THE JAMES A. BAKER III
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NEW ENERGY TECHNOLOGIES:

A POLICY FRAMEWORK FOR MICRO-NUCLEAR TECHNOLOGY

DEVELOPMENT STRATEGY FOR SMALL INNOVATIVE REACTORS (SIR) AND ENERGY SECURITY

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Background and Objective

The global nuclear power industry is at a decisive turning point. Nuclear power's competitiveness is under increased pressure from the international trend toward power market liberalization, and its expansion of the market is facing more obstacles than anticipated -- even in Asia, where the growth has been expected -- because of the difficulty in attaining social consensus. Under these circumstances, new initiatives in nuclear technology – in particular, the development of innovative technologies -- are beginning to attract wider attention. Of these new technologies, small innovative reactor (SIR) designs are proving to be the most intriguing, especially when considering environmental conservation and long-term energy security.

Could these initiatives really play a decisive role in resuscitating nuclear power generation in the long run? Or, could competitiveness continue to be maintained in the future with the employment of advanced reactors based on existing technology? What are the obstacles that have to be surmounted in developing these innovative technologies? The objective of this paper is to analyze the international trend of SIR development, demonstrate its significance for energy security in Japan and in Asia, and thereby contribute to the strategies for future nuclear development.

Global Trend of the Nuclear Power Market and International Reorganization of the Nuclear Industry

Changes in Circumstances Surrounding Nuclear Power: Electric Power Liberalization and Consensus Formation

The world nuclear power market is grappling with two strong adverse currents. One is the liberalization of the electric power market and the other is the ongoing difficulty in gaining social consensus for the continued use of nuclear power as well as its expanded use.

Liberalization of the electric power market is a global trend seen not only in the mature societies of Europe and the United States but also in rapidly growing semi-developed industrial nations such as Chile, Argentina, South Korea, Thailand and the Philippines, where it is advancing through privatization of government-run energy corporations. Because of this trend, nuclear power has struggled to vie successfully for share in a competitive market.

In the United States, where there have been no new orders for the construction of nuclear power plants since 1979, the Department of Energy (DOE) and investors predicted that the economic viability of existing nuclear plants would be uncertain. The outlook was so poor that utilities operating nuclear power plants received low debenture ratings.

Meanwhile, in the United Kingdom, controversy broke out over how nuclear power plants should be treated in the course of privatizing the state-run Central Electricity Generating Board (CEGB). Outdated gas reactors that were categorized as poor for their rate of operation and economic efficiencies were taken over by British Nuclear Fuels Ltd. (BNFL), a state-run fuel cycle company, and only the advanced gas reactors and light water reactors – which were expected to be economically viable -- were transferred to the privately-owned British Energy plc. During that process, however, the cost of nuclear power generation had to be publicly disclosed, which unfortunately demonstrated that the economic efficiencies of nuclear power plants were not as high as had been previously claimed by CEGB. As a result, British Energy announced it would not construct any new nuclear power plants for some time. Given these circumstances, priority was given to improving the economic efficiencies of the existing nuclear power plants immediately, while the likelihood of issuing new construction orders was deemed extremely low.

A key problem facing the industry has been its difficulty in gaining social acceptance for the continued use of nuclear power. Here the most serious issue is how to control and dispose of radioactive wastes and spent fuels. A typical example can be seen in the U.S. in the state of California, where there is a law not to approve any new construction of nuclear power plants unless this problem is solved. Transportation of spent fuel also faces great opposition, reflecting a global issue that may threaten efforts to secure the capacity to stock spent fuels and continue the operation of existing facilities.

Another problem in winning social acceptance is the difficulty of assuring plant safety and the resulting loss of confidence in the nuclear power system. In Japan, since the December 1995 accident at the Monju fast breeder reactor, accidents have occurred one after another, including the criticality accident at JOC in Tokai Village in September 1999 and an incident involving the fabrication of MOX fuel processing data by the BNFL, that have helped magnify distrust in the country's nuclear power safety and development system. This chain of accidents and the growing distrust in Japan regarding the safe use of nuclear energy are believed to have led to the "inhabitants' vote on pluthermal," which took place at the Kariwa Village of Niigata Prefecture in May 2001 and which resulted in the town's rejection of using MOX fuel at a nearby power plant.

Reorganization of the Industry and Improvement in the Economic Efficiency

The 1990's could be perceived as the period of reorganization within the international nuclear industry. The end of the Cold War brought about a substantial alteration in the positioning of the nuclear industry, which had been built up as the strategic industry for electric power generation based on the national policies of leading countries. As the strategic impetus for a nationally controlled nuclear industry seemed to fade and profitability dropped, the nuclear industry entered an era of extensive international reorganization from the onset of the 1990's. Following the globalization of energy market, mergers and acquisitions crossed national lines, creating multinational corporations.

At the end of 1999, the U.K.'s BNFL announced its acquisition of Westinghouse (WH) of the U.S., and immediately followed that with its take-over of the nuclear division of ABB of Switzerland. As ABB had already merged with Combustion and Engineering (C&E) of the U.S., this left General Electric (GE) as the only U.S. manufacturer of nuclear reactors. Before this merger, the nuclear divisions of the French government-owned Framatome and the German corporation, Siemens, had also announced their integration, resulting in an alliance of long-standing European rivals. This trend of reorganization has also permeated Asia as reflected in a report in March 2000 that the shares of Korea Heavy Industries and Construction Co., Ltd. (KHIC), which were owned by GE, were proposed to be sold to BNFL. GE had already established a joint corporation venture for the nuclear fuel-processing sector with Hitachi/Toshiba.

Among the developed countries, Canada (Atomic Energy of Canada Ltd.) and Japan (Toshiba, Hitachi and Mitsubishi Heavy Industries) are the only ones that maintain the same supply system from the same companies that existed in the initial days of nuclear power development. On the other hand, European and American nuclear reactor manufacturers, which numbered more than 10 in the 1970's, have been reorganized into just four companies.

The nuclear power supply industry is finally stepping into the era of large-scale reorganization and multi-national corporations.

In the United States, large-scale reorganization has also taken place among the utilities. While in the early 1990's there were more than 40 medium and small-scale utilities that owned and operated nuclear power plants, mergers and acquisitions have reduced their numbers to about 15.

While some nuclear power plants were closed early[1], a surprisingly better rate of operation and economic efficiency have been attained because of changes in the market environment. The U. S. represents the most outstanding example: the rate of nuclear plant operations was 56.6% in 1980, rising to 86.6% in 1999 and even further to almost 90% in 2000. As a result, the average power generation cost has been reduced to the level of less than 2 cents/kilowatt-hour (kWh); a demonstration that nuclear power plants can well compete with new coal and natural gas combined cycle power plants. As a reflection of this growing trend, many American nuclear power plants started to apply for permit extensions, with the first approval granted by Nuclear Regulatory Commission (NRC) to Calvert Cliffs nuclear power plant.

Expectations for New Technologies

In the new era of multinational corporations in the nuclear world, technology development strategies for next-generation nuclear reactors also reflect a multinational approach. While technology development for short-term needs appears focused on existing nuclear reactors and the problem of wastes replacement, particularly in developed countries, the competition of technology development for next-generation nuclear reactors is aimed at the markets of developing nations, where emerging power needs are being positioned as the targets of corporate strategy.

The report of the President's Committee of Advisors on Science and Technology on energy research and development, titled "Federal Energy Research and Development on Energy for

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[1] In 1999, it was decided to close Millstone-1 at the Maine Yankee Nuclear power plant before the expiration of the approved term.

the Challenges of the Twenty-First Century,"[2] released in 1997, laid the groundwork for future nuclear technology development in the United States. It recommended technology development to secure nuclear power as one of the future options. The Nuclear Energy Technology Research and Development Initiative [NERI] led to a federal budget increase for research and development and the 4th-generation nuclear technology development project.

Economic efficiency, safety, disposal of wastes (reduction in burden on the environment), and public resistance against nuclear proliferation were enumerated in the report as the conditions to be satisfied by the next-generation reactors. Among the new concepts to satisfy such conditions, SIRs are attracting attention. A small reactor is not necessarily new in terms of the history of nuclear power. SIRs offer two key advantages:

1. Module type: Minimization of the initial investment and possibility of cost reduction by mass production and production at factories.

2. Inherent safety: An emergency refrigeration device is not required due to the type of fuel used and the property of a small reactor, while its operation is made easier.

Of the various SIR concepts, the one being examined most closely is the "Pebble Bed Type Module High Temperature Gas Reactor," which has attracted attention since the 1980's. Preparation for ordering these module-type high temperature reactors is already advancing in South Africa.

The focus of the nuclear power industry in recent years has been the task of extending the life of existing reactors in the newly liberalized electricity market. Developing SIRs offers an alternative trend that could reactivate the languishing nuclear power industry.

The Development Trend for Advanced Reactors in Japan and its Tasks

History and Tasks of Nuclear Research and Development in Japan

[2] Report of the Energy Research and Development Panel, The President's Committee of Advisors on Science and Technology, "Federal Energy Research and Development for the Challenges of the Twenty-First Century," November 1997.

Efforts have been underway for more than 30 years in Japan for nuclear research and development targeted mainly at the commercialization of a fast breeder reactor (FBR) that exists in other overseas countries. "Power Reactor and Nuclear Fuel Development Corporation" (PNC), which was established in 1967 as a special corporation, is the nucleus for promoting such R&D with an important mission to develop the FBR and the plutonium fuel cycle that will be required for this type of reactor. Following the establishment of PNC, the nuclear R&D budget of Japan was rapidly increased in the 1980's, reaching a scale comparable to those of other countries. This budget increase was reflected in the commencement of the operation of an experimental reactor, "Joyo" (1977), and the Tokai reprocessing plant and fuel fabrication facilities (1980's).

In 1977, the nuclear non-proliferation policy of U.S. President Jimmy Carter was announced, delaying Japan's planned start-up of the Tokai reprocessing plant. After a protracted negotiation between the Japanese and U. S. governments, the operation of the Tokai plant was ultimately agreed upon, allowing plutonium utilization to advance under the amended Agreement for Cooperation between the Government of the United States of America and the Government of Japan concerning Peaceful Use of Nuclear Energy of 1988.

In the meantime, the Clinch River prototype reactor was canceled in the U.S., while in Germany a similar prototype reactor, SNR-300, was also canceled due to an approval problem involving the start-up of the plant's operation. In France, although the construction of the FBR demonstration reactor, Super-Phoenix, was completed, its operation was eventually halted due to repeated technical troubles. In the early 1990's, most governments decided to suspend the operation of prototype reactors, citing poor economic returns.

Broadly speaking, there are compelling reasons for the arrested development of the FBR. The first reason is that the economic feasibility of plutonium utilization came into question. Development of the FBR was positioned on the assumption that there would not be enough uranium to satisfy demand from the rapid development of nuclear energy. But expansion of nuclear power occurred at a slower pace than expected, resulting in a considerable oversupply of uranium resources. Uranium prices are not expected to recover for some time. In addition, reprocessing involving the recovery of plutonium turned out to be more expensive and the fabrication cost of plutonium fuel higher than expected, reducing the justification for a plutonium economy.

Plutonium supplies also moved into excess supply, following the end of the Cold War. The agreement to reduce the number of nuclear weapons created a security problem regarding the disposal of plutonium from dismantled nuclear weapons. It was internationally accepted that it was necessary to maintain a proper management of plutonium stock, whether it may be from dismantled weapons or civilian use, and efforts began to find ways to reduce the existing stock as soon as possible. These new circumstances eliminated the need to breed plutonium, calling into question the development of fast breeder reactors that burn plutonium.

Characteristics of the new long-term nuclear energy plan

With this background in mind, the Atomic Energy Commission of Japan released the report, "Long-Term Program for Research, Development and Utilization of Nuclear Energy," in November 2000, the first of its kind in six years. The future of nuclear R&D and the significance of the FBR and the resulting nuclear fuel cycle are stated therein as follows:

> "… Given the conditions of geography and resources, in which our country is placed, it is appropriate to establish the basic policy of reprocessing spent fuel and making good use of the recovered plutonium, uranium, etc., securing the safety and assurance of nuclear nonproliferation, while taking the economic efficiency into consideration. Furthermore, it is important for the fast breeder reactor and related nuclear fuel cycle technology (hereinafter called "fast breeder reactor cycle technology") to be able to improve uranium utilization efficiency drastically…(omitted)…and to be developed with a steady effort <u>with a view to securing one of the valid options as the energy for the future</u> in anticipation of unpredictable conditions in the future."[3] (Underlined by the writer)

While these sentences underscore the validity of the FBR and nuclear fuel cycle development -- which had formed the basis of Japan's nuclear energy policy in the past -- it also represented a shift to position FBR simply as one of the "options." This change was based on the recommendations posed by the Special Committee on Fast Breeder Reactors (the first

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[3] Atomic Energy Commission, "Long-Term Plan for Nuclear Research, Development and Utilization, November 24, 2000. http://aec.jst.go.jp/jicst/NC/nc_tyokif.htm.

unofficial consultative conference set up by the Atomic Energy Commission that also included non-experts). This recommendation attracted significant attention. The FBR / nuclear fuel cycle was no longer positioned as primary, but rather as one of many promising future sources of energy, suggesting that its development program might be reviewed in context of economic efficiency or the external circumstances surrounding energy in the future.[4]

In the discussion of the long-term plan, six sectional committees were organized, incorporating the participation of a number of non-experts. Sectional Committee No. 3 was the main arena for the discussion of the merits of the FBR and nuclear fuel cycle, leading to the following conclusions on how to proceed with R&D hereafter:[5]

> "First, it is important to have flexibility for development, in other words, range of options for development. Overseas, for example in France, they are conducting R&D, based on the experiences from the prototype reactor, "Phoenix" and demonstration reactor, "Super-Phoenix", and considering at present the gas cooled reactor as one of the options… (omission) …Also in Russia… (omission) …the lead cooled reactor is developed. In the "Nuclear Energy Research Initiative (NERI)" promoted by the United States since last year, nuclear nonproliferation type nuclear fuel cycle is aimed at, and study has been initiated, considering as an option technology development of medium and small reactors for developing countries, although they are not breeder reactors. In such a way, each country is proceeding with the development of technological options for the future, based on the achievements of the past R&D of that country and keeping the range of options as wide as possible, from which it is thought to be appropriate to adopt the similar concept also in Japan." (underlined by the writer)

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[4] Atomic Energy Commission, Report of the Round-Table Conference on Fast Breeder Reactor, December 1997. The report presents a recommendation, "It is reasonable to proceed with its R&D with a view to pursuing the possibility to commercialize a fast breeder reactor as one of the valid options for the future non-fossil energy sources."

[5] Report of Subcommittee No. 3 of Atomic Energy Commission's Conference to Formulate the Long-Term Plan, "What the R&D for Fast Breeder Reactor and Related Nuclear Fuel Cycle Should be Like and How Should it be Conducted in the Future – Aiming at Securing Technological Option –", May 31, 2000. http://aec.jst.go.jp/jicst/NC/nc-tyokif.htm

The objective of this sectional committee's report was to suggest a departure from the rigid R&D policy of the past, in the hopes of bringing about a significant change in future nuclear energy R&D. However, only the range of technology development in the area of FBR and nuclear fuel cycle was emphasized in the committee's report, without referring to other types of reactors.

In regard to consideration of innovative reactors other than the FBR, the following comment was included in a follow-up report, "Diverse Development of Nuclear Science Technology":

> "(Innovative Reactor) As we look into the 21st century, we have expectations for not only the next-generation light water reactor but also an innovative nuclear reactor of high economic efficiency and safety, suited for the diversified energy supply such as heat utilization and propagation of reactor use. For this purpose, <u>it is necessary</u> for the state, industry and universities to cooperate in <u>studying R&D for innovative nuclear reactors, taking into consideration use of diverse ideas, regardless of reactor's size and formula</u>." (underlined by the writer)

While Japan has maintained an inflexible R&D policy centering on FBR, the concept suggested in the above excerpt demonstrates the first step taken toward the policy of a more diversified R&D. (Note: Although a heavy water moderated/light water gas-cooled reactor, called Advanced Thermal Reactor (ATR), had been under development as an "intermediate reactor" in Japan, the demonstration reactor was canceled as had been the prototype reactor "Fugen.")

Task of Preparing for the Introduction of Innovative Reactors in Japan

There are still many problems that need to be addressed before a new approach to Japan's nuclear energy R&D can be pursued. FBR and nuclear fuel cycle continue to play the pivotal role in nuclear R& D spending plans (see table). The Japan Nuclear Fuel Cycle Development Corporation (JNC, formerly the Power Reactor and Nuclear Fuel Development Institute), a special public corporation, has considerable clout in this area. As the business range of JNC is limited to "R&D for FBR and nuclear fuel cycle and related R&D (including

R&D for radioactive wastes)" under the "Law for Japan Fuel Cycle Development Institute," the JNC is not allowed to engage in the development of other innovative nuclear reactors. The JNC also receives more than half of the total nuclear R&D budget, limiting the amount that can be spent on innovative reactor designs.

Japan's national nuclear R&D budget currently does not support R&D to be conducted on developing an innovative nuclear reactor based on the "once-through" philosophy. This is inconsistent with a key objective of the country's R&D for innovative reactors that is to expand the range of future options. Even in the United States, where the basic nuclear energy policy endorses the "once-through" process, there are efforts to look at an innovative reactor model that embraces the recycling procedure.

Japan's nuclear R&D budget derives from the Special Account for Promotion of Electric Power Resources Development. This budget is guaranteed by three laws pertaining to electric power resources. Control of the special account stays strictly in the hands of specific government institutions (the former Ministry of International Trade and Industry and the former Science and Technology Agency). In regard to the area of advanced reactors, the Science and Technology Agency, which also has former PNC under its management, has principal control.

This organizational and institutional framework is believed to be the biggest reason for hampering the flexibility of Japan's nuclear energy R&D. Considering the recent trend toward administrative reorganization, a good precedent exists to revise the existing mechanism of distributing the R&D budget. It is crucial to have political input in reforming the structure of the R&D budget for nuclear energy.

Within the nuclear energy market itself there is a momentum growing to rethink the budget, with utilities, manufacturers and the fuel industry and regulating authorities taking the lead. Still, the more the know-how of operators, regulating authorities and manufacturers is entrenched in a technology system that has required massive investment like the nuclear energy industry, the more difficult it will be for those players to commit to new technologies. This is referred to as the "path dependence of technology." This gives light water reactors a certain advantage.

In order to move to new designs, motivation must come from either a very acute problem in the existing system, perhaps proven by a serious accident or extremely poor economic performance, or the advent of an exceedingly attractive new system.

We believe it would be considerably difficult to carry out the long-term plan or put into practice the recommendations of past round-table conferences and sectional committees if the present market circumstances continue. Even so, the trend toward developing innovative nuclear reactors, of which the principal focus is the SIR designs, is noteworthy. This global trend is not due to temporary political developments, such as the leanings of the new Bush administration in the U.S., but should be interpreted as the tide leading to next-generation nuclear reactors from light water reactors that may, if correctly followed, possibly drive Japan toward the reform of its current inflexible structure of nuclear energy policy.

What International Cooperation Should Be Like in the Future: Toward Option-Sharing

Current and Expected Status of International Cooperation

The international initiative for the development of next-generation nuclear reactors can be one of the factors for overcoming domestic institutional and organizational obstacles. At present, the initiatives for R&D of the next-generation nuclear reactors are accelerated not only in the United States but also in other countries. In particular, although high temperature gas module reactors are regarded as innovative ones, many of their elemental technologies have already been demonstrated to be valid, raising keen interest in assessing whether U. S. utilities, which are already proceeding with the preparation for issuing orders for new types of reactors, can surmount the above-mentioned impediment.

At any rate, as the global nuclear power industry follows the trend toward reorganization, it is important to pay attention to the international cooperation aimed at the development of advanced nuclear reactors as a broad trend for the coming 10 years. Japan is strongly perceived as being a step behind in this trend, presumably because of the afore-mentioned institutional and organizational obstacles.

From Cost-Sharing to Option-Sharing

As the situation makes it indispensable for Japan to further promote international cooperation, we would like to propose a way for overcoming the organizational impediments. This concept aims at shifting to "option-sharing international cooperation," which advances diverse technological options simultaneously, from the conventional "cost-sharing international cooperation," such as the sharing of the cost for demonstration reactors.

The basic concept of option-sharing is one advocated by Professor Fumio Kodama of Tokyo University. It is one of the international technology development strategies already practiced by major international enterprises with a view to dispersing risks and securing technological know-how.

For option-sharing to work, the following conditions are required:

- Large-scale demonstration projects should be avoided. Such projects generally aim at combining existing technologies rather than basing themselves on innovative ones, and contain larger risks at the same time.

- Selection should be made only after carefully examining available options for innovative elemental technologies. Candidates for key elemental technologies should be presented one after another, by putting in order the conditions to be satisfied by next-generation nuclear reactors and tasks of technology development to be surmounted for attaining those goals (for example: cooling materials, fuel, size, etc.).

- Instead of narrowing the range of technological options at the level of each enterprise or country, projects for technology development should be organized by groups specialized in particular technological options, to fairly share the results and making the projects truly multinational.

- As a result, while each enterprise (or each country) comes away with diverse technological options, technology development can be carried out simultaneously.

The current Generation IV Project practices this formula of option-sharing technology development. Unless, however, this formula is understood properly, Japanese enterprises or government research institutions might miss out on opportunities to acquire the know-how of important technological options. In today's market, risks can be quite high in adhering to a formula that endorses just one specific technology. Rather, it is necessary to pursue the option-sharing formula in a more aggressive manner. In addition, as the option-sharing formula embraces as a wide range of future technological options as possible, it differs from the conventional formula that involves choosing a specific victor in advance and proceeding with the development up to the phase of designing a demonstration reactor. Determining the need for a demonstration reactor and the timing of building it can be made exclusively in the market.

Nevertheless, government funds may be used for demonstration reactors even in the future. In such a case, a democratic and transparent process at the time of the decision for investment is essential. Even in this case, as far as a small reactor is concerned, the risks are reduced since properties of the prototype enable immediate demonstration and development of commercial reactors. By participating in the "option-sharing" formula, there would be no need of scrapping existing technology development for the FBR/nuclear fuel cycle. Commitment to each technological option instead of organized commitment may, however, be a tremendous challenge to overcome in the current system within Japan.

If at this time, when the possibility is emerging for the Generation IV Project to be considered an international project, Japan runs the risk of being left behind because of its domestic organizational obstacles. As international cooperation on examining the merits of developing advanced reactors must be changed so as not to confine the technology development of one country to one specific technology, it is important for Japan and others to study this strategy carefully.

Conclusion: SIR and its Contribution to Energy Security

While the strategies for developing small innovative reactors have been discussed so far, we wish to summarize this study by stating what significance SIR designs can have on the strategy of overall energy security.

First, it can provide an opportunity for Japan to change its current rigid nuclear energy policy to one with a structure that promotes flexibility and diversified options for nuclear technologies. Active participation in the development of SIR and other innovative nuclear reactor designs will offer decisive flexibility to Japan's policy for nuclear development that has up until today only supported the promotion of FBR/nuclear fuel cycle and large-scale reactors.

Second, broadening the scope of reactor options available will play an important role in reinforcing Japan's nuclear technology expertise. Even if the innovative nuclear reactors now under development are not ultimately commercialized, revising the country's nuclear energy R&D program for the coming ten years will attract engineers and develop technological experts for a new generation of reactors.

Third, once the option-sharing formula has been wholly adopted, it can provide a new model of international cooperation in global technology development and contribute to the formation of international trust. Nuclear technologies have so far been developed under individual government initiatives and the cooperation between two nations has been the primary form of international cooperation. Although international cooperation on nuclear energy has to be restricted to an extent from the perspective of nuclear non-proliferation, the option-sharing formula may prove compelling as a model for multilateral and transparent international cooperation. Japan's participation in the competition for developing a next-generation reactor to be accepted as an international standard is also strategically very important for the country to remain competitive within the industry.

Lastly, pursuing the development of SIR designs will contribute to expanding the potential for nuclear energy in the world. Expectations are especially high in Asia for using nuclear energy, although it is questionable whether it is desirable to consider existing light water reactors in new Asian markets from the long-term perspective. As stated earlier, if the path dependence of technology is considered, it is desirable for a country considering a new approach to nuclear energy development to pursue the most advanced nuclear reactor designs as they offer the highest potential. The development of small innovative reactors is not only economically efficient but also excellent in addressing safety and non-proliferation concerns.

It is desirable for Japan to be aggressively engaged in R&D covering innovative nuclear reactors, small ones in particular, which offer the above-mentioned merits.

Table I – 1 Breakdown of Japan's Budget for Nuclear R&D

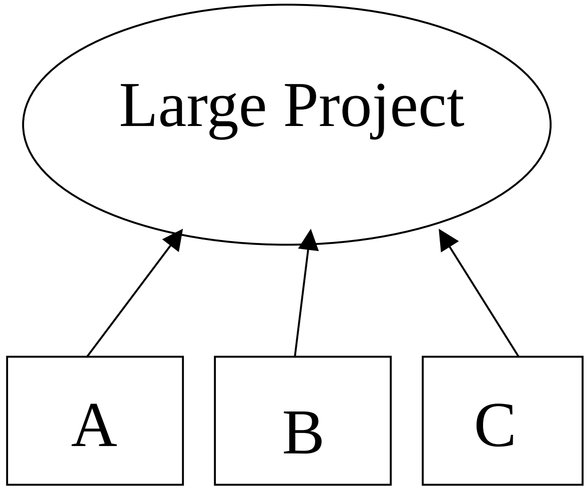
	Japan's Nuclear R&D ($ million)			
	FY2000	%	FY2001	%
FBR	380	20.1	309	17.1
Monju	88	4.6	96	5.3
Joyo	31	1.6	29	1.6
Adv FBR/Fuel Cycle	20	1.1	34	1.9
LWR	69	3.6	88	4.9
APWR/ABWR	25	1.3	23	1.3
Fuel Cycle	44	2.3	65	3.6
Innovative Reactor	8	0.4	15	0.8
HTGR	31	1.6	28	1.6
Fusion	100	5.3	138	7.7
Waste Management	230	12.1	210	11.6
Safety	370	19.5	422	23.4
Others	707	37.3	593	32.9
Total	1895	100.0	1803	100.0

Source: Compiled from Japan Atomic Industrial Forum

An “Option” Sharing R&D Collaboration

Cost Sharing

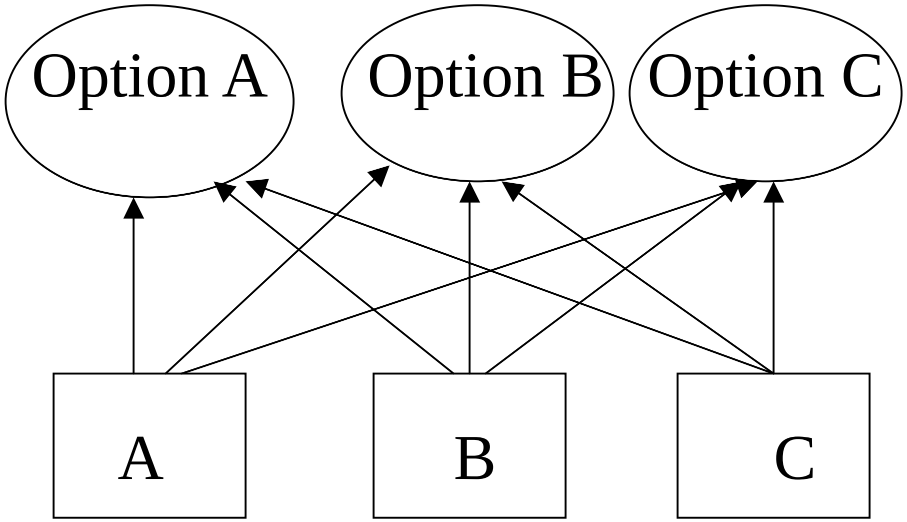
Collaboration



Countries

Option Sharing

Collaboration



Countries