Panel: Key Plutonium Utilization Programs

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Koji Kosugi, Manager, Federation of Electric Power Companies of Japan, Washington Office
Eric Proust, Executive Deputy Director for International Affairs, CEA, France

David Albright: I'd like to call the conference back to order. Next we will hear from a panel on key plutonium utilization programs. We have three speakers on this panel. The first speaker will be Mr. Yoshiyuki Chihara, who is the First Secretary of the Science Section of the Embassy of Japan. The second speaker is Mr. Koji Kosugi, who is a Manager in the Washington Office of the Federation of Electric Power Companies of Japan. The third speaker will be Mr. Eric Proust, the Executive Deputy Director for International Affairs of CEA in France.

Yoshiyuki Chihara: Thank you Mr. Albright, and thank you all for giving me an opportunity to address this conference.

Today I would like to talk about the Japanese long-term nuclear program from the government's point of view. Mr. Kosugi will then present the point of view of the utilities.

Japanese policy on nuclear research, development and utilization for peaceful purposes—particularly about nuclear power generation, the nuclear fuel cycle, and plutonium utilization—is based on the "Long-Term Program for Research, Development and Utilization of Nuclear Energy." I would like to say a few things about the Long-Term Program, which was published in November 2000.

In general, the Long-Term Program describes Japan's basic policy and the policy measures it must take on nuclear R&D and utilization for peaceful purposes. It has been revised around every five years. In order to clearly show the Japanese people, the international community, and all parties involved with nuclear energy, based on an analysis of changes in conditions since the previous Long-Term Program was published, as well as the outlook for the 21st century, the Atomic Energy Commission of Japan (AECJ) undertook to formulate a new Long-Term Program. The AECJ referred study for the formulation of this program to the Council for the Formulation of a Long-Term Program for Research, Development and Utilization of Nuclear Energy in May 1999.

The Long-Term Program Council was composed not only of parties concerned with nuclear energy, but also of persons of learning and experience from various circles, including the business community, legal circles, local siting communities, and the mass media. Its members were thus from a wider range of fields than those of previous councils. The Long-Term Program Council endeavored to reflect the voices of the people in the new Long-Term Program by inviting people to advance their opinions and by holding open forums. In all, 1,190 opinions were submitted by 773 people, and the views of 31 citizens were heard directly in open forums.

Discussions on a new Long-Term Program were taking place at a time of increased public distrust and anxiety in the wake of a series of nuclear-related problems and scandals, including a fire at the prototype Monju fast breeder reactor. With the 21st century near at hand, the council would have to revisit various problems that Japanese nuclear energy activities had thus far experienced, as well as forecast future developments. With that recognition, the Long-Term Program Council began to draw a vision for the coming century by returning to the starting point for research, development, and use of nuclear energy.

Immediately after the council initiated its discussions, a criticality accident occurred at a uranium-processing plant operated by the JCO company, in Tokai-mura, Ibaraki Prefecture. This served only to increase the level of public distrust of Japanese nuclear energy activities. Fully realizing the importance of discussions from the beginning, the Long-Term Program Council widened its view and continued with its work.

The Long-Term Program consists of two parts. Part I includes messages to the people and the international community. Part II includes specific policies on promoting nuclear research, development and utilization.

Now, I would like to show the points of the Long-Term program shortly. At first, a few words about the nuclear power generation: Given a series of nuclear-related accidents, radioactive waste disposal issues, and the backing-away from nuclear power in the United States and Europe, an increasing number of people in Japan think the further promotion of nuclear use should be restrained. However, nuclear energy is important because of global environmental problems, as well as Japan's particular geographical and resource conditions that, unlike the United States or Europe, do not allow it to easily exchange energy supplies with neighboring countries through transmission lines or pipelines. Japan is poor in energy resources and relies on foreign suppliers for most of its energy requirement. Nuclear power helps to provide a stable supply of energy while reducing carbon dioxide emissions. Along with seeking to maximize energy conservation and to develop renewable energy sources, it is a wise and rational policy for Japan to continue making fullest possible use of nuclear power generation as one of the mainstays of the nation's energy supply, taking the energy uncertainties of the future into account.

Of course, safety, nonproliferation, and radioactive waste disposal remain the highest priorities.

Second, about the nuclear fuel cycle. Nuclear fuel cycle technologies can enhance the advantages of nuclear power, including security of supply and lessened environmental impact, by optimizing the use of uranium resources. In turn, this will allow nuclear power to remain a viable energy source for a longer period of time. Therefore, it is appropriate to basically reprocess spent fuel and make effective use of plutonium, uranium, and other elements, while securing safety and nuclear nonproliferation. Taking economic efficiency into account, Japan should make the reprocessing of spent fuel and the use of recovered plutonium and uranium its basic policy, considering the geographical and resource conditions of Japan.

Furthermore, fast-breeder reactor and related nuclear fuel-cycle technologies can significantly increase the efficiency of uranium utilization. When they are commercialized in the future, breeder reactor and related fuel-cycle technologies can make it possible to continue using nuclear power for several hundred years with uranium resources currently known to be both technically and economically available for use, and can reduce the long-term radioactivity of high-level radioactive waste, decreasing the environmental load. Therefore, in order to prepare for an uncertain future and secure promising energy supply options, it is an important strategy to devote steady efforts to the development of these fast-breeder reactor cycle technologies.

In the use of plutonium, concerns about safety and nuclear proliferation, and doubts about the economy and efficiency of investments in research and development, should be fully considered and taken into account. Japan should make clear to the rest of the world its policy of strict adherence to the peaceful use of nuclear energy and its systems. In the use of plutonium, in particular, it is important to gain the understanding and trust of the international community through transparency and commitment to the principle of not holding surplus plutonium for no specific purpose.

Now I would like to try to explain the reason why Japan cannot become nuclear armed. First, Japan has a national interest not to posses nuclear weapons. It is very important for Japan that the world is stable politically and economically, as Japan deeply depends on importing energy, food, and other resources from sources abroad. Because of this, Japan has been making international cooperation in the world and wants to be a respectable country. If Japan were nuclear armed, it would result in the collapse of the coalition with the United States, and bring international strain and objection, especially in the Asian region. Japan would be isolated in the world, and the national economy would be ruined. Nothing would be gained and we would loose everything.

Second, we Japanese, who experienced tragedy of the atomic bombings in 1945, cannot accept the policy to be a user, holder, or maker of nuclear weapons. The national sentiments will never allow this. These sentiments move us to utilize nuclear energy strictly for peaceful purposes and to abolish all nuclear weapons in the world. We Japanese have a special feeling against nuclear weapons and we will never undertake secret activities in either the government or private sector. The transparency and the tension are essential for the nuclear activities for peaceful purposes.

Third, Japan has undertaken many steps to be transparent. As required by the NPT, Japan has a safeguards agreement with the IAEA, and all the nuclear materials in Japan are under the IAEA full-scope safeguards. It is estimated that Japan receives about 20–30 percent of the IAEA's inspection activities. IAEA full-scope safeguards are very effective in Japan, and there has been no report that nuclear materials for peaceful purposes in Japan have been diverted.

Japan also made an active contribution to the formulation of INFCIRC/540, the additional safeguards protocol, which was agreed to at the IAEA Board meeting in May 1997. Japan made a demonstration of expanded declaration and the complementary access based on the additional protocol. Moreover, in December 1999, Japan was the 8th country to conclude a protocol with the IAEA. We believe it very significant that the additional protocol between Japan and the IAEA came into effect, as Japan is the first among counties who are undertaking peaceful uses of the nuclear energy in large scale.

In addition, there is transparency though international observation based on bilateral nuclear agreements. Approximately 70 percent of the nuclear material that Japan possesses is subject to the U.S.-Japan nuclear agreement, and adequate information about these materials has been informed to the United States. From this viewpoint, most Japanese nuclear activities are under the observation of the United States. And almost all the remaining nuclear materials in Japan are under the bilateral agreements with the UK, France, Canada, Australia, and China.

Japan also has undertaken other international nuclear nonproliferation initiatives. As for the Guidelines for the Management of Plutonium, which was made by the consultation among Japan, United States, Russia, Britain, France, and other countries, to enhance the transparency of the utilization of plutonium, Japan actively participated in the consultation. This shows that Japan has no intention other than peaceful purposes to use plutonium.

Japan has also been trying to make a contribution to efforts to dispose of surplus plutonium from the dismantled nuclear weapons in Russia using peaceful nuclear utilization technology. We will continue to make efforts to these and other nonproliferation activities.

Now I would like to show you plans for the recovery and utilization of plutonium until 2010. The following plutonium amounts are in terms of fissile plutonium.

Regarding plutonium separation:

- The total amount of plutonium to be recovered under existing agreements with overseas reprocessing facilities is estimated at approximately 30 tonnes;
- Domestically, upon the start of full-scale operation at the Rokkasho Reprocessing Plant, a little less than 5 tonnes of plutonium will be recovered annually.

Regarding utilization:

- After Monju resumes operation, some hundreds of kilograms of plutonium will be needed annually for research and development purposes;
- According to utility plans, use of MOX fuel will be gradually increased up to 16–18 light-water reactors (LWRs) by 2010. In that use of MOX fuel, according to plans already specified, approximately 0.3–0.4 tonnes of plutonium are expected to be used annually at each unit;
- Approximately 1.1 tonnes of plutonium per year are expected to be used at the full-MOX-core Ooma nuclear power station;
- Plutonium recovered at overseas reprocessing facilities will be used initially, and plutonium recovered at the domestic facility will be used later in line with the expansion of MOX utilization.

In conclusion, I would like to say following. First, considering the geological and resource conditions of Japan—a nation poor in energy resources—and taking into account of reducing carbon dioxide emissions, Japan's basic policy is to preserve nuclear energy as one of the mainstays in the nation's energy supply structure and to maximize its utilization.

Nuclear fuel-cycle technologies help improve the characteristics of nuclear power generation, especially in terms of supply stability, and enable it to continue supplying energy over a longer period of time. Therefore the basic policy of Japan calls for effective use of such materials as plutonium and uranium recovered from spent fuel.

Third, the nuclear energy policy of Japan has to be a special one. Two issues—the strongest feeling against nuclear weapons, and the inevitable situation that Japan must use nuclear energy—are behind the policy.

To gain the international confidence, we Japanese continue to make a great effort to explain the transparency of utilization of plutonium, and make clear that we will never possess surplus plutonium which we don't have the aim to use.

Thank you for your attention.

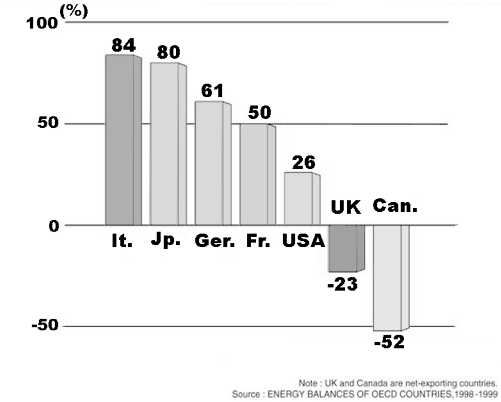
Koji Kosugi: Thank you very much. I am very glad to be here.

As part of this panel discussion on plutonium utilization programs, I would like to provide you with the Japanese electric power industry's perspectives on nuclear energy and especially on nuclear fuel recycling.

The utilities' goal is to enhance Japan's long-term energy security. This goal derives from Japan's special energy situation. In discussing Japan's nuclear power strategy, it is important to examine the underlying issues of energy security, and how the nuclear energy program contributes to Japan's energy system.

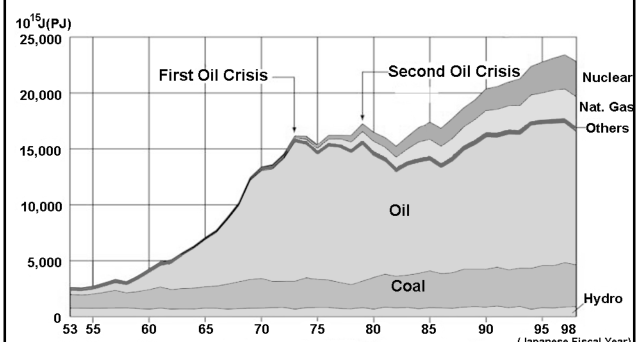
As a country that, just 25 years ago, was almost entirely dependent on imports to meet its energy needs, Japan places considerable importance on enhancing the security and stability of its energy supply.

Figure 1:
Dependence on Foreign Resources Among Major Countries in 1999



Let me explain why Japan's electric power industry requires nuclear energy and nuclear fuel recycling. Japan has scarce energy resources. About 80 percent of its primary energy supplies are imported. When comparing energy import levels among OECD countries, it becomes apparent just how dependent Japan is on imported energy (figure 1). We see the growing concern of American politicians and the public with regard to rising oil prices—even a country with abundant domestic energy resources feels vulnerable to the whims of OPEC and a volatile world oil market. Japan's energy supply is several times more vulnerable than the U.S. energy supply, and therefore energy security is of even greater priority to us.

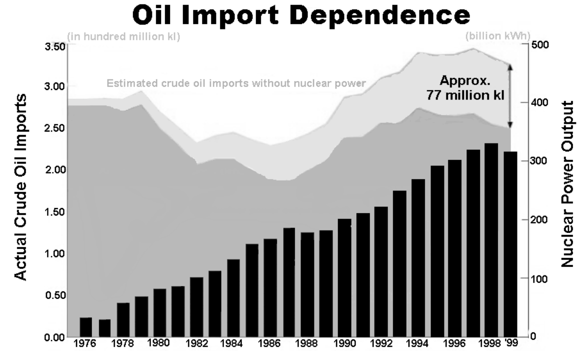
Figure 2:
Primary Energy Supply in Japan



Source: Natural Resources and Energy Agency: General Energy Estimates, 1998

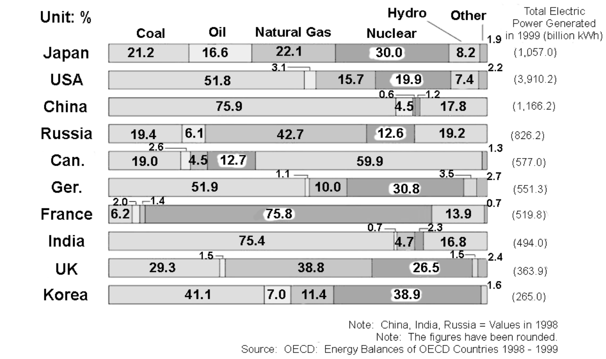
Japan is highly dependent on outside sources to meet its energy needs. However, considerable progress has been made since the oil crisis of 1973, when Japan found itself almost entirely dependent on imported energy. Today, due in large part to Japan's nuclear energy program, that dependence has been reduced to approximately 80 percent (figure 2).

Figure 3:
Nuclear's Contribution to Lowering Oil Import Dependence



At the outbreak of the Arab oil embargo, imported oil accounted for 77 percent of Japan's total primary energy supply, and Japan's economy suffered greatly as a result of the dramatic increase in oil prices from September 1973 to October 1974. Japan's nuclear program has not only helped improve Japan's energy security, it has also served to improve the security of oil consuming countries, including the United States. The Japanese nuclear program displaces approximately 77 million kiloliters of oil, helping to reduce demand and keep price pressure down (figure 3).

Fig. 4:
Power Generation Sources in Major Countries



It is instructive to compare power generation sources—across all fuel types—among the major industrialized countries (figure 4). Nuclear power has played an essential role in enabling Japan to diversify its energy mix. This reduces energy price fluctuations and it creates security.

Figure 5

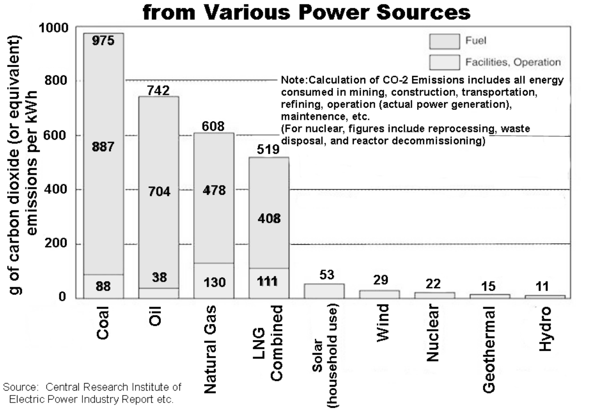
Figure 5 is a picture of a supermarket in Japan in 1973 during the first oil shock. These people were trying to get toilet paper because there were rumors that toilet paper was disappearing from stores. Oil and gasoline prices went up rapidly and these raised the prices of the necessaries of life such as toilet paper, detergent and salt. For example, this toilet paper panic expanded rapidly all over Japan.

Today, one of the most urgent issues faced by Japan's electric industry is the need to reduce carbon dioxide emissions, the major contributor to global warming. Nuclear power plants emit much less carbon dioxide per kilowatt-hour than coal, oil, and natural gas. It even emits less than solar and wind power (figure 6).

Figure 7 is also a picture taken in 1973 in Japan. We believe nuclear power is the best available power source in efforts to combat global warming.

An active and secure long-term nuclear future requires a closed fuel cycle. When factoring in the benefits to energy security and environmental quality, the cost of the MOX program is modest, with nuclear power remaining an economical source of secure energy.

Fig. 6:
Amount of Carbon Dioxide Emissions from Various Power Sources



What does Japan gain from nuclear fuel recycling?

- Energy security;
- Reduction in the volume of high-level nuclear waste;
- A long-term fuel source that emits almost no carbon dioxide and enhances our Kyoto Protocol commitment.

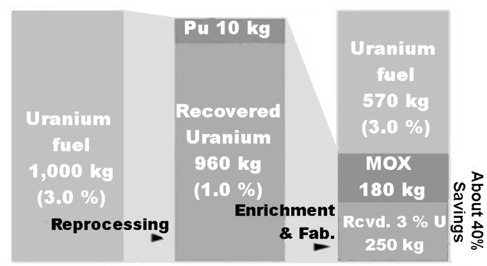
Figure 8 represents the estimated resource savings by recycling. After reprocessing spent fuel, plutonium can be used as MOX fuel. Recovered uranium is enriched again and can be used as uranium fuel as well. Theoretically, about 40 percent of natural uranium resources are saved by recycling, according to this figure.

Figure 7

What is the industry's plan for the nuclear fuel cycle? First, overseas reprocessing is to be undertaken in the short run. Second, the Rokkasho large-scale reprocessing facility is now under construction. As of July 2001, the construction was about 76 percent completed. It is planned to commence operation in 2005.

Third, domestic MOX fuel fabrication is planned to commence operation in 2008 or 2009. Fourth, with regard to MOX fuel use at LWRs, we plan to utilize MOX at approximately 16–18 reactors by 2010. Finally, with regard to spent fuel interim storage, we plan commercial operation of storage facilities by 2010 in Japan.

Fig 8:
Estimated Resource Savings
by Recycling (using 3 % LEU in BWRs)

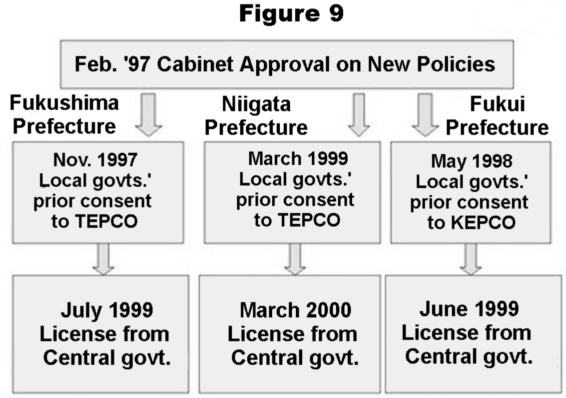


Natural uranium savings rate:
(1,000 kg - 570 kg) / 1,000 kg = Approx. 40 %
Note: The savings rate refers to the savings achieved by each individual power plant.

We currently have approximately 32 tonnes of plutonium located overseas. Of this amount, 22 tonnes are stored in France, and ten tonnes in the United Kingdom.

Considering our policy and situation, we would like to commence MOX fuel loading as soon as possible, based on the Japanese government's policy. But local governments are still reluctant to load MOX fuel. One example of this reluctance was seen in the referendum vote held in May 2001 at Kariwa village in Niigata prefecture. The Kashiwazaki-kariwa nuclear power plant is located near the village. The result of the referendum was a small majority against MOX loading.

Figure 9



TEPCO and KEPCO have already obtained legal approval from central and local government.

It is important to note that the site was cleared for MOX use through legal procedures (figure 9). But we cannot ignore the result of the vote and the intention of local governments, even though the vote is not legally binding.

Since Japanese utilities believe that MOX fuel loading is crucial to ensure a steady energy supply for the country and to reduce stockpiles of plutonium, we are committed to educating the public on the program's necessity and safety. In order to achieve this, we created a council comprised of the twelve companies within the Federation of Electric

Power Companies in June 2001. The council includes the nine electric power companies, as well as the Japan Atomic Power Company, the Electric Power Development Corporation, and Japan Nuclear Fuel Limited.

We have decided on a number of actions to improve and reinforce public trust. One measure involves enhancing mutual understanding and public dialogue. Efforts related to this include explanatory meetings with local communities and visiting people living near power stations for explanation and discussion. Another measure is the support of energy education for the next generation of Japanese. We have also established a Japanese web site, which provides the public with easy-to-understand information about nuclear energy and the utilities' long-term program.

The utilities are deeply committed to nonproliferation. Japan has accepted IAEA safeguards on all its nuclear activities. All of Japan's nuclear material is regularly inspected by the IAEA. Japan also ratified the additional protocol to its IAEA full-scope safeguards agreement for the IAEA's application of strengthened safeguards in 1999. Japan was the first to ratify the protocol among the countries with large-scale nuclear related activities.

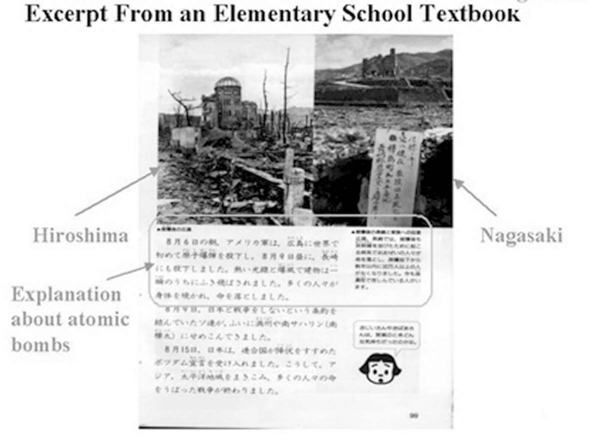
Japan has concluded nuclear cooperation agreement with the United States, Canada, Australia, France, the United Kingdom and China, and has bilateral, legal obligations for the peaceful use of nuclear energy. Japan also participates fully in all aspects of the international nuclear nonproliferation regimes. For example, the Guidelines for the Management of Plutonium (INFCIRC/549), the Nuclear Supplier Guidelines (INFCIRC/254), the Guidelines for the Physical Protection of Nuclear Material (INFCIRC/225) and the Convention on the Physical Protection of Nuclear Materials. Japan's Atomic Energy Law explicitly prohibits the use of nuclear energy for non-peaceful purposes.

The Japanese people experienced Hiroshima and Nagasaki. This picture (figure 10) comes from a sixth grade elementary school textbook. It says: "One bomb killed several thousand people. Within several years, more than 300,000 people died in Hiroshima and Nagasaki."

Every Japanese is thoroughly educated on the horrors of nuclear weapons. I firmly believe our nonproliferation commitment is not only achieved through the legal framework and international regimes but is also deeply rooted in every Japanese as a result of our unique historical experience.

Figure 10

Excerpt From an Elementary School Textbook



In summary, I would like to make a few concluding remarks. First, with scarce domestic energy resources and a reliance on imports to meet 80 percent of its total energy demand, Japan places much greater priority on energy security enhancement than the United States, which imports just over 20 percent of its energy supply.

Second, Japan's nuclear power program has played a crucial role in improving the country's energy security since the oil shocks in the 1970s. Nuclear power has served to diversify Japan's energy mix and benefits all oil consuming nations by alleviating demand pressure.

Third, nuclear energy is an integral part of Japan's commitment to reducing carbon dioxide emissions in accordance with the Kyoto Protocol.

Fourth the Japanese utilities are deeply committed to nonproliferation and maintaining IAEA full-scope safeguards and other international obligations.

Finally, our immediate challenge is to begin MOX fuel loading in LWRs as soon as possible. Doing so represents a crucial step in our long-term effort to fully utilize uranium resources through recycling. Nuclear fuel recycling is a crucial aspect of Japan's long-term energy security. It enables the country to conserve energy resources and increase energy supply stability.

Thank you very much.

David Albright: Thank you, Mr. Kosugi. We will now hear from Eric Proust of CEA before taking questions.

Eric Proust: Thank you very much. I would like to begin by thanking ISIS and its President for giving me the opportunity to contribute to this panel discussion on key plutonium utilization programs.

But I first have to clarify one point: There is no such thing as a French "plutonium utilization program." What exists is a policy for the back end of the fuel cycle, which is based on reprocessing of spent fuel, conditioning of high-level, long-lived waste, and recycling of plutonium as MOX fuel. Plutonium recycling is just one of the components of this triptych.

So, what I would like to do is not only describe the current situation of our plutonium recycling program, and its scheduled short- and mid-term evolution, but also place it in this broader context.

I also would like to devote a few minutes to addressing the usual issues raised by those who criticize our reprocessing and recycling policy, namely: economics, nonproliferation, safety, and environmental impact. And I intend to conclude with a look to the future of nuclear energy, and the progress that should be made in this perspective.

So let's begin with the current situation in France for fuel cycle management, and more specifically with the main parameters underlying the short- and medium-term policy of our national utility, EDF, with respect to MOX fuel.

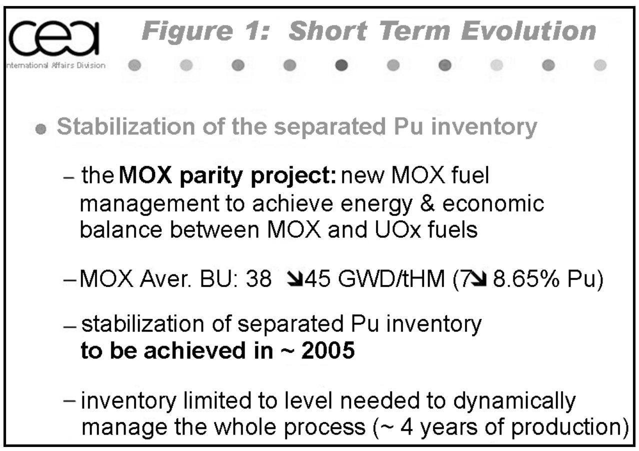
About 400 billion kilowatt hours are produced annually by the EDF nuclear fleet of 58 pressurized-water reactors (PWRs). Around 1,100 tonnes of spent fuel are discharged every year, including 100 tonnes of irradiated MOX fuel. Currently, 850 tonnes of uranium oxide (UOx) fuels are reprocessed annually at La Hague, where uranium and plutonium, which constitute 96 and one percent of the spent fuel respectively, are separated from the true waste: fission products and minor actinides.

Plutonium is recycled in the 20 PWRs from the 900 megawatt-electric (MWe) series that are presently licensed for MOX use in France. This reactor series has been designed from the start to allow MOX use. These 20 reactors are all being operated with cores containing two-thirds uranium fuel assemblies, and one-third MOX fuel assemblies with a plutonium content of 7.1 percent. They currently burn every year 100 tonnes of such MOX fuel, which is fabricated at the MELOX plant of COGEMA. The final high-level, long-lived wastes—fission products and minor actinides—are vitrified.

Let me stress here two points:

- First, the amount of plutonium extracted this year from the 850 tonnes of spent fuel corresponds, as you will see in a couple of minutes, to what is needed for fabricating fresh MOX fuel that will be loaded in reactors in about four years' time. This is what we call the principle of "equality of plutonium flows," which has been translated in INFCIRC/549 as "balancing supply and demand of separated plutonium."
- Second, the spent fuel that currently is being reprocessed was discharged some 8–10 years ago, and the plutonium that is being separated today will be recycled four years from now. You can thus understand that a long lead time is needed for any policy decision to take effect, and the necessity for EDF to develop a fuel cycle strategy with a vision at least two decades ahead.

So, let me turn now to the evolutions scheduled for the present decade and envisioned for the following one.

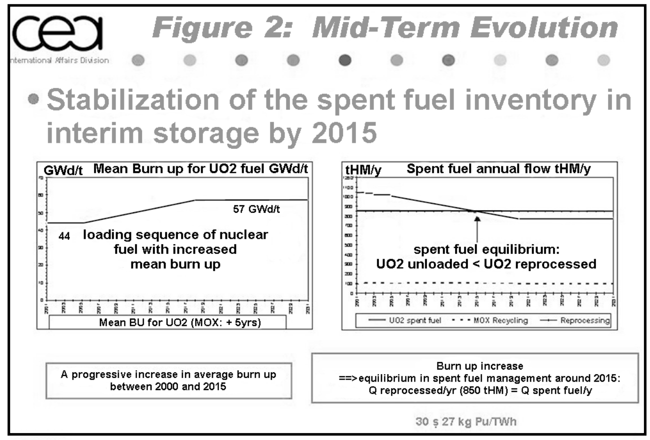


Currently, MOX fuel is licensed in France for three in-core cycles only; that is, a 3-batch reload scheme, which is the same schedule originally used for uranium oxide fuel. To take advantage of the rise in the authorized uranium fuel average burn up from 33 to 48 gigawatt-days per tonne (GWd/t), EDF adopted an hybrid reload strategy—a scheme that uses a 4-batch reload for uranium fuel, and just a 3-batch reload for MOX fuel. This strategy is obviously not optimal.

To improve it, EDF has developed the so-called "MOX parity" project (figure 1). This aims at achieving burn up parity between MOX and uranium fuels, and thus at implementing in 2004 a 4-batch reload management for both MOX and uranium fuel. Reaching this burn up of 48 GWd/t on average will require raising the plutonium content of MOX to about 8.6 percent, a level at which stabilization of the separated plutonium inventory is achieved. That is, the amount of plutonium contained in the 100 tonnes of MOX fuel loaded in the 20 MOX-ified reactors is equal to the amount of plutonium extracted that same year from the 850 tonnes of reprocessed fuel.

Thus, the separated plutonium inventory will be stabilized by 2005 at the level needed to dynamically manage the recycling process at about four years of plutonium consumption. And let me stress that there is a strong economic incentive to minimize this time period. Indeed, the longer the elapsed time between reprocessing and plutonium recycling in a reactor, the higher the buildup of americium 241, which is a neutron poison and gamma emitter, as you all know.

Beyond 2005, owing to a steady increase in burnup performances of the uranium fuel, the amount of spent fuel discharged annually will keep decreasing and, around 2015, EDF should reach a stage where it will be less than the amount reprocessed (figure 2). This in turn will lead to a stabilization of the total inventory of spent uranium and MOX fuels, and a progressive concentration of irradiated plutonium in spent MOX fuel.

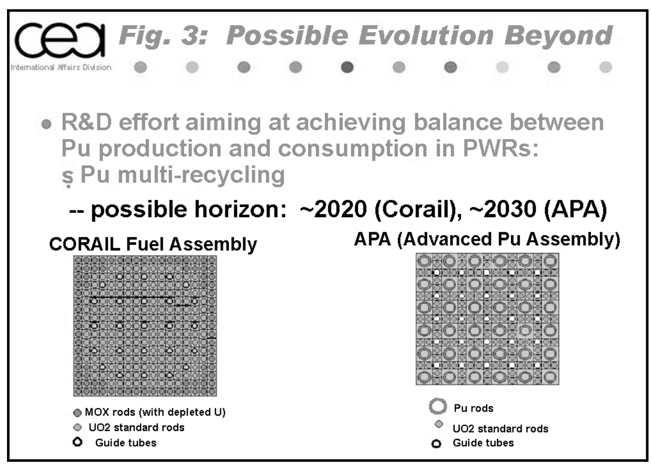


In addition, the reprocessing of higher burn up fuels will produce poorer quality plutonium, whose recycling will require increasing further the plutonium content of MOX fuel.

Looking now beyond the stabilization of the separated plutonium inventory and the progressive concentration of irradiated plutonium in MOX spent fuel, stabilization of the irradiated plutonium inventory is the next desirable objective from both the natural resources and waste management perspectives, as well as for nonproliferation reasons. This goal—achieving a balance between the throughput of plutonium produced and consumed each year—cannot be achieved by the present MOX mono-recycling option. With a nuclear reactor fleet made up of only LWRs—as this will likely remain the situation in France until probably 2050—this will require the implementation of complementary solutions that perform better than the current MOX fuel assemblies.

CEA is therefore devoting some R&D efforts on solutions that only affect the fuel and its cycle, but that require a validation program spread over several years.

A first solution is derived from current plutonium fuel technologies. It consists in new plutonium assemblies, called CORAIL, with islands of standard uranium dioxide (UO_2) rods surrounded by MOX rod (figure 3). Such fuel could for instance be initially implemented in the existing reactors before 2020. A second solution requiring further research and development into the fuel could conceivably be implemented in about 2030. It consists of advanced assemblies, called APA, a heterogeneous bundle including UO_2 rods and annular rods made of plutonium oxide within an inert matrix.



Having described the current reprocessing, conditioning, and plutonium recycling strategy and its scheduled short- and mid-term evolution, let me now turn to a presentation of its global rationale, whose components relate to waste management, optimal use of natural resources, and nonproliferation.

First, let me discuss the management of high-level wastes, which is certainly *the* critical issue for public acceptance of nuclear energy. For most people, the actual concern is the long-term behavior of long-lived radionuclides. Reprocessing and recycling is the key for fully addressing this concern, as it enables a strong reduction of both the volume and the long-term radiotoxicity of high-level, long-lived wastes and their long-term confinement.

Indeed, in the long-term—beyond 200 years and up to 100,000 years—plutonium contributes to approximately 90 percent of the radiotoxic content of spent fuel. Reprocessing makes it possible to separate it from the final waste, in which the remaining quantity of plutonium is limited to an absolute minimum—typically less than 0.1 percent at the end of the La Hague plant's process.

Vitrification of the high-level wastes—that is, the fission products and minor actinides—enables us to obtain a quite small volume of waste packages—about 150 cubic meters per year—which are offering remarkable performance and long-lasting confinement characteristics. In this regard, let me just mention that recent R&D work has shown that water action on the glass would be negligible even after up to 10,000 years.

Another important motivation—the one that was in fact at the origin of the French reprocessing and recycling policy—is to make maximum use of natural resources. This remains a clear objective for the future. Existing LWRs burn only one percent of the natural uranium, and 99 percent is left aside, either in interim storage or in waste disposal. If we don't improve the situation, with increasing energy needs, we shall exhaust uranium resources in a few decades, or at least those that can be recovered at a reasonable price.

Nuclear energy cannot be sustainable without reprocessing and recycling. Reprocessing and recycling is a cornerstone for satisfying future energy needs while mastering greenhouse gas emissions.

Recycling of plutonium as MOX fuel in our LWRs may be seen as an extremely modest step towards this objective of maximum use of natural uranium resources. To be comprehensive, I should add that EDF is also recycling some reprocessed uranium in a couple of reactors.

But let me tell you, MOX use enables us to maintain a high level of operational experience in actinide chemical engineering, in automated technologies, and in industrial organization for site conditions. And this expertise is essential for making the capacity for the development of the nuclear energy systems of the future, for making possible the development of sustainable nuclear energy.

I also maintain that recycling contributes to reducing the long-term proliferation risk of plutonium. Let me recall here a few facts:

- Our 20 MOX-loaded PWRs are currently zero net plutonium producers, and will become net plutonium consumers with the increase of the authorized fuel burn ups beyond the present level;
- One-third of the recycled plutonium is destroyed, and the isotopic ratio of the remaining two-thirds is further degraded;
- Recycling does not only further reduce the "desirability" of plutonium for the potential proliferator, it also enables us to concentrate it in spent MOX fuels, which exhibit a higher and longer lasting radiological barrier;
- Finally, reprocessing and recycling avoids the final underground disposal of 1,100 tonnes of spent fuel, and the associated proliferation risks for future generations.

These statements may seem provocative. They are not. They simply express my feeling that the long-term proliferation risk associated with the direct disposal of spent fuel may have been somewhat underestimated here in the United States.

And please do not misinterpret these remarks as a sign that I underestimate the proliferation risk associated with separated plutonium—certainly not. Allow me to explain my position: Plutonium produced in LWRs is evidently not well suited for making nuclear weapons. But, yes, clearly, a wrong use of it cannot be completely excluded, even though this proliferation route is much more difficult than others. And France is certainly not underestimating this risk. Our country, which is committed to a strong nonproliferation regime, is fully sustaining measures taken on an international basis to adequately manage this risk.

A reasonable way to manage this risk, while taking the full benefit of reprocessing and recycling, is to burn plutonium as soon as possible after it has been separated. This is exactly what we are doing in France; process operations are optimized for minimizing plutonium holdup. And I already have indicated, EDF is aiming to, and will very soon, in 2005, stabilize its separated plutonium inventory at the level needed to dynamically manage the recycling process.

From a nonproliferation perspective—diversion being hardly a proliferation issue for a nuclear weapon state—the only reasonable questions regarding the French reprocessing and recycling policy should focus on the effectiveness and robustness of our national system of materials protection, control, and accounting.

Let me stress here that our national system is indeed quite robust. And in addition, let me remind you that France, being a member-state of the European Union, has placed all civil nuclear materials on our territory under the very stringent Euratom safeguards. We are fully convinced that these very strict domestic and international controls are totally appropriate both to avoid any significant theft, and to give confidence to the international community that this is indeed the case.

And I would add that the French experience, with the Euratom safeguards as well as with the IAEA safeguards at our La Hague plant, allows confirming that reprocessing and recycling operations can be appropriately controlled.

So, let's leave nonproliferation. And because much criticism on our reprocessing and recycling policy has focused on cost considerations, allow me to devote a few minutes to these economic aspects of reprocessing.

I want here to emphasize a recent study[1] commissioned by our Premier Lionel Jospin that should have contributed to put to rest endless debates in France—if not abroad—on the total cost of reprocessing, were these debates somewhat rational. Interestingly—and this is what makes this study all the more important—the three authors were selected to represent a broad coverage of interested parties and point of views: economics, with Jean-Michel Charpin, the head of the French planning agency; environment, with Benjamin Dessus, a Director at our National Center for Scientific Research; and the nuclear sector, with René Pellat, the High Commissioner for Atomic Energy.

To compare various possible scenarios for the future of the existing French nuclear power infrastructure, the authors have captured all the related—past and future—expenditures: all capital costs, including R&D, dismantling, operational cost, front and back-end of the fuel cycle (including, evidently, capital costs for reprocessing and MOX fabrication facilities), and final waste disposal. Divide by the total electricity production, over the lifetime of the nuclear power plants in each scenario, and you get an average nondiscounted cost per kilowatt-hour . This is certainly not a true economic cost, but it is well suited for the comparison of different scenarios.

[1] Jean-Michel Charpin, Benjamin Dessus and René Pellat, *Étude économique propective de la filière électrique nucléaire*, La Documentation française, July 2000. <http://www.plan.gouv.fr/organisation/seeat/nucleaire/rapportangl.pdf>

This report thus enables the comparison between a strategy similar to the one of EDF, and a reconstructed scenario where France would have foregone the reprocessing option. It shows that having engaged into our reprocessing and recycling policy has a modest penalty on the cost of our nuclear kWh: barely five percent more than if we would have made the choice of direct disposal for our spent fuel.

Needless to say, once the capital investments have been made, the extra cost for continuing to reprocess and recycle is totally marginal—less than one percent—compared to the benefits we draw from this policy in terms of waste management.

I have already spoken too long, so I will skip over safety and environmental impact, and will come now to the conclusion. First, the very real threat of global warming severely limits the energy options available to humankind for its sustainable development in a context of growing energy needs, in particular electricity in developing countries. Nuclear energy, supplemented by renewable energies, is the key. So that, sooner or later, nuclear energy will be needed on a larger scale than presently to satisfy these needs. Reprocessing will then more than ever be necessary for reasons of both economy of resources, and waste management.

The existing technology, of which we have now a large industrial experience, has proved to be efficient and economic. But progress should be made and we are working on it in the same way as we are working on future reactor designs.

Taking into account the present concern on waste management, while assuming that the problem of plutonium is completely solved by reprocessing and recycling, we should consider the possibility of destroying the so-called minor actinides, such as neptunium and americium. Several countries have important R&D programs on partitioning and transmutation. We, in France, have already succeeded in developing supplementary processes, which could be implemented in reprocessing plants to extract those minor actinides. We also know how to burn them, either in reactors or in accelerator -driven systems. For the long term, we should try to develop an integrated approach based on recycling of all the actinides in such a way that the actual wastes to be definitely disposed will only be the unavoidable fission products.

Technical solutions can be developed. They include either improvements of existing technologies or the development of new ones such as, for instance, dry processing or pyroprocessing. Another improvement will be to limit as much as possible the transportation of nuclear materials. An objective could be to have reprocessing and fuel fabrication facilities located at the same site and not too far from the reactors.

As a conclusion, I would say that reprocessing and recycling will be, sooner or later, a necessity for use of nuclear energy in a sustainable development. It's already an efficient tool for waste management, and in some countries an industrial reality. It exhibits its own merits in terms of nonproliferation. And it can certainly be improved to be still more efficient, more proliferation resistant, and cheaper.

Thank you.

David Albright: Any questions or comments?

Question: Thank you. I had a question for Mr. Chihara and a second question for Mr. Kosugi.

Does Japan have a position on the proposal that was presented earlier by Mr. Bengelsdorf and Mr. McGoldrick? It seems to me that if Japan could take the lead on that issue, as it did on the plutonium management guidelines, it might make quite a difference.

For Mr. Kosugi: You discussed energy security for Japan. Has Japan undertaken as much research on extracting uranium from seawater, or on renewable energy sources, as it has on the closed fuel cycle?

Yoshiyuki Chihara: I cannot really comment on the proposal by Mr. Bengelsdorf and Mr. McGoldrick from the government's point of view. My personal opinion is that such a regime would enhance the transparency of plutonium stockpiles but, on the other hand, would also impose a burden. My personal opinion is that it should be examined carefully, to see where the balance between transparency and burden lies.

Regarding the extraction of uranium from seawater, I think that some government organizations, such as the Japanese Atomic Energy Research Institute, have done some research on this. As far as I know, this is just in the research phase, and not the commercial phase. As for renewable resources, these are insufficient to replace nuclear power. For example, solar power and wind farms have thin energy densities, and Japan has a very narrow and mountainous geography that is poorly suitable for solar power. So, these are really complementary sources of energy; they cannot replace nuclear energy.

Koji Kosugi: First of all, in terms of the Japanese nuclear fuel cycle program, as I explained, we accept strict IAEA safeguards and we participate in a lot of nonproliferation efforts. I firmly believe that we have no proliferation concerns. Honestly speaking, I have not yet studied the custody proposal, but I think it is worth discussing.

In terms of uranium extraction: I really do not know these costs. In terms of solar and wind power: Solar power is extremely expensive and requires a lot of area. Wind power is cheaper than solar, but still more expensive than nuclear power, and also needs a lot of land. Japan is a small, narrow, mountainous country with limited amounts of flat areas. From that point of view, we believe that nuclear power and nuclear fuel recycling is more beneficial to maintaining our energy security.

Question: I have questions for both the Japanese and French speakers. I would like to begin with our Japanese colleagues. One of you made a statement that the cost of MOX was modest, which I would like to ask you to defend that a bit more. Unless I am way out of date, I believe that you can purchase fresh uranium fuel at a price of about $1,000 per kilogram, or $1 million per tonne. I would like to know what your utility would have to pay for MOX, assuming that it came from Rokkasho, which will cost on the order of $20 billion, or so I am told, once it is completed. My calculations would indicate that the MOX could cost 20 times the cost of low enriched uranium (LEU) fuel.

Would you also address why it is not more economically effective and, from the standpoint of energy security, advantageous for Japan to have stockpiled LEU, instead of proceeding down the path of reprocessing and MOX?

Koji Kosugi: I'll try to answer your questions. First in terms of the cost of the Rokkasho plant, the costs were approximately ¥2.14 trillion. I don't know the current exchange rate.

Question: That is not really what I was looking for. What is the cost of a MOX fuel assembly, per kilogram of heavy metal?

Koji Kosugi: The total generation costs are…

Question: I don't want the total generation costs. I don't want you to make the costs smaller by adding in all the capital costs for reactors, and also operating and maintenance costs. I want to know what the cost of the MOX fuel is, versus the cost for LEU fuel.

Koji Kosugi: About one-third of the commercial light-water reactors will load MOX fuel (figure 1a). For all but one reactor, the fuel will contain less than one-third MOX. The front end costs account for approximately ten percent of the total cost of power generation, and the impact of loading MOX is approximately one percent of the total power generation cost per kWh.

Eric Proust: Excuse me, may I intervene so that my Japanese colleague has some time to get you an answer?

I would argue that it is not relevant to compare the cost of producing MOX fuel with the cost of producing uranium fuel. What you should compare is the overall cost of the fuel cycle, including waste disposal. That is exactly what was done in the report that I mentioned that was commissioned by Premier Jospin. I invite you to look at this report, which contains all the details and analysis that you need.

Figure 1a: Economics of MOX Fuel to LWR

* Percentage ofMOX fuel of all nuclear fuel in Japan: approx. 10 percent
  -- LWRs to load MOX fuel (6 - 18 reactors by 2010: about 1/3 of all commercial reactors (current total=51))
  -- Percentage of MOX fuel in a reactor: Less than 1/3 except for one reactor
* Front-end costs account for approximately 10 percent of nuclear power generation costs
* Cost impact is just about 1 percent by loading MOX
* Considering long-term energy security, this is almost negligible

Question: To follow up some more, I agree with you. I have my own calculations of those figures, but my conclusions may differ from yours. In order to make those calculations more precise, it would be useful for me to know what the cost of the fuel is for uranium fuel versus the cost of MOX.

Eric Proust: I think that it would be difficult, and I do not have that specific information at hand. But I invite you to read the English translation of this report—it is available—and once you have read it, we can discuss it if you have any more questions.

Yoshiyuki Chihara: Please let me explain about the costs. Maybe I will not exactly answer your question, but there is a study by MITI in 1999. It was attached to the Long-Term Program, which I discussed in my talk.

Figure 2a is a comparison of the power generation costs for nuclear, hydro, oil, liquid natural gas (LNG), and coal energy sources, in yen per kWh. Nuclear power, at a cost of ¥5.9 per kWh, is cheaper than the others.

Figure 3a is a breakdown of this cost figure. You can see that the total costs are ¥5.9. I am not sure what the exact information that you are looking for is, but the fuel costs here are ¥1.7 per kWh — both front end and back end, which includes the final disposal of high-level waste.

David Albright: Are there other questions?

Question: Thanks, I have a question or two for Mr. Proust. McGraw-Hill reported this spring that EDF acknowledged that MOX fuel was three to four times more expensive than LEU. Could you respond to that?

Also, in light of the post September 11 security environment, France has stationed surface-to-air missile batteries at La Hague, and the Deputy Defense Minister also has stated that France was considering installing such batteries at each of the nuclear power plants in France. I was wondering if you could bring us up to date on this.

Third, also in light of post September 11, I would ask you to comment generally on an analysis done by the Nuclear Control Institute (NCI) that indicates that—with reactor-grade plutonium—in the event of a sabotage or a severe accident resulting in a breach of containment, you would have 100 percent more latent cancer fatalities resulting from such an accident involving a reactor with one-third core of MOX fuel compared with one that is fuelled entirely with LEU.

Eric Proust: Thank you. Once more, although I understand the usefulness of looking at the costs of producing uranium fuel versus MOX fuel—and I agree that the cost of producing MOX fuel is indeed higher—you have to consider, when deciding on a fuel cycle strategy, the overall costs and benefits. This is what was been done in the report that I mentioned. I would like to stress again that the three authors of this study come from a variety of backgrounds, and at least one of them is not known to be pro-nuclear, to say the least.

I think that the figures are well debated in France, and you certainly know that France has its own vocal, strong critics of reprocessing and recycling from the economic angle. So I think it is important to not only discuss overall absolute figures in terms of billions of dollars, but also to look at the costs in terms of generating costs, or cost per kWh, and whether this impact is really worth the benefit of your strategy. What we have assessed is that, indeed, there is an impact. This impact may or may not be significant, depending on your point of view. The overall impact of having engaged into this reprocessing and recycling strategy—the overall impact over the whole life of the present, existing nuclear infrastructure in France—is five percent of the kWh costs.

The impact of continuing to reprocess from now on, with the existing infrastructure, is just one percent of the cost of the kWh. I think that these results confirm previous studies, in particular the OECD report. You have to consider whether this one percent increase is really worth the benefits drawn from this strategy.

Figure 2a: Current Energy Competitiveness

	Nuclear	Hydro	Oil	LNG	Coal
Power Generation Costs (¥/kWh)	5.9	13.6	10.2	6.4	6.5

Assumes: (1) 1998 average exchange rate of ¥128.02 / $, with a discount rate of 3 percent; (2) avg. 1998 fuel prices of $13.13 / bbl oil, $38.8 / tonne coal, and ¥18,902 / tonne of LNG.

Source: MITI, December 16, 1999

Figure 3a: Breakdown of Nuclear Power Generation Costs (¥ / kWh)

Capital Costs (depreciation, fixed-asset tax, decommissioning)	2.3
Operations and Maintenance	1.9
Nuclear Fuel Cycle:	
Front End:	
-- Procuring ore, ore concentrates, conversion	0.17
-- Enrichment	0.27
-- Reconversion and fabrication	0.29
Subtot., Front End	*0.74*
Back End:	
-- Intermediate Storage	0.03
-- Treatment, conditioning, and disposal of waste	0.25
Subtot., Back End	*0.29*
Subtot., Nuclear Fuel Cycle	*1.7*
Overall Expenses	**5.9**

Source: A Report of the 70th Nuclear Energy Subcommittee, Advisory Committee for Energy, December, 1999.

Note: Power costs are described in an "Application for Permission to Install a Reactor" are calculated on different assumptions from those supporting the above figures; for example, an operating period of 16 years and a 70 percent capacity factor.

I would say that, from the point of view of the government and the utility, the benefits—in terms of waste management and treatment—are worth this cost.

Finally, it is rather easy to assess the economic costs of reprocessing and recycling in France, because we are doing it. We know what the figures are. In contrast, it is much more difficult to assess the costs of direct disposal of spent fuel because there are presently no such direct disposal repositories or demonstrated solutions for the direct disposal of spent fuel. So, how do you assess these costs? I am pretty sure that once the United States has a repository for waste and spent fuel, we will have figures that, I believe, will be higher than the figures that have been taken into account in the OECD report or in this French study.

Regarding your second question, you have heard the comments made by the French Defense Minister. Missiles have been deployed around La Hague and around the nuclear submarine base. The main reason for these deployments is that these sites are quite isolated, and it would take too long for police forces to reach these sites in the event that they are urgently needed. This decision was made after a very fresh, initial analysis undertaken just after September 11. Beyond that, it is clear that we have reassessed the basic design threat after September 11. The reassessment has been made quickly, and we will have to take the time to review it with a cool head.

Question: Just to follow up: There was a report that France was considering installing such batteries at the nuclear power plants. Is that the case?

Eric Proust: This has indeed been considered.

Question: If I could just return to the economics? You indicated that a big cost factor was the ultimate disposal of spent fuel. Are you suggesting that France will not have to address the issue of disposing of spent MOX fuel? Even if you do not reprocess spent MOX fuel, which is not in the plan for the time being, don't you ultimately have a disposal problem that is comparable to the disposal of spent LEU fuel?

Eric Proust: We will see in the future whether EDF decides to reprocess spent MOX fuel. But we are preparing ourselves, in this perspective, with the development by CEA of advanced fuel assemblies that would allow for multi-recycling of plutonium in existing PWRs.

Question: Mr. Chairman, I think that it is high time to break the monopoly of American questioners, and give the floor to a European!

I would like to ask Mr. Proust: In your talk you mentioned new plutonium assemblies. What are the advantages and characteristics of these assemblies? Deeper burnups, for example?

Eric Proust: Thank you for giving me the opportunity to speak more about this. These studies are being made towards the objective of multi-recycling of plutonium. At the present time, and with the present MOX fuel assemblies, it will probably be difficult to recycle the plutonium more than twice. If we want to go beyond that, then we need to modify the design of the fuel assembly, as in the CORAIL design. In this design, the idea is to have "islands" of standard UO_2 rods inside assemblies containing MOX fuel rods. In this case, we would use the present technology for producing MOX fuel rods, but we would use them in a different fuel assembly. This, of course, will require the qualification and validation of the design.

David Albright: Any other Europeans?

Question: Just one comment. I would like to weigh in on the issue of cost and economics. Let the utility decide about the price of the MOX fuel. It is the utility that has to pay for it. COGEMA signed a huge contract in August with EDF, which is the largest nuclear utility in the world. The contract includes reprocessing 850 tonnes of spent fuel per year until 2007, and the production of 100 tonnes of MOX fuel per year.

Of course, the greater quantity of MOX produced would give a more attractive per-unit cost. The determination of costs depends on the quantity requested. Thank you.

Question: I have heard all of the presentations about how reprocessing is good from a waste management perspective. Mr. Proust also mentioned the use of reprocessed uranium. But I am curious whether you classify reprocessed uranium as a resource or a waste, and if it is a waste, what is the disposal track? If it is a resource, then what is the schedule for use? What are the anticipated problems and costs?

For the Japanese speakers, if the reprocessed uranium is a waste, when would you take that waste back to Japan for disposal?

Eric Proust: The reprocessed uranium is not a waste. However, I cannot say at this time when we will use it. EDF used reprocessed uranium, however, not on a large scale at the present time, but rather for a demonstration purpose. One of the questions is whether we will have to wait until fast-breeder reactors are developed before we use reprocessed uranium. I would also mention that, for instance, German utilities are also recycling reprocessed uranium.

Yoshiyuki Chihara: Reprocessed uranium from spent fuel will be used as a resource, but I do not know the exact date when that will begin. As I explained in my presentation, at first the MOX fuel will be loaded, but this has not yet been accepted by the local communities. The Japanese government and utilities are now making a greater effort to gain their confidence.

David Albright: I'd like to ask a follow-up question: Could our Japanese colleagues talk more about when MOX will first be loaded into LWRs, or if they can not, could you talk a bit more about your philosophy and why you won't load it? Also, how successful has the effort been to gain the acceptance of the local communities? Are they more supportive?

Koji Kosugi: After the referendum vote in May 2001 at Kariwa village for the use of MOX at the Kashiwazaki-kariwa power plant, the utilities are making their best effort to gain public acceptance. I think that the local populations are very cautious about loading MOX fuel. It is a big challenge for us. We always appreciate the cooperation of local citizens, concerning not only this issue, but other issues. We need to continue to make a best effort to communicate with the local population.

David Albright: One last question.

Question: Eric, you argued with me on the cost issue. But, when you turned to the issue of the toxicity of the waste, you presented your data in terms of the plutonium, which represents 90 percent of the long-term toxicity. Surely, you would agree that the more appropriate comparison would be the overall health effects from the fuel cycle.

Don't you agree that from the repository—even though France does not have one yet—the toxicity is not the right measure? Instead, you should look at the isotopes that will escape, and their associated health affects. Similarly, on the issue of reducing the volume of waste, I could make an equally silly argument that you have increased the volume of the waste because you have released all of these volatile fission products to the atmosphere, and that your waste volume is really the northern hemisphere, or something close to it. But it seems to me, the right benchmark would be the cost of waste disposal, which is already built into your cost figures.

Eric Proust: The only point I would make is that the present releases at La Hague lead to a dose of 0.06 milisieverts per year to the most exposed person, and the trend is going down towards the goal of 0.03 milisieverts per year. This is a "level of trivial risk," according to the ICRP.

David Albright: Thank you for this discussion. We have heard these debates often, and I do not think that we are changing each other's minds. There remains a fundamental divergence between the United States and our European and Japanese colleagues. But it is always interested to hear. Let us now take a break and get ready for our lunchtime speaker.