the five declared nuclear power parties (China, France, Russia, the United Kingdom, and the United States) to any non-nuclear weapons party. Each non-nuclear weapons party must submit its nuclear facilities to IAEA safeguards inspections for verification. The treaty encourages the free and nondiscriminatory flow of information and technology for peaceful uses of nuclear power. The treaty also states that nuclear weapons parties must negotiate in good faith to reduce the number of nuclear weapons. The treaty was extended indefinitely at the Review Conference in 1995. As of June 1997, the treaty has 185 parties.

IAEA Programme "93+2" and the Additional Protocol

The Programme 93+2 was initiated by the IAEA in 1993 as a consequence of the 1991 discovery that Iraq, an NPT signatory, had been clandestinely pursuing a nuclear weapons program by using "undeclared" facilities, not covered by existing safeguards. The programme began with the development and testing of methods for analysis and monitoring, which were then incorporated into a model protocol. The model "Additional Protocol" was approved by the board of governors of the IAEA in May 1997. The protocol is designed to address some of the perceived weaknesses in the previous safeguards agreement. Under the new protocol, states must submit a broader base of information concerning nuclear-related activities, and upon request, grant inspectors access to other facilities, including "undeclared" facilities. Inspectors will begin using environmental sampling to determine the presence of nuclear materials, and will engage in "short-notice" inspections. The five nuclear-weapons states (the United States, United Kingdom, China, France and Russia) are not required to accept IAEA safeguards on their nuclear activities, but have all announced their intention to apply some of the new safeguards to their commercial nuclear facilities.

Treaty for the Prohibition of Nuclear Weapons in Latin America – "Tlatelolco Treaty"

Entered into force February 1967, this treaty outlaws the testing, use, manufacture, production or acquisition of nuclear weapons by the parties in the Latin America Nuclear Weapons Free Zone. The treaty does not prohibit the use of nuclear facilities for peaceful purposes or the testing of nuclear devices not directly related to military use. The treaty establishes the Agency for the Prohibition of Nuclear Weapons in Latin America and charges it with administering a control system to verify compliance and, when necessary, conducting special inspections in cooperation with the IAEA. Additionally, parties must provide semi-annual reports to the agency on their nuclear activities. Eligibility is limited to parties in the southwestern hemisphere who have negotiated safeguards agreements with the IAEA. As of February 1997, the treaty has 32 parties.

South Pacific Nuclear Free Zone Treaty – "Rarotonga Treaty"

Entered into force December 1986, this treaty outlaws the manufacturing, possession or control of a nuclear explosive device by parties in the South Pacific Nuclear Free Zone. It also outlaws parties from assisting states with civilian nuclear facilities outside the zone unless they conform to IAEA safeguards. Additionally, stationing, testing or dumping by an outside source is prohibited and the framework for monitoring is established. Parties to the treaty are the 13 members of the South Pacific Bureau for Economic Cooperation and SPEC is responsible for administering the treaty.

Treaty on the Southeast Asia Nuclear Weapon Free Zone – "Bangkok Treaty"

Entered into force December 1995, this treaty outlaws the development, manufacture, acquisition, stationing, dumping, or testing of nuclear weapons, devices or waste materials. The treaty does not prohibit the use of nuclear facilities for peaceful purposes. The treaty establishes the Commission for Southeast Asian Nuclear Weapon Free Zone and charges it with overseeing implementation and administering a control system to verify compliance. Parties to the treaty are states in southeast Asia including Brunei Darussalam, Indonesia, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Vietnam who have previously concluded safeguards agreements with the IAEA.

Treaty on the Nuclear Weapon Free Zone in Africa – "Pelindaba Treaty"

Opened for signing April 1996 this treaty outlaws the research, development, manufacture, stockpiling, stationing or testing of any nuclear explosive device and requires parties to dismantle and destroy any devices they may previously have possessed. The treaty does not prohibit the use of nuclear facilities for peaceful purposes. The treaty establishes the Africa Commission on Nuclear Energy to work with the IAEA to verify compliance, collect reports and exchange information, encourage cooperation on nuclear issues, and promote the peaceful use of nuclear technology. Parties are required to submit annual reports on nuclear activities to the agency. Parties to the treaty are states on the continent of Africa and/or members of the Organization of African Unity.

Agreements on Nuclear Weapons Testing

Treaty on Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and under Water – "Partial Test Ban Treaty"

Entered into force October 1963, this treaty prohibits the testing of nuclear devices in the atmosphere, outer space or under water. Tests may not be conducted in an area or in a way that causes radioactive debris to enter another state. The United States, the United Kingdom, and Russia (Soviet Union) are the original parties to the treaty. As of June 1998, the treaty has 94 parties.

Comprehensive Nuclear Test Ban Treaty

Opened for signature September 1996, this treaty prohibits the testing of any nuclear weapons or other test nuclear explosions. The treaty establishes the Comprehensive Test Ban Treaty Organization (CTBTO) charged with ensuring implementation and providing a forum for consultation and inspection. To verify compliance the CTBTO administers the International Monitoring System to detect and identify prohibited nuclear explosions, the International Data Center to process and disseminate information on nuclear activity, and conducts, when requested by individual states, on-site inspections. As of June 1998, the treaty has 149 signatures and will enter into force upon ratification by the 44 states of the Conference on Disarmament that have either nuclear research or power reactors. The United States, one of the 44 states, has signed but not ratified the treaty.

ANNEX III
INTERNATIONAL AND REGIONAL NUCLEAR ENERGY INSTITUTIONS

These organizations are responsible for the regulation, cooperation, and future development of the global nuclear industry. They are concerned not only with safety, but also with the development of advanced technologies and standards.*

International Atomic Energy Agency (IAEA)

The IAEA serves as the world's central intergovernmental forum for scientific and technical cooperation in the nuclear field, and as the international inspectorate for the application of nuclear safeguards and verification measures covering civilian nuclear programs. A specialized agency within the United Nations system, the IAEA came into being in 1957 as a result of President Eisenhower's Atoms for Peace speech to the United Nations. Its objective is to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world. It shall ensure, so far as it is able, that assistance it provides is not used to further any military purpose.

The functions of the IAEA include, inter alia (i) encouragement and assistance of research; (ii) fostering the exchange of information; (iii) training of scientists and experts; (iv) establishing standards of safety and providing for their application.

The Institute of Nuclear Power Operations (INPO)

INPO was founded by U.S. nuclear utilities in response to the Three Mile Island nuclear incident. The main objective of INPO is to promote safety, reliability and plant excellence within nuclear plant facilities. In order to achieve this, INPO established a comprehensive system of training and qualification of utility personnel. Additionally, in 1985, INPO created the National Academy for Nuclear Training to focus and unify industry efforts on a nationwide basis to continue improvements in training and to promote professionalism of nuclear plant personnel. The organization performs periodic operational safety evaluations of all nuclear power plants in the United States and is active in international issues of nuclear safety.

International Nuclear Regulators Association (INRA)

Established in May 1997, INRA is an organization comprised of the senior nuclear regulatory officials from eight countries (Canada, France, Germany, Japan, Spain, Sweden, the United Kingdom and the United States). INRA's goals are to establish a forum for the most senior regulatory officials to exchange views on broad regulatory policy issues; build a global nuclear safety culture; encourage the most efficient use of resources in areas of common interest; enhance the stature of nuclear regulatory organizations worldwide; seek consensus on how regulatory issues may be approached and implemented; facilitate international cooperation in regulation; work to advance safety through cooperation with its members, relevant international organizations (such as the IAEA or OECD/NEA), and other regulatory bodies as appropriate; and identify emerging nuclear regulatory challenges.

International Nuclear Safety Advisory Group (INSAG)

INSAG is an advisory group to the Director General of the IAEA in the fields of nuclear safety, radiation safety and safety of radioactive waste. One of its functions is to recommend the underlying principles upon which safety standards and measures can be based. It is also a forum for exchange of information on generic safety and it advises on appropriate action.

* This is not a comprehensive list of institutions involved in the global nuclear power sector.

Nuclear Energy Agency (NEA)

A semi-autonomous body within the OECD, the NEA's mission is to contribute to the development of nuclear energy as a safe, environmentally acceptable, and economical source of energy through cooperation among its 27 participating countries in Europe, America, and Australia.

Tasks of the NEA include: keeping an adequate nuclear safety research capability in member countries; coordinating international nuclear emergency exercises; arranging international "peer reviews" of national waste management programs; supplying nuclear data and computer programs for use in member countries; contributing to the modernization of the international nuclear liability regime; and publishing statistics and projections on nuclear energy. These publications include an annual OECD report containing nuclear energy data, as well as proceedings of seminars such as the 1995 Waste Management Seminar in Finland, evaluations of technical topics, and updates on legal and regulatory frameworks. In addition, the NEA has several semi-autonomous joint projects such as the International Cooperative Decommissioning program.

Nuclear Suppliers Group (NSG)

The Nuclear Suppliers Group was established in 1975 and issued in 1978 a set of recommendations (known as the "London Guidelines") revised most recently in 1995. Signatories commit themselves to apply restraints and to exercise responsible judgment when exporting sensitive materials, technologies and equipments, or dual use items. In particular, conditions have to be fulfilled by the recipient state with regard to IAEA's full scope safeguards, physical protection level on nuclear material, and re-transfer to third countries by the recipient state.

Pacific Nuclear Council (PNC)

The Pacific Nuclear Council is composed of nuclear societies in the nations around the Pacific Rim. The objective of the Council is promotion and cooperation among member organizations in the sharing of peaceful uses of nuclear science and technology, more specifically through the identification and consideration of nuclear-related topics of mutual interest in the Pacific Basin. The principal present function of the Council is to locate and organize the series of biennial Pacific Basin Nuclear Conferences. In addition, the Council has working groups and task forces for the exchange of information on such subjects as waste management, training, standards, public information programs, and safety.

World Association of Nuclear Operators (WANO)

Chartered in 1989 in response to the Chernobyl accident and modeled after the U.S. Institute of Nuclear Power Operations, this international organization works to enhance safety and performance in nuclear power plants through discussion on operator training and information dissemination. Four regional centers in Atlanta, Moscow, Paris, and Tokyo carry out WANO's tasks of facilitating information exchange, providing members with early notification and analysis of significant events, compiling worldwide plant data, and working closely with other international organizations. Other programs, such as international exchange visits and voluntary peer reviews have been very successful in their efforts to foster communication among plants and enhance nuclear plant safety.

Zangger Committee

The Zangger Committee was founded in 1971 to interpret the Treaty on the Non-Proliferation of Nuclear Weapons requirements for safeguards on exports of nuclear equipment and materials. The Zangger Group has compiled a trigger list, known as the Zangger List, of specific nuclear equipment and materials which must be safeguarded for export. The group is composed of major nuclear suppliers who are also NPT signatories. As of 1997, 35 countries have voluntarily committed to not export trigger list items.

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