Chapter 1
Overview

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1. Why do an International Assessment of the Interim Report?

1-1. Events Leading Up to the Formulation of the Draft Nuclear Energy Policy Outline

In June 2004, the Cabinet Office's Atomic Energy Commission established the New Nuclear Policy-Planning Council with the aim of revising the Long Term Nuclear Program (Chokei)*. A review of the Chokei is carried out approximately every five years. After a little more than a year's debate, on 28th of July 2005, the Council published the *Draft Nuclear Energy Policy Outline*, and on the following day began public comment on this document. The New Nuclear Policy-Planning Council will recommence debate in September 2005, and there is a possibility that the *Draft Nuclear Energy Policy Outline* will be finalized then. It is thought that the reason why the name "Long Term Program" (Chokei) disappeared this time was to clarify the assignment of responsibilities. The formulation of specific plans will be left up to each individual ministry, while the Atomic Energy Commission will only be responsible for formulation of the basic policy.
[*"Chokei" is the Japanese abbreviation for the "Long-term Nuclear Program".]

Compared with the *Energy Basic Plan* and the *Science and Technology Basic Plan*, the formulation of which is required by law, the legal status of the *Nuclear Energy Policy Outline* is unclear. Furthermore, when the *Law for Establishment of the Atomic Energy Commission* was revised in 2001, Article 23, which outlined the legal obligation of the prime minister to respect the decisions of the Atomic Energy Commission, was deleted. Consequently, the legal authority and binding force of the *Nuclear Energy Policy Outline* is unclear, but it cannot be denied that the contents of the *Outline* have substantive authority over the government and also over the private sector.

The New Nuclear Policy-Planning Council, carried out a debate with regard to various fields and issues, and by June 2005 had compiled 10 "interim reports" and "summaries of points for discussion". These reports express the majority opinion of the Council members. The main arguments outlined in the *Draft Nuclear Energy Policy Outline* are based upon the contents of the "interim reports" and "summaries of points for discussion".

1-2. Interim Report Concerning the Nuclear Fuel Cycle Policy

During the deliberations this time, the major focus of public interest was the nuclear fuel cycle backend policy. With construction of Japan Nuclear Fuel Ltd.'s (JNFL) Rokkasho Reprocessing Plant almost finished, and the starting date of operations (referred to as active tests) getting closer, it was a perfect time to stop and rethink the policy and assess whether or not it is appropriate to push forward with the spent nuclear fuel reprocessing option. Consequently, the debate in the New Nuclear Policy-Planning Council was being closely watched.

In principle, policy re-examination can be carried out at any time, but if this chance is lost, it is projected that there will be a huge cost (estimated at 1.55 trillion yen) associated with dismantling the reprocessing plant. This is because it will have been contaminated due to operation. The cost of withdrawal will become immense, resulting in a situation where it will be considered difficult to withdraw. That is why it was said that if the reprocessing policy is to be re-examined, now is the time to do it.

Looking at this situation from the standpoint of the people who want to stick with the nuclear fuel reprocessing policy, the New Nuclear Policy-Planning Council represents the last big hurdle before commencement of operations of the Rokkasho Reprocessing Plant. If the go-ahead to operate the facility is given, the path forward will be clear. In Japan, the reprocessing of spent nuclear fuel is carried out by the private sector, but a characteristic of Japanese policy is that private sector enterprise is strongly bound by government policy. Private sector entities have no legal obligation to abide by government policy, but practically speaking, because of the administrative direction associated with permission for siting nuclear power plants, power companies are left with no other option but to choose to reprocess their spent nuclear fuel. So, for all intents and purposes, the government decision is the private sector decision.

Under these circumstances, the nuclear fuel cycle backend policy was destined to be the biggest issue in the debate. The majority of the first 12 meetings were spent debating this issue. On 12 November 2004, as the first of the 10 “interim reports” and “summaries of points for discussion”, the *Interim Report Concerning the Nuclear Fuel Cycle Policy* (referred to below as the *Interim Report*) was agreed to as a majority opinion. The main points of the *Interim Report* were embedded as is into the *Draft Nuclear Energy Policy Outline*. The gist of the argument is adherence to the historical policy and an expectation (in reality a demand) for smooth operation of the JNFL Rokkasho Reprocessing Plant.

Following the release of this report, JNFL and the Ministry for Economy Trade and Industry (METI) immediately took action. Uranium commissioning of the Rokkasho Reprocessing Plant commenced in December 2004 and in May 2005, the Reprocessing Fund Law* was passed and became law. In this way, even before the finalization of the Nuclear Energy Policy Outline, the Interim Report has already wielded an immense amount of influence. Even though it is classified as a provisional Interim Report, policy is already being forcefully carried out based on its conclusions.
[*Our abbreviated translation]

1-3. Purpose of the Review

During the debate regarding the *Interim Report* in the New Nuclear Policy-Planning Council, several members of the Council, including some who are not necessarily opposed to nuclear power, expressed many concerns about issues such as the following:

i. the financial risk to the operators as a result of adherence to the historical policy;
ii. the impact on the Japanese economy if this risk becomes a reality;
iii. the risk of the imposition of an enormous public burden, due to a bail-out of the operators, or insolvency proceedings;
iv. the fear that the start of operations of the Rokkasho Reprocessing Plant will further undermine the international nuclear disarmament and nuclear non-proliferation regimes.

It was also pointed out that the least that can be said is that there is no rational reason to justify the immediate commencement of full-scale operations of the Rokkasho Reprocessing Plant.

These concerns are well grounded. For this reason, it is necessary to re-examine the basic policy of the *Interim Report* prior to finalization of the *Nuclear Energy Policy Outline*. This is important because continuation of the historical policy which is fixated on the implementation of spent nuclear fuel reprocessing, does not simply stop at Japan's adoption of an energy policy for the immediate future. It also adds a future cause for concern for the Japanese economy and the daily lives of the citizen and it has the potential to precipitate a situation that fundamentally threatens Japan's future position in the international community.

In order to contribute to the debate concerning such a revision, we decided, as a joint project between Japanese and overseas nuclear power policy researchers, to carry out a scientific assessment of the *Interim Report*. Specifically, we carried out a professional assessment, in accordance with international standards, in regard to the appropriateness of the *Interim Report*. By introducing the results of this assessment into Japan's policy decision-making process in real time, and by transmitting the results widely to the international community, we hope to arouse an international climate of opinion, and contribute to the improvement of Japan's policy. This is our main objective.

One more important goal is, by using this method of “international real-time policy assessment”, to establish a paradigm, (an exemplary practical example) so that when important decisions concerning Japan's nuclear and energy policy are made in the future, this method is available as an option for citizens to pursue. When attempting to establish a new approach, it is insufficient to only explain the approach verbally. It is also necessary to present an exemplary practical example, so that the people who follow can emulate the earlier example, which in turn entrenches and improves the new approach.

The main target readers of this report are all persons connected to nuclear and energy policy decision-making. Of course, included in this target group is any member of the general public who has an intention of participating in, or having an influence on, nuclear and energy policy decision-making.

2. Organization and Activities of the ICRC

2-1. Background behind the establishment of the ICRC

During the 12th meeting of the New Policy-Planning Council (held on 12 November 2004) when the *Interim Report* was adopted, Council member Professor Hitoshi Yoshioka of Kyushu University proposed conducting an international review of the report. The Atomic Energy Commission didn't reject the proposal outright, but it took no action in response to his proposal. However, the Takagi Fund for Citizen Science had for some time, at the proposal of then Director Mycle Schneider and Executive Director Tetsunari Iida, secured a budget allocation for a project to carry out a comparative evaluation of spent fuel management options, including the operation of the Rokkasho Reprocessing Plant, and various spent fuel storage options.

At this point, the Takagi Fund and the Institute for Sustainable Energy Policies (ISEP) (of which Mr. Iida is the Director) consulted together and, as a part of the Takagi Fund research project, it was decided to ask Professor Yoshioka to work as the Chairman of an international review project. Professor Yoshioka agreed to accept this role. The entrusted research project is divided into two projects, the “International Critical Review Committee on the Long Term Nuclear Program” (ICRC), and the “Backend Assessment Review” (BEAR). Overseas commission members were invited to Japan for the launching of the project and on 29 March 2005 a kickoff meeting was held, and the project was publicly announced at a press conference.

As for the procedures of the ICRC assessment, first the Japanese commission members proposed the basic review subject matter and issues and between April and August 2005 the overseas commission members each carried out an assessment review based on this framework. The Japanese commission members then made suggestions on the overseas commission members’ reviews. At the same time, the Japanese commission members drafted an overall report (this ICRC Report) based on the contents of the four review reports and, after receiving the consent of the overseas commission members, inserted it at the beginning of the full report.

2-2. ICRC Members

In order to conduct an objective and critical assessment of the New Nuclear Policy-Planning Council's *Interim Report*, committee members with academic ability and high theoretical and empirical skills were chosen from Japan and abroad. The people selected are all experienced and well-respected research and consulting professionals in the nuclear energy policy field.

When selecting the committee members, a common criterion was that they be critical of the reprocessing option, but care was taken to include both people who are opposed to and people who are not-opposed to nuclear energy. With regards to the overseas committee members, it was decided to appoint one person from each of the following leading atomic energy using countries: United States of America, United Kingdom, France, and Germany.

International Critical Review Committee on the Long Term Nuclear Program (ICRC) Overseas Panel Members:

Frank von Hippel (USA)
Professor of Public and International Affairs at Princeton University. Former Assistant Director for National Security in the White House Office of Science and Technology Policy. International authority on nuclear energy policy, whose statements have significant influence on issues not only in the U.S., but internationally as well. He is an advocate of "Citizen Science".

Fred Barker (United Kingdom)
Nuclear policy consultant. Member of the United Kingdom Committee on Radioactive Waste Management (CoRWM), appointed to the committee as an independent member by the UK government. Consultant specialising in nuclear policy analysis and stakeholder engagement.

Christian Küppers (Germany)
Deputy coordinator of the Nuclear Engineering & Plant Safety Division of the Institute for Applied Ecology (Oeko-Institute). Member of the German Commission on Radiation Protection. He is an international authority on nuclear safety and radiation protection, often in cooperation with Michael Sailer (Chairman of the German Reactor Safety Commission and Deputy Director of the Oeko-Institute).

Mycle Schneider (France)
International energy and nuclear policy consultant. Advisor to the German, French and Belgian governments on nuclear power policy. Former Director of WISE-Paris. Co-laureate of the Right Livelihood Award (also known as the Alternative Nobel Prize) with his colleage Jinzaburo Takagi for their joint work on plutonium issues.

International Critical Review Committee on the Long Term Nuclear Program (ICRC) Japanese panel members:

Hitoshi Yoshioka,	Professor, Graduate School of Social and Cultural Studies, Kyushu University (Chair of ICRC)
Tetsunari Iida,	Executive Director of Institute for Sustainable Energy Policies
Yuichi Kaido,	Lawyer
Takeo Kikkawa,	Professor, Institute of Social Science, The University of Tokyo
Yo Fujimura,	Assistant Professor, Graduate School of Science, Kyoto University

3. Characteristics of and Problems with the *Interim Report*

3-1. Conducting a "Comprehensive Evaluation" of the "Basic Scenarios"

First of all, in this section we will provide an overview of the characteristics of and problems with the *Interim Report*. The viewpoint presented in this section represents the common view shared by the Japanese and overseas commission members. Then, in the next section, we will introduce the main features of the reviews of the four overseas members.

In the *Interim Report*, the following four "basic scenarios" were established:
i. reprocessing of all spent nuclear fuel (presumes the operation of a second reprocessing facility);

ii. partial reprocessing (only the first reprocessing plant to reprocess spent fuel, interim storage followed by direct disposal of spent fuel that exceeds reprocessing capacity);
iii. direct disposal of all spent fuel;
iv. moratorium case (interim storage for the time being, then at sometime in the future decide between reprocessing of all spent fuel or direct disposal of all spent fuel).

The *Interim Report* assumed that for those scenarios involving reprocessing, the reprocessing plant will always operate at planned capacity (100% capacity, costs held within cost estimates). With regards to these four scenarios, a comprehensive evaluation was carried out for the following ten issues:

(1) safety assurance
(2) energy security
(3) environmental compatibility
(4) economic considerations
(5) nuclear non-proliferation
(6) technical viability
(7) social acceptability
(8) assurance of choice (flexibility)
(9) issues associated with policy change
(10) overseas trends.

The *Interim Report* concluded that, with regards to the nuclear fuel cycle backend policy, it was rational to adhere to the reprocessing centered option.

3-2. The Conclusion to Adhere to the Current Policy

In addition, the *Interim Report* determined that the basic policy would be adherence to current policy. The three most important points of the historical reprocessing policy are as follows.

i. With regards to the management of spent nuclear fuel, reprocessing is considered the only implementable option. Laws and ordinances which effectively bind private companies are firmly maintained and legal interpretation of them by the administration is not altered. Legal measures to make direct disposal of spent fuel possible will not proceed.
ii. Private enterprise is expected to smoothly startup and operate the Rokkasho Reprocessing Plant. The government will not intervene to adjust output in order to maintain balance between plutonium supply and demand.
iii. A mechanism will be put in place to enable private enterprise to retrieve the costs associated with reprocessing. (In this regard, the Electricity Industry Committee of METI's Advisory Committee for Natural Resources and Energy proposed the enactment of a *Reprocessing Fund Law*. The Atomic Energy Commission gave its approval for this.)

However, there is one important change from existing policy. This is that research and development into direct disposal was suggested on the grounds that technological development takes place in order to respond to future uncertainties. (This is specified in the *Draft Nuclear Energy Policy Outline*.)

3-3. Problems with the Methodology of the Comprehensive Assessment

The *Interim Report* adopted an “comprehensive assessment” method based on multiple options. The adoption of this methodology is to be commended. However, the most obvious approach, namely to choose the best policy based on an overall policy assessment was not adopted.

Policy is something which indicates the government's views regarding the methods of achieving a certain goal. The government chooses as its policy the best of the various options available. The priority and weighting assigned to the various criteria and issues of assessment are determined depending on the objectives established. Of course, the appropriateness of the policy goal itself must be examined from the point of view of public benefit.

As policy options, aiming to reprocess all spent nuclear fuel, or aiming to directly dispose of all spent nuclear fuel, are policy options with specific meaning. The strategies required in order to aim for a desired state must also be included within these options. When such strategies are drawn up, of course, all de facto conditions (initial conditions, boundary conditions) concerning the backend operations, must be taken into consideration. Among these, the six most important points are as follows:

i. Japan already holds over 40 tons of plutonium from reprocessing carried out in England and France.
ii. There is no existing program capable of consuming huge quantities of plutonium (such as the use of MOX fuel in light water reactors, or the fast-breeder reactor cycle program) and there is no prospect in sight of realizing such a program.
iii. The Japanese government has publicly pledged to the international community that it will not hold surplus plutonium.
iv. The international nuclear disarmament and nuclear non-proliferation regime is in serious danger of falling apart and the commencement of operations at the Rokkasho Reprocessing Plant will have an effect on this situation.
v. There is no prospect in sight for final disposal of the high-level radioactive waste (vitrified waste) which results from reprocessing.
vi. There is no prospect in sight for dealing with the spent MOX fuel that results from the utilization of plutonium.

When developing a strategy, it is necessary to take into account these various de facto conditions, along with the uncertainties associated with reprocessing and the business risks which accompany these uncertainties. The best policy from among those policy options that incorporate such a strategy should be chosen. Of course, what is deemed the best policy will change depending on how the various factors governing the backend operations change in the future. However it is not possible to estimate future changes with a high degree of accuracy. Therefore, there are hazards associated with making a judgment about the best option and it is necessary to include many disclaimers in regard to future uncertainties. When future generations retrospectively assess today's policies, they will also scrutinize whether or not consideration of the uncertainties was appropriate.

However the *Interim Report* completely bypassed the above mentioned comprehensive policy evaluation and instead did something that is similar but not the same. It presented abstract “project implementation scenarios” under the name of “basic scenarios”, which take into consideration neither policy goals, nor de facto conditions, nor project uncertainties, nor the risks associated with them, then conducted a comprehensive evaluation of these scenarios. This effectively became a “general comparative assessment” between the reprocessing and direct disposal methods. (Actually, it is also inadequate as a “general comparative assessment”. A symbolic proof of this is the addition of the cost of a change of policy to the issues for assessment. In a general comparative assessment, a smuggling of initial conditions cannot be done. A partial, methodologically eclectic assessment was carried out so as to obtain a result that is advantageous to adhering to the pro-reprocessing policy.)

The fatal defect which resulted from employing this methodology was that an assessment of some selectable policies was bypassed and the policy which was considered to be the best by the great majority of people was left out of the options from the outset. That option was as follows: regardless of the route taken in future, put a freeze on reprocessing until progress is made in consuming the existing plutonium from reprocessing in Britain and France. (If this policy option had been adopted, a situation similar to the moratorium case in the Interim Report might or might not have been attained. Generally speaking, just because a policy option aiming for a certain condition is adopted, it does not necessarily follow that the “basic scenario” corresponding to that condition will be realized. Rather, it would not be surprising if the correlation between the two were low.)

Abruptly, from the general comparative assessment of the two methods, a conclusion which completely adheres to current policy, was derived as a realistic policy choice. Even supposing that one arrives at the conclusion that the reprocessing option is in general a better choice, it is still a big logical jump to get from there to a conclusion which entirely affirms the current policy. Is it not necessary to carry out a careful assessment from the point of view of the public benefit for each and every policy?

3-4. Problems with each of the Individual Assessment Items

The scenario assessment in the *Interim Report* is effectively a comparison of the reprocessing and direct disposal methods. However, it is not necessarily possible to conduct a simple comparison of the strengths and weaknesses of these two methods. Therefore, for each issue assessed (nuclear non-proliferation, safety, energy security, economics, environmental compatibility, etc), depending on which assessment criteria are employed and which criteria are prioritized, the result of the assessment of the advantages and disadvantages of the two methods will change greatly. In this context, it must be said that the balance of the assessment criteria used in the *Interim Report* was seriously distorted. An overall characteristic was that those perspectives which where advantageous for reprocessing were emphasized, while those which were disadvantageous were either not taken into consideration or were downplayed. With regards to direct disposal, there was a pronounced tendency to take the opposite approach. The real weaknesses of reprocessing were considered to be of no significance. On the other hand, imagination was employed to the utmost when listing the weaknesses of direct disposal, while no opposite point of view was provided. The assessment problems of each individual item are concisely listed below.

(i) Nuclear Non-Proliferation

The *Interim Report* concludes that as long as appropriate safeguards and measures to protect nuclear material are adopted, there is no significant difference between reprocessing and direct disposal. In other words, they assume that the rules will be strictly followed, and find reprocessing and direct disposal to be equal. However, it is clear that the proliferation risk brought about by the separation of plutonium (reprocessing) places a further burden on nuclear material management, so the grounds for determining them to be equal is obscure.

(ii) Safety Assurance

Following the same line of argument, the *Interim Report* judged both scenarios to be equal. However, it inappropriately assumed that there could not be a severe accident at the reprocessing plant, or that an accident could not occur at one of the various facilities associated with the reprocessing plant (for example, an accident involving a leak of high-level liquid waste). Also, this approach is inappropriate with regards to radiation exposure and radioactive leaks during normal operations, because it is not in keeping with the spirit of the ALARA principle (As Low As Reasonably Achievable). Daily releases of radioactivity from nuclear reprocessing plants are thousands of times greater than those of nuclear power plants [see STOA Report].

(iii) Energy Security

The *Interim Report* only considered uranium resource savings in concluding that the reprocessing scenario was superior. However, for decades to come, it is hard to imagine a situation where uranium will become difficult to obtain due to shortage of supply. Even if this is assumed, a comparative assessment of the effectiveness of other alternative countermeasures (such as increasing a uranium reserve) should have been carried out, so the grounds for the *Interim Report*'s conclusion are obscure here too. The *Interim Report* also ignored the management risk which will result from the heavy economic burden of reprocessing and the consequential risk of unstable electricity supply.

(iv) Economic Considerations

The *Interim Report* found the direct disposal scenario to be superior for this item. The results of calculations of backend related costs for the 59 year period to the year 2060 were that the scenario involving reprocessing of all spent fuel would cost 1.6 yen/kWh, while the scenario involving direct disposal of all spent nuclear fuel would cost between 0.9 and 1.1 yen/kWh. The ratio of the two scenarios was between 1.5 and 1.8. Of all the assessments carried out, this was the most quantitative analysis and the only analysis to yield a well-founded result. However, by accentuating the cost of a change of policy (where full spent fuel storage pools lead to the stoppage of nuclear power plants), the *Interim Report* drew the conclusion that the direct disposal option was not necessarily superior. But the grounds for this conclusion were extremely weak. The *Interim Report* completely ignored the extremely high economic uncertainties of the reprocessing option (accidents etc., supply balance adjustment, changes in the international political situation, changes in public opinion, and so on) and the management risks which accompany these uncertainties. When a concrete policy for action is decided, it is essential that these uncertainties and management risks be taken sufficiently into consideration. However, in a project assessment of abstract, fanciful business plans under the name of "basic scenarios", such factors fall outside the scope of consideration.

(v) Environmental Compatibility

The *Interim Report* pointed to the compactness of the high-level waste repository site and argued that since plutonium reutilization would be a method of "recycling", as such it would be highly compatible with the goal of achieving a closed-loop economy*. On this basis the *Interim Report* found the reprocessing scenario to be superior. On the one hand, it strongly emphasized that risks associated with final waste disposal are greatly reduced by removing the plutonium, even though in reality the effect of removing plutonium is not very great. On the other hand, it concluded that emissions of radioactivity (during regular operations, and during accidents) are of no significance. The fact that huge amounts of low and intermediate level waste are generated as a result of reprocessing and the dismantling of associated facilities was also not taken into consideration. With regards to spent MOX fuel, the *Interim Report* assumed that it could be reprocessed and reused over and over again without problem, but no consideration was given to the effects of its strong radioactive toxicity and its degrading plutonium quality.
[* ‘Closed-loop economy’ is one possible translation of the Japanese term ‘junkangata shakai’, but there is no completely satisfactory translation. It is a uniquely Japanese term, which refers to a society where the environmental impact due to waste is kept to a minimum. In Japanese bureaucratic parlance it is commonly translated as ‘recycling-based society’. Promoting recycling is certainly one of the means, but if one takes into consideration the fact that recycling doesn't always result in a reduced environmental burden, it is a misleading translation.]

(vi) Flexibility (Assurance of Choice)

The Interim Report *made the assumption that, because reprocessing leaves open the possibility for future development, a fundamental quality of reprocessing is that it provides flexibility of choice. In addition, it took the view that by proceeding with reprocessing, the current technological infrastructure and international understanding (previously obtained agreement) in regard to Japan's reprocessing operations will be maintained. For these reasons it found reprocessing to be superior. However, as noted above, the* Interim Report *suggested that research and development into direct disposal should be carried out in order to respond to future uncertainties. It is therefore difficult to comprehend why the conclusion that adherence to the reprocessing option is highly flexible was not adopted consistently throughout the report.*

In addition to the above, the *Interim Report* also carried out investigations in regard to “technical viability” and “social acceptability”. An acknowledgment of “overseas trends” was also included. The overall conclusion was that the reprocessing scenario was superior to the direct disposal scenario. In order to reach this conclusion, it is necessary to apply a weighting to each of the individual items, but this was not done. Admittedly, given that the *Interim Report* judged that direct disposal was inferior under every criterion (putting to one side the validity of that assessment), regardless of the weighting applied, the same conclusion would have been reached.

3-5. A Summarization of the Problems

As indicated above, the *Interim Report*, contains serious flaws in both the logical structure and in the assessment of the individual items. This is the conclusion of the international assessment carried out by Japanese and overseas experts. The suggestion that foreigners are unable to assess the Japanese case is fundamentally not applicable. This is because the reasoning of the *Interim Report* pays almost no attention to the peculiarities of the Japanese situation. The style of debate developed in the report is essentially universal.

4. Results of the reviews by overseas panelists

4-1. Overall characteristics

In this section the overall characteristics of the review by the four overseas panelists, along with the characteristics of each of their individual reports, will be briefly introduced. All of the panelists, with respect to their special fields of expertise, provided a broader and deeper analysis and evaluation than was offered in the brief overview in the previous section. Each in his own different words identified a general problem with the Interim Report. This was the lack of clarity in regard to the evaluation criteria and the lack of any clear weighting system for the ten issues evaluated. The Interim Report's evaluation criteria for the ten issues are not in themselves particularly complicated. The reason why they were criticized in this way is that the Interim Report emphasized those issues which are favorable for reprocessing and ignored or downplayed those issues which are unfavorable for reprocessing. As a result, the priority of the issues for evaluation is difficult to understand in any systematic way. The Interim Report used these unbalanced evaluation criteria to draw the conclusion that reprocessing is superior. However, because of the low reliability of the evaluation method, all of the overseas panelists judged that the reliability of the conclusion was extremely low.

In regard to the evaluation of each individual issue, the overseas panelists made many similar comments to those made by the Japanese panelists and also to the comments made by those members of the New Nuclear Policy-Planning Council who were critical of the reprocessing option. This confirmed and strengthened our own understanding.

The overseas panelists' reviews contained very critical comments on three of the issues: safety, environmental compatibility and non-proliferation. On the other hand, there was little discussion of the cost of a change of policy. Also there wasn't much discussion about energy security. To some extent this reflects the peculiar realities of Japan. However, more importantly, from an international perspective, it might have been quite unbelievable for them that the Japanese government would decide to use plutonium on the basis of this type of reasoning.

Below are some of the important points made by more than one of the panelists.

In regard to safety, the Interim Report made no mention of the fact that highly active liquid waste at reprocessing facilities in both the UK and France has accumulated beyond the quantity predicted. This is due to the fact that the reprocessing plants and the vitrification facilities have not operated smoothly. The panelists pointed out that this is a very serious problem.

In regard to environmental compatibility, for the full reprocessing scenario the Interim Report only considered the glass canisters from reprocessing spent uranium fuel. The effect of the radioactivity and the heat generation of spent MOX fuel were completely ignored. The overseas panelists assumed that since an evaluation of the scenarios was carried out for the Interim Report, obviously a life cycle assessment for the reprocessing scenarios must also have been carried out, including an assessment of the environmental compatibility conditions of the spent fuel from plutonium-containing MOX fuel. They raised questions about concluding that reprocessing was superior without conducting such an assessment. The unsoundness of the evaluation of the scenarios was clearly demonstrated in regard to this point.

Besides these points, they also raised questions about the Interim Report's emphasis on Japan's lack of technical know-how in regard to direct disposal, despite the fact that there are countries which have chosen the direct disposal option. This point was repeated to a surprising degree in the Interim Report under such issues as 'safety assurance' and 'technical viability'.

The overseas panelists' comments also showed their great interest in the international problem of nuclear proliferation. The Interim Report stated that on this issue there was no significant difference between reprocessing and direct disposal. However, the overseas panelists made several incisive criticisms of this view. They pointed out that, in regard to preventing proliferation, totally different scales in time (present and distant future) and space (surface facilities for handling plutonium and sub-surface disposal facilities) were conflated. The point was made that the so-called 'plutonium mine' problem identified for the direct disposal option also applies to the disposal of glass canisters. The overseas panelists also noted the grave implications of Japan's choice for international peace.

4-2. Particular features of each individual report

4-2-1. Fred Barker (UK)

Mr. Barker welcomed the fact that the New Nuclear Policy-Planning Council developed several future scenarios for the management of spent fuel and evaluated a broad range of issues, both technical and social. However, because the evaluation method itself was not sufficiently robust or rigorous, he concluded that it did not produce a reliable policy decision.

Mr. Barker pointed out that an overall problem with the evaluation method is that two obvious analyses were not carried out. First, there was no sensitivity testing, for example of the effect on the relative merits of each scenario of changes in quantitative conditions, such as energy supply and demand. Second, there was no systematic analysis of the implications of changes in key assumptions ('what if' analysis), for example, failure of reprocessing and vitrification facilities to operate smoothly, as has occurred in the UK .

In his review he gave specific examples of how each issue evaluated in the Interim Report was evaluated from a very narrow point of view. In particular, he cited the situation in the UK, where a large quantity of highly active liquid waste has accumulated at the commercial scale reprocessing plant in Sellafield due in part to difficulties with the vitrification facility. This has become a matter of considerable regulatory concern. It is a major failure of the Interim Report that this important safety issue was not considered.

The lack of balance in the discussions carried out by the New Nuclear Policy-Planning Council can be seen throughout the Interim Report. Problems which have actually occurred as a result of reprocessing were mentioned above, but the Interim Report treated them as if they were insignificant. On the other hand, the reduction in the 'inherent radioactive harm' as a result of extracting the plutonium from the final waste was emphasized as evidence of the superiority of reprocessing. This argument has been around for a long time. However, in regard to geological disposal, it is recognized by people in the nuclear energy field that the important issue is the mobility of the radioactive isotopes. Therefore, the problem for safe disposal is isotopes other than plutonium. Reducing the level of radioactivity by removing the plutonium does not translate directly into increased safety in terms of reduced radiological dose. Mr. Barker also indicated that there may be little difference between disposal of glass canisters and direct disposal in regard to the level of safety.

In regard to the cost of a change of policy, he said that, in the case where the reprocessing plant is not operated, including the cost of building replacement thermal power plants is an extreme scenario. In a more realistic scenario, new interim storage facilities could be built to avoid nuclear power plant closures. He also said that the money already invested in the construction of the reprocessing plant should be treated as a sunk cost and should not be included in the cost of a change of policy.

Mr. Barker did not attempt to refute the conclusion that reprocessing is superior. He provided a constructive assessment. The nuclear fuel cycle is an issue with sharp divisions between those for and against. He recommended that the scenarios to be evaluated and the evaluation criteria, which he critiqued in his review, should be improved. He said it is desirable that a policy decision should be informed by analytical methods such as numerically weighted multi-criteria assessment and strengthened implementation analysis. The view of people with different points of view should be obtained and assessed through stakeholder participation, as is being done in the UK.

4-2-2. Mycle Schneider (France)

Mr. Schneider investigated in detail the unbalanced, one-sided nature of the evaluation criteria for all of the ten issues evaluated in the Interim Report. His report overlaps with those of the other panelists, but Mr. Schneider emphasized in particular the gaps in the Interim Report from the perspective of safety and security in the context of terrorism, such as the September 11, 2001 attack in the US.

The Interim Report emphasized the 10-20% uranium saving resulting from reprocessing. However, Mr. Schneider presented the reality in his own country, France, which is the world leader in the commercial use of plutonium and where in 2004 nuclear power accounted for 78% of electricity supply. However, nuclear power plants supplied only 42% of commercial primary energy use in France and only 17.5% of final energy use. The use of plutonium in light water reactors accounts for about 10% of that, so plutonium is of only marginal significance to France’s energy supply, providing only 1% to 2% of the final energy consumed in the country. Mr. Schneider pointed out that it would be quite possible to replace it in ways with lower associated economic and social costs. It is still the case that 71% of France’s final energy consumption is covered by fossil fuels and that both these and uranium are imported. Furthermore, he questioned why Japan should be in a rush to start up a reprocessing plant, given that the 40 tons of plutonium already owned by Japan is equal to the amount consumed by France over 25 years.

Mr. Schneider pointed out the ineffectiveness of reprocessing for energy security, given that fast breeder reactors have failed worldwide. He also emphasized that throughout the world in recent years the recognition that acceptance of nuclear power is increased if plutonium is not used has been gaining strength, even among proponents of nuclear energy.

The Interim Report said that in the case of direct disposal, because the final waste contains plutonium, it is more difficult to find disposal sites. Mr. Schneider questioned the basis for this claim, pointing out that the strongest opposition worldwide has been to facilities which handle plutonium, such as reprocessing facilities. The Interim Report said that if a policy decision is postponed and temporary storage is continued, local residents will fear that a final repository will not be found and interim storage facilities will become semi-permanent facilities. Consequently, it is difficult to find interim storage sites. Mr. Schneider’s response was that the role of the operators and local and federal authorities is precisely to resolve this mistrust.

Mr. Schneider is well versed in the circumstances of nuclear energy in Japan. He provided a detailed analysis of each issue for evaluation. He emphasized that, considering the Japanese public’s great mistrust towards nuclear energy, to choose to use plutonium on the basis of the unbalanced arguments provided in the Interim Report would do nothing to reduce that public distrust.

4-2-3. Christian Küppers (Germany)

Mr. Küppers focused principally on three of the Interim Report’s issues for evaluation: safety assurance, environmental compatibility and nuclear non-proliferation. From these perspectives, he concluded that reprocessing is the least desirable and that direct disposal is the most desirable choice. He argued powerfully for the opposite conclusion to the Interim Report on the grounds that the Interim Report was wrong to ignore;

i. radiation doses below the dose limits established by the International Commission on Radiological Protection (ICRP);
ii. the possibility that accidents beyond the design basis might occur;
iii. differences in the number and kind of facilities where major accidents could occur;
iv. the physical limits of safeguards;
v. appropriate weighting of the different evaluation criteria.

Mr. Küppers's conclusion is not based on a comprehensive analysis of all the issues for evaluation, so it is debatable whether it can be accepted as is. However, his review is a good example of how the conclusion reached from an evaluation of the scenarios can change as a result of the choice and weighting of criteria. The Interim Report concluded that there is no significant difference between reprocessing and direct disposal in regard to safety and nuclear non-proliferation and that reprocessing is superior to direct disposal in regard to environmental compatibility. However, Mr. Küppers (along with all the other overseas panelists) concluded that direct disposal is far superior on all these issues. Thus, it is not possible to deduce that reprocessing is the superior option in the simplistic fashion of the Interim Report. It is necessary to redo the assessment, fairly evaluating each criterion and giving appropriate weightings to the different criteria. Mr. Küppers's arguments are briefly summarized below.

Regarding safety assurance, of course nuclear energy facilities must fulfill the required safety standards, but that doesn't amount to a guarantee of safety. There is a big difference between the reprocessing path and the direct disposal path with respect to the risk of a disastrous accident and the risk of worker exposure to radiation. In the reprocessing path, reprocessing plants, which discharge at least four orders of magnitude more radioactivity than nuclear reactors, and MOX fuel fabrication plants, which result in two orders of magnitude higher radiation exposure for workers than uranium fuel fabrication plants, will be operated. Compared to the direct disposal path, in which the radioactive materials are sealed in the spent fuel through interim storage to final disposal, in the reprocessing path there are many scenarios in which large quantities of radioactivity may be released. The reprocessing path entails great risk of radiation exposure to workers and to the general public. Although the dose during normal operations of a reprocessing plant may be lower than natural radiation and the ICRP limits, the exposure of the public should be kept as low as reasonably achievable. Therefore, it is a mistake to argue that there is no difference between direct disposal and reprocessing.

In regard to compatibility with a 'closed-loop economy', Mr. Küppers points out that after reprocessing the volume of radioactive waste is larger than before, but only a negligible part of the radioactivity in the spent fuel is separated for reuse. Also the heat generation and radioactivity of the spent MOX fuel is very great, so it is absolutely wrong to say that reducing the quantity of resources used and waste produced, reusing and recycling create a closed-loop economy and that reprocessing is consistent with this philosophy.

From the perspective of nuclear proliferation, a problem for reprocessing and MOX fuel fabrication plants is that international safeguards, designed to prevent theft of plutonium and its diversion to nuclear weapons, cannot function effectively. This is a physical limitation of safeguards-based inspections. When managing the quantity of plutonium on the basis of 'countable items', for example spent fuel assemblies, the error is small. However, in 'bulk-handling facilities' like reprocessing plants and MOX fuel fabrication plants, where plutonium is handled in great amounts in free-flowing separated form, unavoidably the measurement error far exceeds the quantity required to produce a nuclear weapon. The Interim Report downplays these practical risks. It gives the same weight to the risk of plutonium being dug up from a geological repository in the far distant future, when plutonium and nuclear weapons may have lost the military importance that they now have, as to the real and present above ground risk. In this future scenario it assumes, completely unrealistically, that this massive operation could be carried out unnoticed. Mr. Küppers is very sceptical of this comparison.

4-2-4. Frank von Hippel (USA)

Mr. von Hippel provided examples to precisely and concisely illustrate the one-sided nature of the Interim Report's evaluation. He expressed great concern regarding the safety of the reprocessing plant. Also, from the standpoint of an overseas panelist, he placed great importance on the problem of proliferation, arguing that the start-up of the Rokkasho Reprocessing Plant is not just a domestic issue but also an international issue. The first problem is that it makes it easier for terrorists to get hold of plutonium. As he points out, "plutonium separated *anywhere* is a potential threat to cities *everywhere*". The second problem is that, at a time when countries suspected of being a proliferation concern are making moves to build nuclear fuel cycle facilities, Japan's example undercuts ongoing international efforts to resist this growing trend.

Mr. von Hippel pointed to serious problems with the Interim Report's argument that the proliferation risk associated with reprocessing is of the same level as the risk associated with direct disposal. The proliferation risk associated with direct disposal is that in hundreds of years' time terrorists might raid the spent fuel repository a few hundred meters underground and steal the plutonium. This plutonium would have to be extracted from the strongly gamma-emitting spent fuel inside metal containers, each weighing tens of tons. Mr. von Hippel argues that, if there are central governments hundreds or thousands of years in the future, "they ought to be able to keep terrorist groups from recovering plutonium from a central nuclear-waste repository hundreds of meters underground much more easily than a government today could prevent the theft of plutonium in surface storage, processing or transport." Terrorists can approach MOX fuel without heavy shielding from gamma rays. This is a definitive difference between the scenarios. The Interim Report said that once the gamma radiation has decreased, between a few hundred and a few tens of thousands of years from now, the spent fuel repositories in the direct disposal scenario will become ideal plutonium mines for terrorists. However, Mr. von Hippel points out that there will also be significant quantities of plutonium in the glass canisters produced in the reprocessing scenario. If the reprocessing plant operates for forty years, enough plutonium for 400 nuclear weapons will accumulate in the material buried with the glass canisters. Furthermore, he warns, "if plutonium is still being separating and recycled in that distant future, it will still be more difficult to protect on the surface than the dilute plutonium stored in a few national repositories under hundreds of meters of rock."

The large-scale use of plutonium extracted through reprocessing will indicate to other countries that Japan has gained the nuclear-weapons option. Consequently, proceeding with reprocessing in Japan provides a justification for other countries which say that all countries have the right to their own nuclear fuel-cycle plants. In support of this position, Mr. von Hippel cited the example of statements made to him by high-level Iranian officials. He concluded that if Japan, the only country thus far to have cities devastated by nuclear bombs and the home to the world's leading nuclear disarmament movement, decides to use plutonium, it will have a huge impact on other countries and will do severe damage to the international nonproliferation regime.

5. Assessment of the cost of a change of policy

5-1. Why treat the cost of a change of policy as a separate issue?

The four overseas panelists discussed the issues of nuclear non-proliferation and safety in detail, but there were relatively few critical remarks regarding the other issues (security of supply, cost of a change of policy, etc.).
As in Japan, in Europe and in the US, common sense dictates that due economic compensation should be provided in a situation where freezing or terminating the reprocessing option would have a large impact on the local economy. However, the Interim Report argued that freezing or terminating the reprocessing option would rapidly lead to a deadlock in the management of spent nuclear fuel; that there was a high possibility that this in turn would cause the majority of nuclear power plants to cease operating long-term; and that the cost of constructing and operating replacement thermal power plants should be included in the cost of a change of policy. This story line was probably all a bit too far-fetched for not only to Japanese Panelists, but also the European and US panelists. It was difficult for us to come to terms with

the fact that the Interim Report was seriously arguing this case and that this argument permeated the overall assessment.

Nevertheless, this issue played an important role in the deliberations of Japan's New Nuclear Policy-Planning Council. Furthermore, the costs the *Interim Report* links to a policy change are quite large. To the extent possible, people associated with Japan's nuclear industry wanted to avoid these costs. It could be interpreted to be a major motivation for their support for sticking with the existing policy. For that reason it was judged necessary that the Japanese panelists provide a separate analysis for this one issue. The issue is discussed below.

5-2. The Interim Report's evaluation methodology in regard to the cost of a change of policy

The Interim Report assumes that if the current reprocessing policy were frozen or changed, there would be no further increase in spent fuel storage capacity (onsite storage and interim storage) and the 1,000 tons of spent nuclear fuel already accepted by the Rokkasho Reprocessing Plant would be returned to the nuclear power plants where it originated.

As a result, it was assumed that the spent fuel storage pools established at the nuclear power plants would fill up one by one, and, one by one, the nuclear power plants would shut down. The view of the Interim Report was that there was a high probability that this would happen. Even in the most favorable case there would be no extra storage capacity until 2015, while in unfavorable circumstances this situation would continue until 2020.

As a result, almost all nuclear power plants would cease operating. The Interim Report judges that the cost of this would be between 11 trillion and 22 trillion yen (for replacement thermal power plants and increased use of existing thermal plants).

Furthermore, in addition to the above costs, the Interim Report included the cost of construction and dismantling of the Rokkasho Reprocessing Plant (a little less than 3 trillion yen) in the total cost. This is a relatively low figure compared to the above amount, but it is nevertheless huge and it gives the reader the impression that a change of policy would entail a huge economic burden.

5-3. Errors in the long-term nuclear power plant shut down scenario

However, it is inappropriate to include the cost of construction and dismantling of the Rokkasho Reprocessing Plant (a little less than 3 trillion yen in total) in the total cost. The construction cost has already been invested and the cost of dismantling is an unavoidable cost. These are not costs which will be incurred in future as a consequence of a change of policy. These are sunk costs. In fact, there would be considerable savings linked to policy change if it occurs before the plant goes into active testing and gets plutonium contaminated.

In addition, the long-term nuclear power plant shut down scenario contains the following three errors.

1. Even if reprocessing proceeds, in the case of accidents, or due to adjustments in the plutonium supply and demand balance, there is still the risk of a long-term shut down of the Rokkasho Reprocessing Plant, or that it will be forced to operate for an extended period of time at low capacity. In such cases the same risks as those discussed above arise, so there should be no great difference between proceeding with reprocessing and freezing or changing the existing policy. However, no consideration is given to this in the Interim Report.

2. Long-term dry storage of spent nuclear fuel has relatively few safety problems compared to other types of nuclear facilities. Therefore, from the perspective of protection from risks to life and health, it

should be easier to find a site for this type of facility than for other nuclear facilities. The idea that it would take even longer to find a site for such a facility than for a nuclear power plant (that in the most favorable case there would be no progress for 10 years) is unreasonable. For example, in Germany since July 2005 spent fuel shipments to reprocessing plants are totally banned, and all spent nuclear fuel is stored at on-site dry storage facilities. We are told that gaining the acceptance of the local communities was not particularly problematic.

3. A long-term stoppage of the majority of nuclear power plants as a result of the overflow problem of spent fuel storage pools would be a serious situation for all concerned. The consequence would be that the whole nuclear power system (including the nuclear fuel cycle system) would be seen as high risk and inadequate in regard to security of supply. It would lose the support of the market and of the general public and be faced with extinction.

However, this is not a risk associated solely with a change of policy. It is a risk that could also easily re-emerge in association with repeated accidents, or with adjustments to the plutonium demand and supply balance. So if there is any reality in this scenario, it is because nuclear power by nature entails high risk of cost escalation and is inferior in regard to security of supply. Nuclear power is having enough problems surviving in a liberalized electricity market. It is quite likely that it will disappear as a result of natural selection. Moreover, if lots of replacement thermal power plants were built, they would take away the demand for existing nuclear power plants which had been closed for a long period of time. One would predict that they would be shut down permanently.

Consequently, the long-term nuclear power plant shut down scenario is not realistic. If it ever began to happen, there is a strong possibility that it would develop into an organized nuclear phase-out scenario.

5-4. The real problem associated with a change of policy

Despite the fact that the above scenario is not realistic, the fact that it was given prominence in the Interim Report suggests that the ‘real costs of a change of policy’ associated with putting a freeze on reprocessing are considerable. These ‘real costs of a change of policy’ are not costs of a type which the public will pay. They are costs which people associated with the nuclear power industry will have to pay. Of course, some of them will be passed on to the public, but the consequences primarily will concern companies and institutions directly associated with the nuclear power industry.

The greatest of these ‘real costs of a change of policy’ is that people associated with the nuclear power industry will lose some of their special privileges. Even if reprocessing is not cancelled, just frozen for a while, the impact could be significant. The continued existence not just of reprocessing itself, but also of related businesses and of businesses which were approved on the assumption that reprocessing would become problematic. One such example is research and development into fast breeder reactor cycle technology. Furthermore, by freezing reprocessing, the sense of the whole nuclear power industry as an industry with poor development potential could be strengthened, or at least there is a high probability that this impression will be conveyed to the public. It is felt that there is a danger that the whole nuclear power industry could incur significant damage this way. This damage would not only be felt by people directly involved in the nuclear power industry, but by all people with a vested interest in the nuclear power industry.

Another important ‘real cost of a change of policy’ relates to the fact that the existing policy is propped up through the alignment of the vested interests of a large number of people. Changing this will arouse conflicts between these people. There is a strong possibility that constructing a stable new community of interests will be a slow process. There will be many associated risks and costs.

For example, the power companies signed a safety agreement with Aomori Prefecture regarding its acceptance of spent fuel on the assumption that the spent fuel would be reprocessed. If they breach this agreement, consultations will be demanded regarding return of this spent fuel and they will lose the temporary destination for their spent fuel. It is appropriate to take the view that this will not cause spent fuel pools to overflow and the majority of Japan's nuclear power plants to close down long-term, but it is true that power companies will be faced with a major problem. There is a high risk that they will have to pay various costs in the short term, even if they would save considerable funds in the future. As for the government, it is highly likely that as a result of a change of policy it will be forced to reallocate staff and budgets. Furthermore, if the policy change is carried out against the will of the power companies, it is possible that they, as the owners of the Rokkasho Reprocessing Plant, will claim damages from the government. Local districts that are economically and budgetary heavily dependent on the nuclear fuel cycle will not be able to look forward to the tax income that would have arisen from the operation of the reprocessing plant. They would be forced to drastically change their local development plans. They would demand preventative action and claim compensation, so it is understandable that no one wants to change this rigid status quo.

However, the Japan Atomic Energy Commission should not keep postponing a change of policy in deference to vested interests. It should decide on the best policy from the perspective of the public good. It should also devise policy measures adequate to ameliorate regional economic difficulties.

5-5. The uncounted costs of not changing policy

In evaluating the scenarios, if the cost of a change of policy is considered, but the cost of not changing policies is not considered, then clearly the evaluation is unbalanced. Most significant in this regard are the financial costs and the increased risk thereof. In regard to reprocessing, a huge investment has already been made in the Rokkasho Reprocessing Plant, including construction costs of 2.19 billion yen. However, if it is decided to proceed with the reprocessing option, there will be huge costs to pay in future, including the cost of constructing and operating a MOX fuel fabrication facility. If a second reprocessing plant is constructed, the costs will escalate further. Furthermore the Interim Report estimates that the reprocessing option will be much more expensive than the direct disposal option. However, this estimate is based on the assumption that the Rokkasho Reprocessing Plant will operate perfectly at full capacity. The risk that it might not achieve this for one reason or another is not considered at all.

If that risk becomes a reality, besides the fact that reprocessing will come to a standstill, the unit cost of reprocessing will escalate. There is a real possibility that this will put pressure on the management of the power companies. This will stimulate action from investors and influence financial markets. The impact could even ripple through the entire Japanese economy. If the financial difficulties become long-term, reprocessing will be abandoned. There is also the possibility that the public will have to pay the huge bankruptcy costs.

Some members of the New Nuclear Policy-Planning Council repeatedly demanded that an assessment be made of the uncertainties associated with reprocessing and the management risks and the financial risk to the public that these entail. However, in contrast to the cost of a change of policy, this was almost totally ignored. The two cases should have been compared from the perspective of public benefit.

6. Conclusion

Given that in the past the back end of the nuclear fuel cycle had been completely excluded from policy debate, the fact that this Interim Report considered placing a freeze on reprocessing and direct disposal as policy options could be seen as a step forward. It was also laudable that the Interim Report acknowledged that economic analysis showed that direct disposal is much more economic than reprocessing. However, in regard to the other judgments made, there were serious deficiencies both in logical structure and in the evaluation of individual issues. Consequently, it failed to prove that, from the point of view of public benefit, the existing policy regarding the reprocessing of spent fuel is the best policy. The report of the international assessment panel proves that the Interim Report was a failure in this regard.

Overall, this report confirms that both overseas and Japanese panelists shared the same basic understanding, the overseas panelists identifying the same problems as the Japanese panelists. In particular, both agreed that the Interim Report based its decision on a very crude evaluation.

The main aim of the International Committee was to investigate the appropriateness of the Interim Report, rather than to propose an alternative policy. The latter is the job of a sister group, known as the BEAR Group. This group is working in parallel with the International Committee. Many of the members of the International Committee are also participating in, or cooperating with the BEAR Group.

The conclusion that can be drawn from the International Committee's investigation is that the Atomic Energy Commission should re-evaluate the policy on the back end of the nuclear fuel cycle articulated in its draft Nuclear Policy Outline. It should demand that Japan Nuclear Fuel Ltd. put a freeze on operations at the Rokkasho Reprocessing Plant, while it conducts an investigation, based on correct methodology, to discover what is the appropriate policy option.

If the Atomic Energy Commission conducts this investigation itself, it will be necessary for a new council to be chosen, with membership that can debate for and against the current policy in a holistic and balanced fashion, under a neutral chairperson with a neutral secretariat.

If the Atomic Energy Commission is unable to establish an appropriate policy decision-making forum, the government should take responsibility for establishing a new decision-making forum, in an organization other than the Atomic Energy Commission, to conduct a new review. This review should not focus narrowly on nuclear energy policy, but should investigate nuclear energy policy, including the back end of the nuclear fuel cycle, in the context of the entire energy policy framework.

Chapter 2

ICRC REVIEW

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1. Introduction

This paper is a contribution to the international review of the interim decision of the New Nuclear Policy Planning Council on nuclear fuel cycle policy in Japan.

In preparing the paper, the author has used the translation of the Planning Council's Interim Report by the Citizens' Nuclear Information Centre (CNIC)[1]. The author has also had the benefit of discussions with members of the ICRC and its secretariat during a visit to Japan at the end of March, 2005.

The paper has the following structure:

- Section 2: Deficiencies in the Planning Council's Assessment Method
- Section 3: Key Issues in Judgements of Scenario Performance
- Section 4: Methods for Improved Assessment
- Section 5: Stakeholder Participation in Assessment
- Section 6: Conclusions

2. Deficiencies in the Planning Council's Assessment Method

In principle, two central features of the Planning Council's approach to assessment are to be welcomed:

- the development of scenarios[2] which encompass a wide range of possible spent fuel management futures; and
- the identification of assessment criteria that encompass a broad range of relevant technical and social issues.

However, as far as the author can judge from available material, this promising start is not built upon to develop a robust and rigorous assessment method. In particular:

a). *There is an insufficiently systematic and rigorous approach to judging scenario performance against criteria*

As outlined in Section 3, many of the evaluations against specific criterion are open to criticism, with a need for a more robust and rigorous approach.

[1] CNIC [Internet]. Translation of the AEC Planning Council's Interim Report Concerning the Nuclear Fuel Cycle Policy. [updated 12 November 2004]. Available from: http://cnic.jp/english/topics/policy/chokei/longterminterim.html. (Also attached at the end of this report).
[2] The four scenarios are: 1 reprocess all spent fuel; 2 reprocess spent fuel, but direct dispose of the quantity which exceeds the capacity of the Rokkasho reprocessing plant; 3 direct dispose of all spent fuel; and 4 store spent fuel and decide in the future whether to reprocess or dispose.

b.) There is no formal assessment of the relative importance of the different criteria

It is not immediately obvious whether the Planning Council considers all criteria to be equally important, or whether it is making implicit assumptions that some criteria are more important than others. The Planning Council's views and reasoning about the relative importance of different criteria should be made explicit, as should the impact of these views on the overall assessment.

c). There is no attempt to undertake any sensitivity testing to explore how varying assumptions and judgements might impact on the overall assessment

For example, the assessment is based on an official reference case for the total electricity generated by nuclear power between 2000 and 2060. However, it is possible to envisage different plausible energy futures with varying contributions from nuclear power. A comprehensive approach would explore the potential impact of different energy futures on the assessment of spent fuel management scenarios. In addition, a more formal assessment method (see Section 4) would allow the impact of varying judgements of (i) scenario performance against criteria and (ii) the relative importance of criteria to be explored.

d). There is no systematic attempt to analyse 'what if' questions across the scenarios

Although this is done to a degree for direct disposal scenarios, there appears to be very little analysis of the implications of the failure to meet key assumptions in reprocessing scenarios. Obvious examples of 'what if' questions relate to poor reprocessing or vitrification plant performance. A systematic analysis of such questions can help inform more robust decision-making (see Section 4).

3. Key Issues in Judgements of Scenario Performance

The following examples support the argument that many of the Planning Council's evaluations of scenario performance against specific criterion are insufficiently rigorous.

3-1. 'Safety Assurance'

Although a serious safety issue, there is no discussion in the Interim Report about the hazards associated with the accumulation of highly active liquid (HAL) waste from reprocessing. This accumulation could occur if the performance of vitrification plant did not meet expectations, as has been the case in the UK where the accumulation of HAL at Sellafield has been a matter of considerable regulatory concern.

In particular, in February 2000, the UK Nuclear Installations Inspectorate (NII) announced that it was requiring BNFL to reduce stocks of HAL to a 'buffer volume' by around 2015. This was because the NII believes:

> "that there has to be a demonstrable reduction in potential hazard (and hence risk) by reducing the amount of HLW stored as Highly Active Liquor and that the around 2015 date must therefore be achieved, as any shortfall will be publicly unacceptable."[3]

The lack of consideration of the safety implications of the potential accumulation of highly mobile, long-lived radioactive material, is a significant omission in the Interim Report.

[3] NII, 'The Storage of Liquid High Level Waste at BNFL Sellafield', 2000, p1. In January 2001, the NII formalised its requirements for HAL stock reduction by issuing BNFL with a 'Specification', Health and Safety Executive, 'HSE Enforces Waste Reductions at Sellafield', Press Release, 31 January 2001.

3-2. 'Energy Security'

The Interim Report considers energy security largely in terms of the impact of the scenarios on the supply of uranium. This is a very limited and narrow way of looking at energy security issues.

In the UK in the 1990s, attention focussed on how most effectively to enhance diversity in electricity supply as a response to unpredictability in the costs, technical performance, risks and environmental impacts associated with any single electricity source. In general, the argument goes, the greater the variety, balance and disparity of electricity generation sources within a supply system, the more diverse, and secure, is that electricity system[4].

The converse argument is that the more an electricity supply system relies on a single source of electricity supply, whether it be coal, nuclear or a specific type of renewable power, the less diverse and ultimately less secure is that system. It follows that any steps that perpetuate over-reliance on particular electricity sources is arguably contributing to reduced energy security.

It has been argued that this is particularly the case with over-reliance on nuclear power:

> "The two most serious accidents of recent years (Three Mile Island and Chernobyl) provide evidence of the contagious effect of a nuclear accident. An accident anywhere affects nuclear power almost everywhere. Given the strength of public reaction to accidents and feared accidents .., introducing more nuclear power into an electricity supply system may well reduce security. Although the primary fuel may appear to be available, there is a constant danger that, because of events at home or abroad, future building might be deferred, some existing capacity might be shutdown or derated, and stricter regulation might lead to high costs."[5]

3-3. 'Environmental Compatibility'

The Interim Report appears to make the argument that reprocessing is advantageous on environmental grounds because of the reduced toxicity of HLW compared with spent fuel, particularly over time. The implication appears to be that the removal of plutonium from the HLW stream significantly improves repository safety. Once again, this is a limited and narrow approach to assessment of an important issue in the comparison of scenarios.

One starting point for a more complete assessment is acknowledgement that the long-term safety of deep geological disposal depends on the immobilisation of radioactivity. Then, as has been pointed out:

"Studies of plutonium mobilisation suggest that it will not move far out of the near-field of the repository under most conditions. Removing plutonium does not therefore bring great improvements to long-term safety, which is determined more by the prevalence of nuclides like neptunium-237, technetium-99 and iodine-129. These occur in the same amounts in spent fuel and reprocessing waste."[6]

This position is supported in an appraisal from the IAEA. This shows that in terms of (a) the delay between disposal and the start of dispersal of nuclides from a deep repository and (b) the rate of dispersal

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[4] 'Variety' represents the number of electricity sources in a portfolio. 'Balance' takes into account the relative magnitudes of the contributions of the different sources. 'Disparity' involves consideration of factors such as the geographical origins of fuel supplies, the firms involved in trading fuels or operating stations, the vendors involved in supplying equipment, and the different regulatory and political issues invoked by different electricity sources. For further discussion see, A Stirling. 1994. New Nuclear Investment and Electricity Portfolio Diversity. COLA Nuclear Review Submission Volume 5.

[5] C Robinson. 1990. Reviewing Nuclear Power in Prospects for Nuclear Power in the UK and Europe. SEEDS. Discussion Paper. 53p.

[6] F Berkhout. 1997. Reprocessing and the Environment in Energy and Security, No 2.

into the environment, a range of nuclides are likely to have a far more significant radiological impact than plutonium[7]. Overall, although highlighting that a complete and detailed safety assessment is not yet possible, the IAEA appraisal concludes that:

"For the direct disposal of spent fuel, the order of magnitude of the individual doses to the public are not expected to be significantly different from the impacts from disposing of high level reprocessing waste."

A number of factors complicate this picture of broad comparability:

- Firstly, reprocessing generates significant quantities of plutonium contaminated Intermediate Level Waste (ILW), introducing additional concerns about the mobility of plutonium in a repository containing such wastes. These concerns arise from the formation and mobility of colloids (very fine suspended particles). In the UK, it is thought that the organic material contained in ILW can enhance the production of colloids[8].
- Secondly, the recycling of plutonium in MOX could increase the quantity of more mobile actinides, such as neptunium-237 that are consigned to a repository[9].

The Interim Report also suggests that the space required for the deep disposal of VHLW is between a half and two thirds of that for the disposal of spent fuel. The basis for this suggestion should be explored in more detail. For VHLW and spent fuel, required repository volume is largely determined by the heat outputs of the wastes. The Interim Report's suggestion therefore appears to be linked to a view that the heat output of VHLW is typically two thirds that from spent fuel.

In addition, it should be noted that the Interim Report does not appear to consider VHLW from reprocessing spent MOX fuel in this assessment. This VHLW requires more repository volume due to its higher heat output than VHLW from uranium fuel. Taking into account the volume of VHLW from spent MOX fuel and ILW produced during reprocessing, the overall repository volume required for reprocessing wastes is unlikely to be significantly smaller than for the equivalent amount of spent fuel[10].

3-4. Nuclear non-proliferation

The Interim Report argues that there is no significant difference between the scenarios in terms of non-proliferation. The basis for this position appears to be that the short-term storage of MOX powder and the deep disposal of spent fuel would both be required to meet internationally agreed monitoring and physical protection systems. However, this type of argument is weak because it is premised on the assumptions that these systems will provide equivalent levels of protection for each scenario, and that they will be applied consistently and work effectively over time (i.e. that they will not breakdown).

A more thorough and rigorous analysis would assess the resistance of the different scenarios to the main classes of proliferation and terrorist threats, including 'host nation breakout'[11], theft for a proliferant nation or for a sub-national group, and terrorist attack. Resistance to these threats arises not only from engineered and institutional protection systems, but also from the intrinsic properties of the forms of plutonium. A full assessment would consider the intrinsic properties of the forms of plutonium material

[7] IAEA. 1997. Nuclear Fuel Cycle and Reactor Strategies: Adjusting to New Realities. Proceedings of an International Symposium Table V. 216p.
[8] Following the Public Inquiry into the siting of a Rock Characterisation Facility in the UK, it was accepted that further research was required on this issue, C S McDonald, 'Cumbria County Council: Appeal by UK Nirex Ltd', Report of the Inquiry Inspector, 1997, paras 6c.60, 6C.65 and 6C.185-188.
[9] C Kueppers, M Sailor. 1994. The MOX Industry or the Civilian Use of Plutonium. IPPNW report Table 7/1, 64p.
[10] Where separated plutonium is recycled as MOX fuel, account should also be taken on the reprocessing side of the need to dispose of spent MOX fuel. As this is likely to have a heat output of 2-3 times higher than conventional spent fuel, it will require a correspondingly greater repository volume.
[11] Where a country holding the plutonium containing material decides to recover it for use in nuclear weapons.

at different stages within a scenario, and how resistant the material form is to theft, plutonium separation, and hostile attack.

The Committee on International Security and Arms Control (CISAC) of the US National Academy of Sciences has assessed the relative importance of a range of 'intrinsic barriers' to host nation breakout and theft, when analysing which plutonium forms could be considered to meet the so-called 'Spent Fuel Standard'[12]. These intrinsic barriers include:

- Barriers to theft: the mass and bulk of the item[13], concentration of plutonium in the item, radiation hazard, technical difficulty of part separation of plutonium from the item on site, and thermal, chemical and nuclear signatures aiding detection.
- Barriers to separation: technical difficulty of disassembly, technical difficulty of dissolution and separation, quantity of material to be processed, hazards to separators, signatures aiding detection.
- Barriers to use: deviation of isotopic composition from 'weapons grade'.

In principle, it would be possible to build upon this type of approach to develop a more complete analysis of the proliferation resistance of each scenario.

3-5. Extra cost in reversing reprocessing policy

The Interim Report refers to the results of some basic cost comparisons of the four scenarios that were carried out by the Secretariat to the Planning Council. These cost comparisons are based on a 'greenfield' analysis, which assumes all new facilities (and no sunk costs). The Interim Report then outlines the results of further work that estimates the costs involved in reversing the current reprocessing policy.

The basic cost comparisons are contained in a translation provided by the CNIC[14]. Table 6 in the translation presents the results in terms of unit costs in yen/kWh. For Back End costs alone, the unit cost for scenario 1 (all reprocessing) is estimated at 0.94 yen/kWh and for scenario 3 (all direct disposal) at 0.33 – 0.46 yen/kWh. In other words, the costs of reprocessing and disposal of the resulting radioactive wastes are estimated as around 2-3 times higher than the costs of storage and direct disposal of spent fuel.

This estimate is consistent with the results of a critical review of an OECD/NEA assessment of the economics of the nuclear fuel cycle[15], which was co-authored by the current author. This critical review (the 'Sadnicki et al report') explained how - based on a 'greenfield' analysis - the OECD/NEA report found reprocessing to be twice as expensive as interim storage and direct disposal, even using assumptions heavily biassed towards the reprocessing case. Examination of more plausible assumptions indicated that reprocessing was up to three times more expensive than direct disposal.

The Sadnicki et al report pointed out that this dramatic difference in costs raised the possibility that a switch from reprocessing in THORP to storage and direct disposal could actually offer financial benefits. The report went on to estimate the future cash flows involved, focussing on the important case of the spent fuel from German reactors that was to be reprocessed in THORP. It estimated that savings could be made by switching to storage and direct disposal.

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[12] CISAC. 2000. The Spent Fuel Standard for the Disposition of Excess Weapon Plutonium: Application to Current DOE Options.
CISAC argued that judgements about compliance with the SFS should depend only on the intrinsic properties of the final plutonium form, not on the extent of engineered and institutional protection.
[13] CISAC defined an item as the "smallest embodiment of the final plutonium form that could be removed from a storage facility without a degree of on-site physical processing (cutting, blasting etc) likely to be impractical for anybody but the host state".
[14] CNIC [Internet]. New Nuclear Policy-Planning Council: Costings for Direct Disposal of Spent Nuclear Fuel. Available from: http://cnic.jp/english/topics/policy/chokei/disposalcost.html.
[15] The OECD/NEA assessment is contained in "The Economics of the Nuclear Fuel Cycle", 1994. The critical review is contained in M Sadnicki, F Barker and G MacKerron. 1999. THORP: The Case for Contract Renegotiation. Friends of the Earth. pp7-12.

The Sadnicki et al report argues that the correct approach to estimating the costs of reversing a reprocessing policy is to undertake a ‘future economic analysis’[16]. In this type of analysis the pattern of *all* cash flows over *future* years is evaluated, including capital, operating and decommissioning costs, and payments for the provision of products or services. This approach does not therefore take into account *past* costs and payments, which are considered sunk.

For the current review, the key questions then become: is the Interim Report’s approach to estimating the costs of reversing reprocessing policy based on an assessment of future cash flows alone? And, if so, are reasonable assumptions made for all the main activities that have to be costed?

Although limitations of time and source material do not allow a detailed assessment of these questions, two points of concern arise immediately. Firstly, it appears that the Interim Report’s finding that extra costs would arise from reversing reprocessing is based on an analysis that includes a figure of 2440 billion yen invested in Rokkasho. If this money has already been spent, it should be considered as sunk costs and should not be included in the analysis.

Secondly, the Interim Report assumes that the reversal of policy would result in the shutting down of nuclear power plants (as spent fuel storage facilities become full), with their replacement by new fossil powered stations. The costs of new stations are then included in the analysis. However, it is questionable that the analysis should be based on such an extreme scenario, when it seems plausible that despite the hurdles to doing so, new interim storage facilities could be built to avoid nuclear power station closures. The costs of additional storage facilities should then be included, rather than the costs of new stations.

These two changes alone could make a significant impact on whether financial benefits or costs are estimated to arise from a change in policy.

4. Methods for Improved Assessment

Section 2 outlined a number of deficiencies in the Planning Council’s assessment method. These were summarised as:

- An insufficiently systematic and rigorous approach to judging scenario performance against criteria
- No formal assessment of the relative importance of the different criteria
- No attempt to undertake any sensitivity testing to explore how varying assumptions and judgements might impact on the overall assessment
- No systematic attempt to analyse ‘what if’ questions across the scenarios

These deficiencies suggest that the Planning Council’s approach would benefit from the use of more formal *decision-aiding* tools. Two potentially helpful methods are outlined below.

4-1. Multi-Criteria Assessment

The first tool that could in principle enable a more robust and rigorous assessment is ‘Multi-Criteria Assessment’ (MCA). The main steps in a MCA are normally:

1. identify the decision context, aims and starting assumptions.
2. identify and characterize the options that will be assessed.
3. identify the criteria against which the options will be assessed.

[16] Sadnicki et al. 1999. pp57-60.

4. evaluate the performance of each option against each criterion (leading, for example, to the allocation of numerical 'scores').
5. assign 'weights' to each of the criteria to reflect their relative importance.
6. combine the weights and scores for each of the options to derive overall values.
7. conduct a sensitivity analysis of the results to changes in scores and weights.
8. discuss the results and their implications for decision-making.

In a sense, the Planning Council has gone part of the way through a MCA by identifying scenarios and assessment criteria, and carrying out a fairly rudimentary evaluation of scenario performance against criteria (steps ii-iv). In principle, it would be possible to extend and develop the Planning Council's assessment by adopting a more formal MCA approach.

It should be noted that there are many ways of undertaking a MCA, depending on the aims of the assessment, and the availability of time, resources, data and analytical skills. All MCA approaches follow the basic steps, but differ, for example, in how they 'score' option performance, 'weight' criteria, combine weights and scores, and facilitate sensitivity testing. Various software packages are available to assist with these steps. In the UK, detailed guidance is available on how to undertake and make the best use of MCA for the appraisal of policy and other decisions[17].

Using an MCA method does not however provide a panacea[18]. Care has to be taken to avoid a number of pitfalls associated, for example, with a lack of clarity about when value judgements are being made, or placing too much emphasis on the numerical outputs from combining scores and weights. Nonetheless, MCA does offer advantages over less formal forms of assessment. These include:

- a systematic approach that enables the basis for judgements to be visible, documented and capable of presentation to outside audiences;
- the inclusion of appropriate specialist knowledge, particularly in identifying the metrics and data that can be used to inform judgements of option performance against criteria;
- the inclusion of a wide range of stakeholder perspectives in reaching judgements about scores and criteria weighting;
- an approach that allows uncertainties and differences of view to be identified, documented and addressed through systematic and comprehensive sensitivity testing;
- an approach that enables large amounts of complex information to be handled in a consistent way; and
- an iterative approach, allowing steps in assessment to be re-visited and revised as appropriate in the light of further information or discussion.

4-2. Implementation Analysis

In his detailed assessment of decision-making about THORP in the UK[19], Walker argues that decisions about major technological developments should be subject to a test of achievability that might be termed an 'implementation analysis'. For Walker, the purpose would be to make transparent:

[17] J Dodgson, M Spackman, A Pearman and L Phillips. 2001. DTLR Multi-Criteria Analysis Manula. Office of the Deputy Prime Minister. A more accessible introduction to MCA can be found in G Butler, C McCombie and A Pearman. 2004. Review of Options Assessment Methodologies and their Possible Relevance to the CoRWM Process. IDM18

[18] See, for example, A. Stirling. 1995. The Nirex Multi-Attribute Decision Analysis, Proof of Evidence to the Rock Characterisation Facility Public Inquiry. This sets out the disputes that can arise around the application of an MCA method.

[19] W Walker. 1999. Nuclear Entrapment: THORP and the Politics of Commitment. Institute for Public Policy Research.

- the actions and activities (current and future) entailed when a given proposal is put into effect;
- the plans (or options) that have been developed or are being developed in regard to those actions and activities; and
- the status of those plans in terms of acceptance and implementation.

Walker argues that such an analysis would help decision-makers and stakeholders:

- to form judgements about the probability that the claimed outcomes can be achieved;
- identify areas where special difficulties and risks might emerge;
- gain a better understanding of the commitments that are being entered into;
- make explicit the additional actions that will be required of governments so as to realise the proposal;
- help identify the important "what if" questions; and
- enable a full comparison of the relative merits of the alternatives.

The application of this sort of analysis to the 'back end' of the fuel cycle has much to recommend it. Indeed, there would be merit in applying it systematically to each of the scenarios identified in the Interim Report. In addition to helping decision makers develop a clear understanding of the risks, commitments and required actions (and consequent actions) in different courses of action, it would highlight the need to avoid 'all or nothing' policies, and the strategic value of flexibility in spent fuel management.

5. Stakeholder Participation in Assessment

There is increasing recognition internationally that decision-making in controversial policy areas can be improved by engaging with stakeholders with a wide range of perspectives and knowledge.

In the UK, there are a number of examples of programmes of stakeholder engagement, intended to inform decision-making at policy, strategic, or operational levels. These include:

- *Committee on Radioactive Waste Management (CoRWM)*: this independent committee has been set up to advise the UK Government on long-term approaches to the management of radioactive wastes and materials. The Committee has its own budget to commission specialist papers, and to organise public and stakeholder engagement. The Committee is proposing a short-list of options that include various forms of long-term interim storage, and/or shallow or geological disposal. The Committee is developing plans for assessing these options using a participative form of MCA[20]. It is due to make recommendations to the UK Government in July 2006.

- *BNFL sponsored National Dialogue*: this ran from 1998 to 2004 and involved key stakeholder groups, including industry regulators, local government officials, trade unionists and environmentalists. The Dialogue was facilitated by an independent third party called The Environment Council and produced a variety of detailed reports that have encouraged BNFL to work on contingency plans and alternative approaches[21]. In the process of producing these reports, a number of formal *decision-aiding* tools were used, including MCA and 'Strategic Action Planning'[22].

[20] CoRWM. 2005. How should the UK manage radioactive waste? 2nd Consultation Document. Section 2. See also www.corwm.org.uk.[Internet]
[21] Environmental council [Internet]. BNFL National Dialogue Reports. Available from: http://www.the-environment-council.org.uk/templates/mn_template.asp?id=221.
[22] Strategic Action Planning can be seen as a form of implementation analysis. See the basic introduction in G Butler, C McCombie and A Pearman. 2004. Review of Options Assessment Methodologies and their Possible Relevance to the CoRWM Process. IDM18.

- *Dounreay Best Practicable Environmental Option (BPEO) Consultation*: the UKAEA has been developing the use of participative BPEOs around the Dounreay site in North Scotland as an aid to decision-making on site clean-up and decommissioning. These participative BPEOs are based on a form of MCA[23].

If the Planning Council's assessment were to be developed and extended using the *decision-aiding* methods outlined in Section 4, there would be a strong case for involving representatives from key stakeholder groups. A participative form of MCA would, for example, allow uncertainties and differences of view in performance scoring and criteria weighting to be identified and addressed through sensitivity testing, and for joint discussion of the implications for decision-making.

6. Conclusions

This review has argued that there is a wide range of deficiencies in the Planning Council's assessment. In particular, there is:

- An insufficiently systematic and rigorous approach to judging scenario performance against criteria
- No formal assessment of the relative importance of the different criteria
- No attempt to undertake any sensitivity testing to explore how varying assumptions and judgements might impact on the overall assessment
- No systematic attempt to analyse 'what if' questions across the scenarios.

The review has illustrated how many of the Planning Council's evaluations of scenario performance against specific criterion are open to criticism, and require a more robust and rigorous approach. This is argued to be the case with regard to evaluation against the criteria of 'safety assurance', 'energy security', 'environmental compatibility', 'nuclear non-proliferation', and 'cost in reversing reprocessing policy'.

The deficiencies in the Planning Council's approach suggest that it would benefit from the use of more formal decision-aiding tools. Two potentially helpful methods are outlined in the review: Multi-Criteria Assessment and Implementation Analysis.

Finally, the review suggests that if the Planning Council's assessment were to be developed and improved using these sorts of methods, then there would be added benefit from involving representatives of key stakeholder groups in the assessment. This should result in more robust analysis and improved decision-making.

[23] Entec UK Ltd. 2004. Particles Best Practicable Environmental Option Public Consultation: Review of the Proposed Consultation Process. and Faulkland Associates. 2004. Evaluation of the Dounreay BPEO Stakeholder Programme: Main Report, C2014 R01-1.

Chapter 3

ICRC REVIEW

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1. Introduction

In November 2004 the Japan Atomic Energy Commission (JAEC) has released its *Interim Report Concerning the Nuclear Fuel Cycle Policy* (hereafter the Interim Report)[1]. After requests from members of a JAEC working group to get the document officially reviewed by international experts remained vain, the establishment of the International Critical Review Committee on the Long Term Nuclear Program (ICRC) was initiated. The present paper is part of the ICRC analysis process.

It should be clearly stated that neither the mandate of the ICRC nor its resources are designed to prepare its own in depth analysis of possible futures of the Japanese nuclear power program. The ICRC, as its name suggests, has been established to provide an external, independent view on the coherence and nature of the JAEC Interim Report.

2. JAEC Methodology

The Interim Report lacks a clear explanation of the applied methodology. The reader would like to have precise understanding of the mandate, the definition of the role of the various actors[2] (secretariat, composition of working groups, external experts) and the justification of their selection. The rules of the interaction between the various actors and members of the public also remain unexplained. Effective and democratic stakeholder involvement is excluded if the public is merely invited to listen but occasions to voice opinions that have to be taken into account are not provided for.

The Interim Report states, that, “if the deliberations of the Technical Investigation Subcommittee are counted, 18 meetings were held over a total of 45 hours.” In order to appreciate the work accomplished it would be helpful to know how many person-days of research and analysis work has been carried out under the auspices of JAEC and by whom prior to the editing of the report.

It is also unclear by what mechanism the elements of information and analysis provided by external experts were to be taken into account in the process. Analysis and comments offered by independent experts have neither been reflected in the Interim Report nor have they been visibly refuted.

Overall, it is not transparent for the reader of the Interim Report *why* JAEC reached the conclusions it has reached. Most of the statements are not backed up by arguments nor by scientific references. It is not a

[1] CNIC [Internet]. Translation of the AEC Planning Council’s Interim Report Concerning the Nuclear Fuel Cycle Policy. [updated 12 November 2004]. Available from: http://cnic.jp/english/topics/policy/chokei/longterminterim.html. (Also attached at the end of this report). The author is not in a position to judge whether other elements of information have been made available by JAEC in Japanese language.

[2] In a letter to the JAEC Chairman dated 4 March 04, the author has expressed concern about possible conflict of interest in the case of JAEC secretariat staff that is at the same time on the pay-role of the nuclear industry (see Appendix 2). In his reply dated 19 March 04, the JAEC Chairman simply indicated that the JAEC secretariat “is composed of government employees, who act under the obligation of the National Public Service Law” (see Appendix 3).

problem if JAEC reaches different conclusions from other authors as long as those conclusions are backed up by a transparent and solid chain of argumentation. This is not the case in the Interim Report.

In addition, there are areas where additional in depth research is urgently needed – in particular relating to safety and security aspects that derive from a post-911 perspective – but that have not been mentioned in the Interim Report. In a recent testimony in the US House of Representatives, Matthew Bunn, Senior Research Associate at the University of Harvard's Belfer Center for Science and International Affairs, who is also lead author of a major study into spent fuel management options[3] stated: "No complete life-cycle study of the safety and terrorism risks of reprocessing and recycling compared to those of direct disposal has yet been done by disinterested parties. But it seems clear that extensive processing of intensely radioactive spent fuel using volatile chemicals presents more opportunities for release of radionuclides than does leaving spent fuel untouched in thick metal or concrete casks."[4]

JAEC has chosen a number of spent fuel management scenarios that do not reflect the entire spectrum of issues involved. The underlying rationale for the selection and definition of these scenarios remains obscure (see next point for further discussion of the scenarios). Certain options have been ruled out from the start. For example, the four selected scenarios have not been compared to one or several nuclear phase-out scenarios. If JAEC is convinced that the nuclear options are clearly favourable over non-nuclear options, the explicit comparison of the entire range of options would help decision makers and the public to understand the reasoning.

3. Definition of the Scenarios

The definition of the scenarios is essential to the evaluation of possible policy options. In the following part, possible shortcomings of the scenario definitions are discussed.

Scenario 1: "Reprocess spent fuel after storing it for an appropriate period of time".

Scenario 1 seems to suggest the reprocessing of *all* spent fuel. This is technically and economically difficult and seems practically impossible. Since the amount of spent fuel currently discharged annually already reaches a higher tonnage than the design throughput of the Rokkasho plant, the scenario implies the building of a second reprocessing plant.

However, there will always be some spent fuel to be disposed of in the end. In particular, if the reprocessing option suggests the reuse of the separated plutonium in the form of Light Water Reactor (LWR) MOX fuel, at least some spent MOX fuel will have to be disposed of at some point, even in the highly unlikely case of multi-recycling. While the reprocessing of MOX has been technically demonstrated, currently there is no utility in the world that seriously considers reprocessing spent MOX. The quality and fissile content of the plutonium degrades during the use in the reactor. Therefore the incentive to extract plutonium further decreases after a MOX passage in the reactor from any point of view (energy, toxicity, economics etc.).

In the evaluation sheet of the scenarios, JAEC indicates a certain volume of spent MOX fuel in Scenario 2. It is unclear why this would apply to Scenario 2 and not to Scenario 1.

[3] Matthew Bunn et al. 2001. Interim Storage of Spent Nuclear Fuel - A Safe, Flexible, and Cost-Effective Near-Term Approach to Spent Fuel Management. A Joint Report from the Harvard University Project on Managing the Atom and the University of Tokyo Project on Sociotechnics of Nuclear Energy.
Available from: http://bcsia.ksg.harvard.edu/BCSIA_content/documents/spentfuel.pdf

[4] Matthew Bunn. 2005. The Case Against a Near-Term Decision to Reprocess Spent Nuclear Fuel in the United States. Testimony for the Subcommittee on Energy, Committee on Science, US House of Representatives 2005.

The scenario does not specify what shall happen to the over 40 tons of already separated Japanese plutonium. However, it seems logical that Japan demonstrates a way how to deal with such a large amount of plutonium – the quantity corresponds to the total amount of plutonium that has been absorbed in the French fast breeder reactor and LWR MOX programs over a 25 year period (1973-1998) – *before* a decision on the separation of further amounts of plutonium is taken or even put into practice.

Alternatives to plutonium reintroduction into reactors, in particular the management as radioactive waste, either in glass or ceramic form, are not presented and do not seem to have been evaluated.

The scenario assumes that all intermediate and high-level wastes from reprocessing would be smoothly conditioned and brought to final storage. It does not envisage any technical difficulties neither potential evolution of technical specification and therefore the potential need to review the waste management schemes. This is of particular interest to already generated waste forms, including from overseas reprocessing operations.[5] As for spent fuel and plutonium, a number of different management and disposal routes are to be envisaged.

Scenario 2: "Reprocess spent fuel, but directly dispose of that quantity which exceeds reprocessing capacity."

This scenario explicitly takes into account the fact that current reprocessing capacity is not sufficient in order to handle the current or foreseeable spent fuel output of the Japanese nuclear power plants. It also explicitly envisages the direct disposal of spent MOX fuel. Otherwise, comments on Scenario 1 apply.

Scenario 3: "Directly dispose of spent fuel".

Supposedly Scenario 3 designates what usually is called the "once through" option. This means that none of the spent fuel that is not currently under reprocessing contract abroad would be reprocessed.[6] While the scenario does not explicit what would happen to the existing already separated plutonium, it would allow for the option not to generate any MOX fuel and bring existing plutonium stocks under a waste management scheme. However, no indication is given as to what the management of existing waste streams would look like.

Scenario 4: "Store spent fuel for the time being and at some time in the future choose whether to reprocess it or directly dispose of it."

In the short and medium term, Scenario 3 and 4 do not seem to present significant differences. However, the report does not clarify what are the main implications envisaged. Essentially, the question is to what extent the interim spent fuel storage management would be altered under the two scenarios. This is not specified in the Interim Report.

4. Evaluation of the Scenarios

The JAEC states to have carried out a "comprehensive evaluation" of the four scenarios. In order to do this it has established 10 criteria: (1) safety assurance, (2) energy security, (3) environmental compatibility, (4) economic considerations, (5) nuclear non-proliferation, (6) technical viability, (7) social

[5] In France, for example, it is illegal to store foreign nuclear waste. It would therefore be simplistic to assume that there will be a swap of intermediate level and "old" conditioned waste (bitumen, concrete) for a smaller volume of additional high level waste.

[6] All of the fuel under contract with the French company COGEMA has been reprocessed already. The remaining spent fuel to be processed at BNFL's Sellafield facility is unknown. After the detection of a significant spill at the Sellafield THORP plant, it is not excluded anymore that the facility will remain shut down permanently. What should happen in that case to foreign yet unreprocessed fuel remains unclear. A German utility has definitely renounced a shipment to Sellafield that was contracted and already scheduled for the month of June 05.

acceptability, (8) assurance of choice, (9) issues associated with policy change, (10) overseas trends. JAEC has broken down the criteria into the following four categories:

Category I: Prior conditions, which are essential to the viability of the scenarios, such as safety assurance and technical viability;

Category II: Factors, which can be used to compare the policy significance of the scenarios, such as energy security, environmental compatibility, economic considerations, nuclear non-proliferation, and overseas trends;

Category III: Practical, restrictions such as social acceptability (problems finding a site) and issues associated with a change of policy; and

Category IV: Assurance of choice, that is adaptability in the light of future uncertainty associated with the scenarios.

The Interim Report does not clarify whether the criteria have been looked at under lifecycle analysis conditions that include all necessary activities at and between all of the necessary facilities. This is particularly relevant for safety and security issues linked to transports. There are great differences between the scenarios as to the need for particularly problematic shipments (eventually separated plutonium[7], fresh MOX fuel, spent fuel). Key issues concerning strategic choices in spent fuel management strategies are not addressed. Those include wet versus dry storage, centralised versus decentralised storage, away-from-reactor (AFR) versus on-site storage.

While each single criteria stipulated by JAEC could and should be discussed, there seem to be at least two major lacking criteria:

- the level of security and possibility to protect against terrorism and its effects;
- the compatibility of a plutonium economy under all circumstances with the requirements of a functioning democracy.

Also, not only the definition of each qualitative criterion is insufficient but it is unclear how they are weighted against each other. For example, how is the choice to be made between an option that increases energy security but is less proliferation proof and an option that provides the opposite qualities? How do you weigh an option that is higher risk for 50 years but lower risk after 1,000 years versus another that is lower risk for 500 years, but higher risk after 1,000 years? The Intermediate Report does not ask leave alone answer these fundamental questions.

Category I: Criteria (1): Safety Assurance

The sentence "almost no possibility that a difference between the scenarios will arise in regard to safety assurance" does not have a single reference. There are dozens of major reports that have discussed safety issues linked to plutonium separation and use versus non-reprocessing options in great detail and length and have come to significantly different results.[8]

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[7] Unforeseen plutonium shipments might be seen necessary in the case of the lack of expected performance of MOX fuel fabrication facilities. Following repeated delays in MOX fabrication, the Sellafield MOX plant subcontracted MOX fabrication to the French company COGEMA, which used plutonium of other origin. The equivalent quantity of plutonium will eventually have to be shipped from the UK to France.

[8] In particular see Matthew Bunn et al.
The author has been involved in several major projects on the plutonium economy including:
a) Mycle Schneider et al. 2001. Possible toxic effects from the nuclear reprocessing plants at Sellafield (UK) and Cap de La Hague (France), commissioned by the Scientific and Technological Option Assessment (STOA) programme at the European Parliament. WISE-Paris. 154 p.
Also see: http://www.wise-paris.org/english/stoa_en.html

One has to differentiate between safety under normal operating and under accidental conditions. The reprocessing scenarios demand the transformation of a solid waste form – the spent fuel assemblies – subsequently into liquid and oxide form. It is obvious that the physical-chemical condition of the materials involved has potentially a great impact on the relative safety of plant operators and the population.

One major study, the "STOA Report[9]", concludes on releases from La Hague, the French site that houses the reference plant for the Rokkasho reprocessing facility:

"Releases of radioactivity from La Hague to the environment are several orders of magnitude larger than releases from a nuclear reactor. Releases of some radionuclides have decreased in the past while liquid and gaseous discharges of other key radionuclides have increased significantly. A further group of radionuclides is not being measured in effluents. Increases of radioactive releases from La Hague in the 1990s and expected future discharges are in violation of obligations under the OSPAR Convention." During a European Parliament hearing on 12 March 2002, Margot Wallström, then European Commissioner for the Environment, told the parliamentarians that the analysis of the discharge data in the « STOA Report » was *"found to be consistent"* with data collected by Commission services.

JAEC states that "the point has been made that scenarios 1 and 2, which involve reprocessing, require more facilities to handle spent fuel than the other scenarios, and therefore could entail a higher release of radioactivity into the environment. However, the exposure doses resulting from these releases will be low and well within the regulatory limits. They will also be much lower than exposure from natural radiation.

The reference to exposure from natural radiation is misleading. Background radiation is not without harm. Currently available radiation models indicate that there is no threshold for health impact from low levels of radiation. In other words, current knowledge indicates that people exposed to background radiation experience health detriment equivalent to the level of exposure, without any level being considered as safe. In the case of a country like France this means that the relative risk of exposure to background radiation corresponds to several thousand lethal cancer cases every year.

A recent large study[10] on over 400,000 workers from 15 countries indicates a significant risk increase through radiation exposure including in very small doses: "Overall, on the basis of our central risk estimates, we estimate that 1-2% of deaths from cancer (including leukaemia) among workers in this cohort may be attributable to radiation. This assessment actually increases the risk estimate that is currently underlying the international radiation protection regime.

In addition to exposure from normal operating conditions, the "STOA Report" concludes on the accident hazard in the case of La Hague:

> *"Past accidents at La Hague include at least one accident that led to population doses significantly exceeding EU limits. Accidents are estimated to be responsible of 36% of the leukaemia risk level for the 0-24 year age category around the La Hague site. The hazard potential of the La Hague spent fuel stores is very large. The accidental release of a fraction of the caesium inventory in the cooling pools could cause up to 1.5 million fatal cancers."*[11]

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b) Jinzaburo Takagi (Dir.), Mycle Schneider (Ass. Dir.) et al. 1997. Comprehensive Social Impact Assessment of MOX Use in Light Water Reactors. Final report of the International MOX Assessment. Citizen Nuclear Information Center (CNIC), Tokyo, Japan. English, Japanese and Russian editions, 335p.
Also see: http://cnic.jp/english/topics/cycle/MOX/ima/

[9] see Mycle Schneider et al.

[10] Elizabeth Cardis (dir.) et al. 2005 .Risk of cancer after low doses of ionising radiation: retrospective cohort study in 15 countries. British Medical Journal: 331:77.

[11] see Mycle Schneider et al.

Similar consequences, or worse, are to be envisaged under a terrorist attack scenario.[12] Under non-reprocessing schemes there are many ways to avoid large spent fuel inventories in pools.

If JAEC does disregard the findings of international assessments it should explain in detail why and what the own statements are based on, so as to allow for detailed analysis and debate.

Category I: Criteria (6): Technical Viability

While it is true that the reprocessing and vitrification technologies have been fully developed, until today it proves complex and difficult to implement. The lack of operability of the Sellafield vitrification facilities lead to the regulator required shut-down of the THORP reprocessing plant in the past. The current post-accidental situation after a serious Level-3 incident in the THORP clarification cell is another indicator of the complexity of the system. As of the end of 2004, La Hague – and this is much less well known – as well as the Sellafield site had 1,000 m^3 or more high active waste in liquid form stored on the site. This liquid, easily dispersable, contains on each site several dozen times the amount of cesium-137 released during the Chernobyl accident that accounts for about three quarters of its radiological impact. A high active liquor backlog of such a size had never been planned. It is several times larger, in both cases, than envisaged on design basis. It is very surprising therefore that JAEC seems to consider that the problem is solved.

The Interim Report estimates that "there is a lack of accumulated technical knowledge on which to judge the suitability of direct disposal in the Japanese disposal environment". That is certainly true. However, it is unclear, why JAEC considers it "by contrast" to the reprocessing option. In fact, the final disposal problem remains in the case of vitrified waste. In addition, while the plutonium path inherently leads to several different waste streams (vitrified high-level waste, cemented and bitumen intermediate level waste, solid, gaseous and liquid low level waste) that considerably increase the complexity of the waste management compared to Scenarios 3 and 4 that induce a solid high active waste (the spent fuel) and minor quantities of low level radioactive waste in the case of wet storage (which can be prevented through adoption of a dry storage option).

Category II: Criteria (2): Energy Security

Historically the question of energy security has been an important argument used in favour of nuclear power in Japan, just as in France. JAEC states that scenarios 1 and 2 have "the effect of reducing the amount of uranium required by between 10% and 20%". Since plutonium can be reintroduced into reactors replacing a certain amount of uranium, the principle of that statement is theoretically obvious, even if one can discuss the figures. However, while Japanese spent fuel has been reprocessed for almost 30 years (in Japan since 1977), no plutonium has so far been reintroduced into an LWR and little into fast breeder reactors. As stated above, the current amount of already separated Japanese plutonium corresponds to the quantity that has been reused in breeders and LWRs in France over a 25-year period.

Energy security should not be measured in mere terms of additional primary energy content. In this respect, the Interim Report fundamentally lacks the identification many and discussion of most possible alternatives to the separation and use of plutonium. As a matter of supply security, should be integrated into the consideration, for example, the potential of:

- Enrichment tailings: the waste from the process of uranium enrichment still contains considerable amounts of fissile uranium-235 that could be separated at low cost if justified by high uranium prices;
- The build-up of a strategic uranium reserve;[13]

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[12] Following the 7 July 05 London terrorist attacks up to 5,000 "non-essential" Sellafield workers were told to stay at home for four days after the site that houses the UK's plutonium facilities went on "amber alert" although the site was said to be at no specific risk.

[13] See for example Paul Leventhal, Steven Dolly. 1995. A Japanese Strategic Uranium Reserve: A Safe and

- Uranium extraction from seawater;
- Uranium separation from phosphate mining activities;
- Increase in uranium fuel burn-up to levels difficult to achieve with plutonium fuels;
- Thorium resources;
- Finally, a whole range of non-nuclear energy services options (efficiency, CHP, renewables[14], etc.) that could be combined with Scenarios 3 and/or 4 in order to increase supply security.

The Intermediate Report refers to the first point and states that a view was held that "a comprehensive assessment should consider, in addition to reprocessing, reducing the concentration of the tailings. It seems like a quite obvious case of "cart-before-horse" to consider reprocessing before the efficient implementation of an already practiced industrial activity, which is uranium isotope separation or enrichment. The Intermediate Report further notes that "in response to this view it was pointed out that the superiority of scenario 1 becomes much more pronounced if the fast breeder is established, so the path towards implementation of the fast breeder should be made clearer." The argumentation is identical to the one that has led to the conceptualisation of the first generation of breeder reactors, including the Monju reactor that has been consuming rather than generating electricity over the past 10 years.

Considerations on supply security must take into account historical experiences in Japan and in other countries. The devastating failures of the fast breeder programs in Europe and the US have led to the subsequent abandoning (or eternal moratoria) of reprocessing programs in most of the European countries. In the UK, one of the two only countries that operate commercial reprocessing plants, there is now open debate about the question whether to restart the THORP facility, currently shut down for an indefinite period of time after the detection of a major leak. The internal BNFL inspection report on the incident notes: "This event has demonstrated that despite high quality construction, serious faults can occur within THORP which breach primary containment. Given the history of such events so far, it seems likely that there will remain a significant chance of further plant failures occurring in the future even with the comprehensive implementation of the recommendations in this report."[15] Under those circumstances a potential strategic dependency on a scheme to produce a difficult-to-use primary energy material seems a questionable way to take care of the legitimate concern of supply security.

In addition, nuclear power only provides electricity, while the energy consumption of any given society is mainly non-electric. The role of an energy source should be examined according to its potential to cover the energy *service* needs of a given society. In France, for example, in 2004 nuclear power plants supplied 78% of the electricity, but just 42% of commercial primary energy and only 17.5% of the final energy consumed in the country. The plutonium fuel loaded into 20 French reactors (max. one third of the core) generates 8%-10% of the nuclear electricity in the country.[16] In other words, plutonium fuels provide between 1% and 2% of the final energy consumed in France. The contribution of plutonium to "supply security" is not only marginal, it is irrelevant since it can easily and cheaply be substituted by a number of other options. At the same time, 71% of French final energy is still being provided by fossil fuels (oil, gas, coal). All of the French uranium and all of the fossil fuels are imported.

Finally, supply security has to take into account other parameters like flexibility, security and system robustness that are not reflected in the parameters used in the Intermediate Report on this specific criterion.

Economic Alternative to Plutonium. Science & Global Security: Vol.5. pp1-31.

[14] See for example Marc Fioravanti. 1999. Wind Power Versus Plutonium: An Examination of Wind Energy Potential and a Comparison of Offshore Wind Energy to Plutonium Use in Japan. prepared for the Institute for Energy and Environmental Research. Available from: http://www.ieer.org/reports/wind/summrec.html/.

[15] BNFL. 2005. Fractured Pipe With Loss of Primary Containment in the THORP Feed Clarification Cell. Board of Inquiry Report.

[16] The quantity of plutonium absorbed in the French MOX program corresponds to the output of one of the two reprocessing lines at La Hague and is equivalent to the expected throughput of the Rokkasho plant.

Category II: Criteria (3): Environmental Compatibility

In the scenario evaluation, the JAEC Secretariat is noted as stating: “Reprocessing aims to recover and reuse resources and thus reduce waste. Reducing the quantity of resources used and waste produced, reusing and recycling create a closed-loop economy. Reprocessing is consistent with this philosophy.”

The Secretariat correctly states that reprocessing *aims* to recover and reuse resources. Unfortunately, this is the theory, not the practice. Hardly any of the recovered Japanese plutonium has been reused. On the contrary, it is quite likely that, to date, the overall lifecycle analysis of Japanese plutonium separation and use would result in a negative energy balance.

There is no other “closed loop” industry that would be permitted to emit as many pollutants, in quantity and quality, to the environment than the plutonium industry. Furthermore, the statement that reprocessing is “reducing the quantity of (…) waste produced” is factually wrong.

The Intermediate Report states: “The volume of high-level waste would be reduced to between 30% and 40% and the space required to bury it would be reduced to between a half and two thirds of that if the spent fuel had been disposed of directly. Therefore, this scenario is superior.” It would be interesting to see the underlying calculations to this affirmation. Other comparative calculations on waste generation get to significantly different results.[17] Under all circumstances, it is indispensable to appropriately address the following issues in the evaluation:

- There is no incentive to reprocess MOX fuel. Spent MOX fuel has to be either cooled much longer prior to final disposal than uranium fuel (roughly an additional 100 years, according to a scenario by the French utility EDF) or it needs a much larger final storage volume (four times the volume of uranium fuel, as envisaged by JAEC itself) because of the much higher heat output.

- Waste volumes are not limited to high-level wastes. Significant amounts of intermediate level wastes arise in the reprocessing scheme that don’t even exist in the once-through path. In addition, large amounts of low level wastes are generated and either discharged into the environment or conditioned as solid waste. Volumes are particularly significant in the case of decommissioning wastes from the reprocessing plant. In volume terms it is obvious that reprocessing entails the generation of a significant larger quantity of waste than the once-through option.

Category II: Criteria (4): Economic Considerations

The following economic criteria have been spelled out in the Intermediate Report:

- How should differences in economic merit be measured?
- In regard to economic merit, from the point of view of the burden on households, how does this compare with recycling of such things as cars, electrical appliances and general industrial items?
- What is the difference in the cost of the nuclear fuel cycle in terms of the cost of production of electricity?

While the first question has not been explicitly answered in the Intermediate Report, the two other criteria are heavily biased and set out from the start to lower significance of the economic advantage of the once-through options over the plutonium fuel scenarios. The question is altered implicitly from what is the most economic option in the framework of a global cost-benefit analysis to what could Japanese electricity and taxpayers afford to pay for. Comparisons with consumer goods like cars and refrigerators are grossly misleading. The impact of an individual given consumer good and its recycling, the level of individual taxpayers’ choice and the level of intergenerational consequences of a given practice are by no

[17] see Yves Marignac, Xavier Coeytaux. 2002. Volumes de déchets radioactifs à vie longue associés à la gestion du combustible usé (colis / barrières ouvragées). WISE-Paris.

means comparable. While JAEC clearly admits that Scenario 1 is the most expensive one, it does not clarify what system lifecycle analysis based cost-benefit evaluation actually looks like.

As the author has pointed out in his presentation to JAEC on 2 March 04, even if Rokkasho did operate for 40 years with an unlikely load factor of 100%, the cost per gram of separated plutonium (based on TEPCO's 40 year plutonium economy cost estimate) would be 40 times the current price of gold. At the same time, the British and French owners of dozens of tons of plutonium attribute into their official accounts a zero value to their plutonium stocks. It is unclear why the Japanese electricity customer and taxpayer should pay an exceptionally large sum of money for a substance that is considered worthless in the countries that hold the world's largest stocks of the same substance.

In fact, one might wonder, whether Japan has approached the European plutonium stockholders in order to inquire under what conditions they would transfer those stocks to Japan and what the outcome would have been. It is quite likely that, independent of any strategic and security considerations, the European plutonium stockholders would actually pay the Japanese counterpart to take over responsibility for the awkward material.

JAEC does not seem to pay attention to the relative level of economic risk. A large number of additional facilities obviously induce a larger potential for construction delays, incidents and accidents during building and operation and therefore disruption of economic income. Japan Nuclear Fuel Ltd. (JNFL) announced on 28 March 05 that Rokkasho is now scheduled to start-up in May 2007, another 10 months later than expected. The construction cost estimate was increased yet another time by 2.3% to reach ¥ 2.19 trillion. Already in 2004, the start-up had been delayed by a full year, following the discovery of defective quality-control measures on welds in the spent fuel pools[18]. As a result, "tens of kilometres of welding have to be re-examined in detail", noted the nuclear department of the French embassy in Tokyo.[19] In other words, the cost figures that have been taken into account in the Intermediate Report are already obsolete a few months after its publication.

The latest THORP accident is another good illustration of high economic risk in the plutonium industry. THORP was expected to contribute about a quarter to the Nuclear Decommissioning Agency's £ 2.2 billion annual budget. This is now jeopardized. Besides the loss of income, the accident will entail either significant repair costs or will leave the plant with a significantly reduced nominal capacity. The costs are in any case adding up to several hundred million pounds sterling.

Category II: Criteria (5): Nuclear Non-Proliferation

There are essentially two primary materials for a nuclear explosive device: highly enriched uranium (like in the case of the Hiroshima bomb) and plutonium (like in the Nagasaki bomb). The Intermediate Report states that "when conducting reprocessing, in order to avoid giving rise to international concerns about nuclear proliferation and nuclear terror, it is necessary to create strict, internationally agreed safeguards and measures for the protection of nuclear materials". It is unclear to what extent JAEC considers that beyond the existing national and international safeguards regime it considers it necessary "to create" additional or different safeguards and physical protection measures.

The Intermediate Report states that "in the case of scenario 1, so that pure plutonium oxide doesn't exist at the reprocessing plant, uranium nitrate and plutonium nitrate solutions are combined to make MOX powder (mixed oxide powder)". If at any point in time, Japan decided to legally withdraw from the Nuclear Non-Proliferation Treaty because it intended to produce nuclear weapons, it would be technically no problem to add a chemical unit that allows for the transformation of plutonium nitrate into plutonium metal that can be used directly in nuclear weapons. In other words, the existence of a large-scale plutonium separation plant – a situation that does not exist in any other non-nuclear weapons state –

[18] A number of serious potential implications of the incident have been raised by Yves Marignac, John Large. 2004. Submission to the Inquiry Committee on Rokkasho Reprocessing Plant Comprehensive Inspection.

[19] Service nucléaire. 2004. Ambassade de France au Japon, *La situation du nucléaire a Japon.* MINEFI

makes Japan a latent nuclear weapons state. The country would be technically within months rather than within years of a significant nuclear weapons capability.

The perception of international observers of the original nuclear weapons taboo has changed remarkably over the last ten years or so. A paper on nuclear weapons and Japan published by the Federation of American Scientists[20] concludes:

> *"Japan's nuclear power program based on reprocessed plutonium has aroused widespread suspicion that Japan is secretly planning to develop nuclear weapons. Japan's nuclear technology and ambiguous nuclear inclinations have provided a considerable nuclear potential, becoming a 'paranuclear state'. Japan would not have material or technological difficulties in making nuclear weapons. Japan has the raw materials, technology, and capital for developing nuclear weapons. Japan could possibly produce functional nuclear weapons in as little as a year's time. On the strength of its nuclear industry, and its stockpile of weapons-useable plutonium, Japan in some respects considers itself, and is treated by others as, as a virtual nuclear weapons state."*

The International Atomic Energy Agency (IAEA) has recently raised the "possibility of 'break out' from the Non-Proliferation Treaty (NPT) by non-nuclear weapon States (NNWS) with advanced nuclear fuel cycle technology and/or stocks of enriched uranium or separated plutonium – intentions cannot be verified"[21].

If Japan intends to dissipate "widespread suspicion" about potential nuclear weapons ambitions[22], Japanese leaders will have to provide a reasonable and solid argumentation about the "raison d'être" of its plutonium programme. JAEC has not.

The Intermediate Report states: "In the case of scenario 3, the temptation for diversion of this material will increase in the period between hundreds and tens of thousands of years after disposal, so it will be necessary to develop and implement an efficient and effective internationally agreed monitoring and physical protection system. When these things are taken into account, there is no significant difference between the scenarios on the issue of non-proliferation." JAEC again mixes timeframes that differ by orders of magnitude without applying a transparent weighing mechanism. Under all scenarios, most likely will remain some spent fuel containing still plutonium quantities equivalent to thousands of nuclear weapons. Depending on the geological environment, in any system of deep geological disposal efficient safeguards are technically extremely difficult or even impossible to implement (in salt formations, for example). However, with the monitoring difficulty also increases the access problems.

JAEC does not seem to have looked at the proliferation implications of the fact that the plutonium oxide can be extracted chemically from the mixed oxide fuel and therefore represents a potential prime target for subnational groups.

Category II: Criteria (10): Overseas Trends

The vast majority of spent nuclear fuel discharged from reactors worldwide is not reprocessed. The representation in the Intermediate Report is one-sided and superficial. The Intermediate Report states that "countries with large scale nuclear power generation, such as France, Russia, China, and countries with a

[20] Federation of American Scientists. 2000. Nuclear Weapons Program – Japan.
[21] Tariq Rauf. 2005. Background & Report of the Expert Group on Multilateral Approaches to the Nuclear Fuel Cycle. presentation at the International Conference Multilateral, Technical and Organizational Approaches for the Nuclear Fuel Cycle Aimed at Strengthening the Non-Proliferation Regime, Moscow, 13-15 July 05
[22] see also David McNeill. 2005 July 31. Japan stockpiles plutonium as threat of nuclear escalation spreads across Asia – Hiroshima: Sixty years after the dawn of the Atomic Age, survivors look back amid fears their nation's postwar pacifism is at risk. [natl ed]; Independent on Sunday, London.

basic policy of continuing with nuclear power, or poor energy resources within their own borders are choosing reprocessing". The Intermediate Report omits to mention that:

- France, Russia and China are nuclear weapons states;
- Russia reprocessed a very limited amount of fuel in an old, particularly polluting facility and has abandoned the construction of a commercial size facility in Krasnoyarsk[23];
- China does not have any commercial reprocessing facility operating and is only in the course of building a small-scale pilot plant;
- France has lost all of its foreign clients for commercial reprocessing, besides a small contract for Dutch fuel and faces now a gigantic overcapacity or the closure of one of the two reprocessing lines;
- As of 1st July 05, the shipment of spent fuel from German nuclear power plants to any reprocessing plant is prohibited by law;
- In the UK, following the most recent serious incident, subsequent to the edition of the Interim Report, there is now open debate about the possible permanent closure of the THORP facility.

While only a small fraction of spent fuel generated in the world has been reprocessed in the past, there is a clear tendency to even more marginalise the plutonium industry in the future.

However, one current international trend is the substantial increase of the uranium price. The question is whether this would be a lasting development and whether it could constitute a new incentive for the separation of plutonium. The answer is no, because the price is to a large extent an artificial one and its impact on the cost of the nuclear kWh is marginal.[24] The uranium mining industry has been trying for many years to get the price back up that in 2003 was on the level of 1974, about a quarter of the peak in 1978, the time when the large scale plutonium programmes, including major overseas reprocessing contracts were launched. Since 2000 the uranium industry has produced only about 55% of the world consumption, the rest being drawn from large stocks, down-blending of weapons grade uranium and the re-enrichment of recycled uranium. No wonder, after several incidents in operating uranium mines and difficulties to implement the US-Russia agreement on down-blending of weapons uranium, the uranium price went up, "the historically low price of uranium reaching a 'floor' as approached or perhaps even dropped below the production costs of uranium producers".[25]

Category III: Criteria (7): Social Acceptability and Criteria (9): Issues Associated With Policy Change

The current official Japanese plutonium policy is met by increasing distrust of Japanese and international public opinions. As the Australia based Uranium Information Centre (UIC) puts it: "Public support for nuclear power in Japan has been eroded in the last few years due to a series of accidents and scandals."[26] The sodium fire at Monju, the fire in the waste conditioning facility at Tokai and various serious cover-up and criminal cases like the Monju video manipulation, the MOX fuel and reactor quality-control falsification brought public trust in the Japanese nuclear industry to an all time low. Also, all these cases had serious economic consequences. As the UIC reports, the shut down of TEPCO's 17 reactors, some of

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[23] The author has visited the facility, which in many publications is still listed as "under construction". However, no active building work has been ongoing for over 10 years and the already existing parts (basements and walls, no roofs) would certainly have to be torn down because they were exposed unprotected to Siberian weather for many years.

[24] According to French government figures, at a price of US $20/lb, the share of the natural uranium purchase corresponds to 5% of the cost of the nuclear kWh (see Approvisionnement en matière et intérêt du recyclage Material supplying and reprocessing-recycling benefit. by Florence Fouquet, sous-directrice de l'industrie nucléaire, Cyrille Vincent, chef du bureau Politiques publiques et tutelles et Arnaud Locufier, adjoint au chef du bureau Politiques publiques et tutelles, Direction générale de l'énergie et des matières premières (DGEMP), in *Contrôle*, n° 162, February 05

[25] OECD-NEA, IAEA. 2004. Uranium 2003: Resources, Production and Demand. OECD-NEA. Paris.

[26] Uranium Information Centre. 2005. Nuclear Power in Japan. Briefing Paper. 79p.

them for over two years, led to replacement power costs on average 50% higher than the official nuclear generating costs (5.9 yen/kWh). TEPCO "expects the whole fiasco to cost it about 200 billion yen"[27].

The series of accidents and scandals also eroded Japanese Prefectures' confidence into the MOX fuel "Pluthermal" program. The use of MOX fuel is – correctly – seen as additional risk and is even less accepted by public, local and regional administrations than the operation of nuclear power plants itself.

The Intermediate Report argues in favour of reprocessing because "at this stage Japan lacks accumulated technical knowledge in regard to direct disposal that takes into account Japan's natural conditions and finding a locality which will accept the final disposal of spent fuel, which contains plutonium, would be expected to be much more difficult than finding a site for the final disposal of glass canisters". At this stage, Japan lacks accumulated knowledge and a mechanism for the selection of appropriate disposal concepts and sites for *any* waste category. It would be interesting to know why JAEC expects that finding a final disposal site for spent fuel would be "much more difficult" than in the case of vitrified high-level waste. Are there any social studies available, any opinion polls carried out? In addition it would be interesting to include studies on how the final disposal of MOX fuel, including five times more plutonium than uranium fuel – inherent to any realistic reprocessing option – would be accepted as compared to direct disposal of uranium fuel.

In every country that has operated nuclear power plants and plutonium facilities the latter have caused vastly more opposition than in the case of nuclear power plants. In fact, there is an increasing number of nuclear industry and utilities representatives, including in France, that consider the plutonium business harmful to the future of nuclear power. Also, no pro-nuclear government that followed the Green-Red administration that decided in 1998 to shut down permanently the Superphénix fast breeder reactor has ever envisaged to overturn that decision and restart the reactor or the breeder program. No other nuclear project drew as much public and internal criticism in France than the plutonium program.

However, the idea that the disposal of high-level vitrified waste would be easier to implement in terms of public opinion than the spent fuel direct disposal is entirely contradicted by the experience in Germany. Massive protests accompany every single return of vitrified high-level waste from the French La Hague plutonium factory to the German Gorleben site. Over 30,000 policemen had to protect railways, transfer stations and storage site. This high-level opposition takes place although Gorleben so far is only an interim storage facility and has been investigated so far only under the mining law and not under the nuclear legislation for final disposal and while all of the reactor sites have implemented intermediate dry store concepts without major disruption.

The Intermediate Report argues that Scenario 4 would suffer from the problem of "maintaining over a long time period the technology and human resources, as well as the international understanding, in regard to Japan's reprocessing program". The relevance of this point largely depends on the time frame and the significance that the country would assign after several decades to plutonium as an energy resource or as a primary ingredient for nuclear weapons. The maintenance of competence in the nuclear sector is not a specific issue concerning reprocessing in particular but a general problem, which has to be addressed effectively. Concerning the "international understanding" of the Japanese plutonium program, this could certainly only improve over the current situation.

The Intermediate Report also argues that "many interim storage facilities will become necessary (9~12 sites by 2050), but because no policy decision has been made about disposal after storage, it will be difficult for local people to remain confident regarding the 'interim' status of the facilities, so there is a strong possibility that attempts to find a site will stall and, one by one, currently operating nuclear power plants will be forced to cease operating". It is unclear why 9-12 sites for interim storage facilities would be necessary. The spent fuel could be maintained in dry storage at the reactor sites as in the German case and at an increasing number of sites in the world. It is quite possible that local people have difficulties "to remain confident" regarding the interim status of the facilities. However, it is the responsibility of

[27] ibid.

operators, local and federal authorities to implement a credible policy scenario. The policy that has been promoted over the past three decades and that continues to be advocated by JAEC certainly lacks that high level of credibility. It is unclear why this should lead to premature closure of operating units.

JAEC suggests an original analysis approach in looking at the consequences that would stem from the mere fact that there would be a policy change under certain scenarios in addition to looking at advantages/disadvantages of a given scenario itself. The Intermediate Report stipulates that “there is a strong possibility that the search for a final high-level waste disposal site, which has already begun, will be affected by the policy change and become stalled for a long period of time”. The Intermediate Report does not elaborate on the statement, but if a policy shift is considered necessary as a result of a cost/benefit analysis then it would be absurd to argue that one has drops the policy change because it would possibly delay the implementation of a final repository scheme. This conclusion seems all the more surprising as Japan seems decades away from the opening of a high-level waste repository anyway.

Category IV: Criteria (8): Assurance of Choice

JAEC considers that the all-reprocessing Scenario 1 is “superior” to the other scenarios “because it maintains infrastructure for technical innovation which can respond to changes of circumstances in regard to reprocessing (human resources, technology, knowledge, etc.), while maintaining international understanding of Japan's reprocessing program”.

This is another example of the systematic bias in the Intermediate Report in favour of the reprocessing option. The reprocessing option, the logical “fait accompli” scenario is presented as “superior” because of the disproportionate and unjustified weighting of a single parameter that is maintaining competence. The methodology of the building and operating for decades of a multi-trillion yen operation for the mere purpose of maintaining competence is not only extremely inefficient. There are many characteristics of the plutonium economy that are of specific non-reversible nature including the following:

- The invested huge amounts of capital into the infrastructure of the plutonium economy.[28]
- The intrinsic danger of the operation of additional high-risk facilities and shipments.
- The permanent exposure of concentrated large radioactive inventories and shipments to attack.
- Massive discharges of radioactive and other toxic pollutants into the environment.

5. Conclusion

JAEC, in the conclusion of the Intermediate Report, narrows the four original scenarios down into two options, “a path based on reprocessing and a path based on direct disposal”. A thorough argumentation why the scenario variations have been abandoned at the end has not been given.

JAEC stipulates as “basic stance” for Japan’s future nuclear fuel cycle policy “to adopt the effective use of plutonium, uranium, etc. recovered by reprocessing spent fuel”. Essentially three reasons are given for this opinion that will be commented on one by one:

1. While the reprocessing option is recognized as being more expensive under current conditions, it is judged “superior from the perspective of 'energy security', 'environmental compatibility' and 'adaptability to future uncertainty', etc.” It is also felt that future pressure on the uranium markets and a long term commitment to nuclear power could even reverse the economic disadvantage of the plutonium option.

JAEC has failed to demonstrate the relative advantage of the plutonium fuel option in the area of environmental protection and system flexibility. It has flatly dismissed or ignored substantial evidence for

[28] In this regard it would constitute a helpful illustration to calculate the comparative cost of the build-up of a strategic uranium reserve at a uranium price of US $10 /lb, an average price level that was held on the international spot market for 15 years between 1988 and 2003.

the particular problems of the plutonium economy in these areas. JAEC has also given unjustified weight to a theoretical minor uranium saving of 10%-20% and has ignored or downplayed numerous other options that could achieve the same or better results at lower economic and social cost.

JAEC obviously vastly overstates and misrepresents the impact on "energy security" of the plutonium economy. This is well illustrated by the analysis of the French case, the only one to have actually implemented the scheme that is being promoted by JAEC:

- Japan has separated plutonium for over 25 years and has still not reused a single gram of the over 40 tons of stocks of the material into one of its commercial reactors. It took the French State utility 25 years to absorb the same quantity of plutonium into its reactor program. Considering the uncertainties and costs of its future use, it is logical that the owner – just like its British counterpart – has allocated a zero value to its stocks in the accounts;

- In 2004 French nuclear power plants supplied 78% of the electricity, but not more than 42% of commercial primary energy and only 17.5% of the final energy consumed in the country. The plutonium fuel (MOX) generates 8%-10% of the nuclear electricity in the country.[29] In other words, plutonium fuels provide between 1% and 2% of the final energy consumed in France. At the same time, 71% of French final energy is being provided by fossil fuels (oil, gas, coal), all which are imported into France just as all of the uranium.

None of this is taken into account in JAEC's final judgement. Considering the weight JAEC seems to allocate to the energy supply issue, the explicit critical analysis of the French case should impact heavily on the outcome of JAEC's recommendations.

2. JAEC argues that the Japanese government and industry have heavily invested in the past in order to implement the plutonium economy. This investment, labelled "social capital", JAEC states "has great value and should be maintained", since Japan "has established nuclear power as a core ingredient of its electric power generation".

The value of that proclaimed "social capital" is highly doubtful. First of all, the definition is questionable. JAEC defines it in terms of "technology, trust of local communities, international agreement on numerous issues related to reprocessing". The idea of *social collective benefit* is entirely missing. The plutonium option does not provide anything more to the Japanese society than, at best, an insignificant fraction of energy service.

It should be clearly stated that, so far, a large share of the social *cost* of the Japanese plutonium program is being paid for by non-Japanese citizens since the vast majority of Japanese plutonium has been separated at European reprocessing plants. The essential cost is being paid for by European citizens in terms of the impact of the radioactive emissions of the two European reprocessing facilities into air and sea that account for over 80% of the collective dose stemming from the past use of nuclear power in Europe.

There is a great difference between technical analysis and political decision-making. JAEC seems to have great difficulties in separating both. Its very influential secretariat staff is co-financed by the nuclear industry, which induces a conflict of interest unacceptable by international standards. It also makes technical *and* policy based evaluations. Its role is ambiguous. Its composition is neither independent nor representative. JAEC's ambition seems to be limited to guarantee continuity of Japan's nuclear policy, not to provide analysis based policy recommendations. JAEC's performance risks to be counter-productive by all means, and especially when it comes to public trust. While nuclear issues have always

[29] The quantity of plutonium absorbed in the French MOX program corresponds to the output of one of the two reprocessing lines at La Hague and is equivalent to the expected throughput of the Rokkasho plant.

been surrounded by the myth of “unintelligible” expert knowledge, citizens in all countries have shown that they have an unmistaken understanding of the limits of trust in institutions.[30]

3. JAEC states that “in order to further nuclear power and the nuclear fuel cycle, it is essential to obtain the understanding and support of the public”. Policy change would lead to distrust and therefore to potential difficulties in the acceptance of intermediate spent fuel storage and further operation of power plants.

JAEC seems to be more driven by the acceptance of nuclear power than by the in depth cost-benefit analysis of a spent fuel management option assessment. This attitude does not seem to be appropriate for the task JAEC has been appointed for. However, it can be argued that even if JAEC’s key objective was a high-level of adherence to nuclear power use in Japan, the unbalanced support of the plutonium option could turn out to be counterproductive. There is a growing pro-nuclear community internationally that thinks that public acceptance of nuclear power would grow strongly if the plutonium economy was cut out.[31]

For an international observer it is surprising that, at a time of profound public distrust in Japan, JAEC considers that the nuclear industry’s credibility would benefit from an unmodified, literally stubborn attitude of business-as-usual towards long-term energy policy-making.

JAEC has chosen to publish a document that repeats the erroneous visions of the 1970s that urged for the implementation of a plutonium fuel based energy economy following sky-rocketing uranium prices in view of an expected exponential growth of nuclear energy programs that never occurred. While the errors of the past have already lead to substantial social costs, 30 years later, it seems indispensable to take into account not only past errors – nationally and internationally – but also new dimensions like the post-911 situation, the development of uranium resources and prices, technical developments like high burn-up uranium fuels, smaller electricity generating units in liberalised energy markets and the unprecedented potentials of energy efficiency and non-nuclear energy options.

The JAEC Intermediate Report appears like a document of the past. It ignores historical developments, disregards evidence that has been submitted and seems to be heavily biased towards the perpetuation of the status quo. It does not seem to be the appropriate basis for political decision-making in an area that entails consequences for hundreds of generations to come.

[30] In a recent poll for the French Institute for Radiation Protection and Nuclear Safety; on the question “do you trust the French authorities on their protective actions of people in the following areas?” on radioactive waste 22.7% answered Yes, but 46.5% said No (29.1% said More or Less). On the question of the Chernobyl fallout in France only 9.5% said Yes but 68.2% said No (17.4% said More or Less). Source: Baromètre IRSN. – Perception des Risques et de la Sécurité.

[31] One of the outspoken proponents of international restrictions and control of reprocessing activities is the Director General of the UN’s International Atomic Energy Agency who initiated a proposal to put a number of strategic facilities – that would include the reprocessing plant at Rokkasho - under international management, stated: “"We should be clear: there is no incompatibility between tightening controls over the nuclear fuel cycle and expanding the use of peaceful nuclear technology. In fact, by reducing the risks of proliferation, we could pave the way for more widespread use of peaceful nuclear applications. Also see: http://www.un.org/apps/news/story.asp?NewsID=14996&Cr=nuclear&Cr1=terrorism

Chapter 4

ICRC REVIEW

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1. Introduction

This paper is a contribution to the international review of the interim report of the New Nuclear Policy-Planning Council on nuclear fuel cycle policy in Japan (in the following quoted as the "Interim Report"). The Interim Report compares four scenarios how to deal with spent nuclear fuel. The scenarios differ in the amounts of spent fuel that are reprocessed, stored for reprocessing in the future or stored for direct final disposal.

In preparing the paper, the author has used the translation of the Planning Council's Interim Report by the Citizens' Nuclear Information Centre (CNIC)[1]. The author has also had the benefit of discussions with members of the ICRC and its secretariat during a visit to Tokyo at the end of March, 2005.

The paper is focused on the aspects of the interim decision of the New Nuclear Policy-Planning Council on nuclear fuel cycle policy in Japan that are related to high-level radioactive waste management. The following aspects are discussed in this paper:

- Section 2.: Radiological Impact of Reprocessing, Interim Storage and Final Disposal of Spent Fuel
- Section 3.: Safety of Reprocessing, Interim Storage and Final Disposal of Spent Fuel
- Section 4.: Proliferation Risks Related to Separated Plutonium and Spent Fuel
- Section 5.: Overseas Trends
- Section 6.: Conclusions

These sections refer to the criteria (1) safety assurance, (3) environmental compatibility, (5) nuclear non-proliferation and (10) overseas trends in the Interim Report.

A general weakness of the arguments in the Interim Report is that there are no statements about the relative importance of the different criteria. It is not immediately obvious whether the Planning Council considers all criteria to be equally important, or whether it is making implicit assumptions that some criteria are more important than others. The Planning Council's views and reasoning about the relative importance of different criteria should be made explicit, as should the impact of these views on the overall assessment. Probably, some of the misleading conclusions would not have been drawn by regarding differences in the importance of the different criteria.

[1] CNIC [Internet]. Translation of the AEC Planning Council's Interim Report Concerning the Nuclear Fuel Cycle Policy. [updated 12 November 2004]. Available from: http://cnic.jp/english/topics/policy/chokei/longterminterim.html. (Also attached at the end of this report).

2. Radiological Impact of Reprocessing, Interim Storage and Final Disposal of Spent Fuel

The Interim Report states:

> *"The point has been made that scenarios 1 and 2, which involve reprocessing[2], require more facilities to handle spent fuel than the other scenarios, and therefore could entail a higher release of radioactivity into the environment. However, the exposure doses resulting from these releases will be low and well within the regulatory limits. They will also be much lower than exposure from natural radiation. Therefore, it cannot be said that these releases represent a significant difference between the scenarios."*

The common approach to evaluate radiation exposures from artificial sources is to discuss the justification of the practice, the optimisation of radiation protection and the compliance with dose limits (this is the bases of the recommendations of the ICRP, e.g. ICRP-60[3], IAEA Basic Safety Standards[4], EU Basic Safety Standards[5] and national rules).

The principle of justification means that a practice should only be adopted if its intention cannot be achieved without or with significantly lower radiation exposure. In the case of reprocessing the intention to use plutonium cannot be achieved without reprocessing the spent fuel.

The optimisation means that the resulting radiation exposures must be as low as reasonably achievable (ALARA principle). The statement in the Interim Report totally ignores the ALARA principle. It is stated that the releases of radioactivity from a reprocessing facility are not significantly higher than those from an interim storage and final disposal facility only on the grounds that radiation exposure is low, well below the limits and much lower than natural exposure. Table 1 shows the limits for releases of radioactivity of the German reprocessing facility in Wackersdorf (licensed but construction stopped in 1989) and the Rokkasho reprocessing facility.

Table 1: Limits for releases of radioactivity of two reprocessing facilities (in Bq/yr)

Nuclide/group	Reprocessing facility Rokkasho[6]	 Wackersdorf
Aerial discharges		
krypton	$3.3 \cdot 10^{17}$	$1.6 \cdot 10^{17}$
tritium	$2 \cdot 10^{15}$	$1.5 \cdot 10^{15}$
iodine-129	$1.3 \cdot 10^{10}$	$1.8 \cdot 10^{9}$
Liquid discharges		
tritium	$1.8 \cdot 10^{16}$	$3.7 \cdot 10^{13}$
all beta-emitters (except tritium)	$7 \cdot 10^{11}$	$1.3 \cdot 10^{10}$
all alpha-emitters	$9.8 \cdot 10^{9}$	$4.4 \cdot 10^{8}$
iodine-129	$2.6 \cdot 10^{10}$	$1 \cdot 10^{8}$

[2] Scenario 1: all spent fuel is reprocessed; Scenario 2: quantity of spent fuel that exceeds reprocessing capacity is disposed.
[3] International Commission on Radiological Protection. 1991. Recommendations of the International Commission on Radiological Protection. Publication No. 60.
[4] International Atomic Energy Agency. 1996. International Basic Safety Standards for Protection against Ionising Radiation and for the Safety of Radioactive Sources. IAEA Safety Series No. 115. Vienna.
[5] European Union. 1996. Council Directive of the European Union Laying Down the Basic Safety Standards for the Protection of the Health of Workers and the General Public Against the Dangers Arising from Ionising Radiation. 96/29/Euratom.
[6] see, for example, CNIC. November 1997. Final Report of the International MOX Assessment. Comprehensive Social Impact Assessment of MOX Use in Light Water Reactors. IMA Project, table 3-10.

The data presented in Table 1 show a significant difference of the limits for releases of radioactivity for those radionuclides that are relevant for the resulting doses to the public from the Rokkasho and Wackersdorf facility. Dose-relevant radionuclides are iodine-129 and the beta-emitters (except tritium) and alpha-emitters in waste water. The limits that were licensed for the Wackersdorf facility are much lower than those of the Rokkasho facility, even when the annual capacities of the facilities are taken into account (800 tHM in Rokkasho versus 500 tHM in Wackersdorf). This means that the releases of radioactivity to the environment from the Rokkasho reprocessing facility are not as low as reasonably achievable and that the ALARA principle is violated. Natural radiation exposure is no adequate criterion to compare radiation exposures in the different scenarios.

The situation at existing reprocessing facilities is as follows:

- Discharges of dose-relevant long-lived radionuclides from reprocessing facilities (including the Rokkasho facility) are at least four orders of magnitude higher compared with nuclear power plants[7]. Liquid discharges from the Sellafield plant have been reduced since the 1970s but are still at least four orders of magnitude higher compared with real liquid discharges from nuclear power plants.
- There is an accumulation of long-lived radionuclides especially in the marine environment around the reprocessing facilities that is much higher than nearby nuclear power plants[8].
- Long-lived radionuclides are spread over very long distances, e.g. technetium-99 from Sellafield is measured at different Scandinavian coasts, in Greenland etc.

Additional exposures and risks result from the following facts:

- Reprocessing causes transports of radioactive materials over long distances (from nuclear power plant to reprocessing facility, from reprocessing facility to waste storage facilities and to fuel fabrication facilities).
- The fabrication of MOX fuel causes enhanced radiation exposure of workers, compared to fabrication of uranium fuel[9]. In the (meanwhile decommissioned) Siemens fuel fabrication facilities for MOX and for uranium fuel fabrication the individual and collective dose for workers was two orders of magnitude higher per tHM of produced fuel for MOX than for uranium fuel. Due to the difference in specific activity and inhalation dose coefficients, the standards for protection against inhalation are roughly a million times stricter in plutonium processing than in uranium processing (related to the mass). Additionally, the dose rate from gamma radiation is higher for plutonium than for uranium because of the americium-241-content of plutonium, growing with the time after separation from spent fuel[10].
- The difference in specific activity and inhalation dose coefficients between plutonium and uranium also means that there is a major difference in risks to the public by possible accidents. Such accidents can be fire or external impacts like earthquake and aircraft crash that cause a release of relevant amounts of fuel material. The release of a defined mass of plutonium has roughly a one million times higher radiological consequence than the release of the same amount of uranium.

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[7] see, for example, IMA-Report, chapter 3.5.1.

[8] this is evident by the results of activity measurements according to the related reports by the operators and authorities; see, for example, C. Küppers and A. Benischke. 2000. Ermittlung der möglichen Strahlenexpositionen der Bevölkerung aufgrund der Emissionen der Wiederaufarbeitungsanlagen in Sellafield und La Hague (Assessment of the potential radiation exposure of the public by radioactivity releases from the reprocessing facilities in Sellafield and La Hague). Öko-Institut. Darmstadt. (in German).

[9] see, for example, IMA-Report, chapter 3.4.

[10] for details, for example see, C. Küppers, M. Sailer. 1994. The MOX Industry or The Civilian Use of Plutonium – Risks and Health Effects Associated with the Production and Use of MOX. Report from the German and Belgian Sections of The International Physicians for the Prevention of Nuclear War (IPPNW).

- The use of MOX fuel in nuclear power plants can enhance the probability of incidents and accidents in these plants. Radiation exposure can be higher after severe accidents with core damage in MOX-fuelled reactors[11]. If, in a long-term view, plutonium is used as fuel in fast breeder reactors, the special safety aspects of such reactors, due to a very high power density and the use of liquid metals for cooling, must be taken into account.

Direct final disposal (including interim storage) has the following advantages from the perspective of radiation protection:

- Spent fuel is stored in casks that prevent releases of radionuclides to the environment and that give protection even against severe impacts. The spent fuel is housed in a container of steel or cast iron with a wall thickness of 30 to 40 cm. The cask consists of a container body and a cap system, which normally comprises two caps and different sealings for each cap. The sealing systems for both caps should be leak-proof for more than forty years. The thick wall of the storage cask serves as the protection against radiation as well as heavy external impacts. The dry storage of spent fuel in casks is in large part based on passive safety features with low failure probability. Therefore, there are very low risks by interim storage facilities in comparison to other nuclear facilities. Dry storages for spent fuel even are the nuclear facilities with the lowest routine releases of radioactivity to the environment, whereas reprocessing facilities cause the highest contamination of the environment among all facilities of the nuclear “fuel-cycle”.
- In the case of reprocessing the amount of plutonium in the final disposal is reduced, but the use of plutonium as fuel causes a much higher inventory of other long-lived transuranium nuclides in the spent fuel, the reprocessing wastes and in the final disposal (e.g. neptunium-237). Therefore, the radiological long-term safety of a final disposal is not necessarily higher, if plutonium is separated from spent fuel by reprocessing.

Taking into account all these aspects the conclusion is that reprocessing (and use of plutonium in fuel) is the option with the highest radiation exposures to workers and the public. There is a significant difference in radiation exposures and risks between the scenarios defined in the Interim Report. The higher the quantity of reprocessed fuel in a scenario is, the higher will be the radiation exposure and risk. The difference in radiation exposure between the scenarios is several orders of magnitude (resulting from the exposure by reprocessing versus the much lower exposure by nuclear power plants and the nearly-zero exposure by dry storage facilities for spent fuel), so that this difference is obviously very significant. The oppositional statement of the Interim Report is the result of its very restricted perspective, reduced to the question of compliance with dose limits and to the comparison with natural exposure.

3. Safety of Reprocessing, Interim Storage and Final Disposal of Spent Fuel

The Interim Report states:

> *“In regard to ‘safety assurance’, by preparing appropriate response measures, taking into account the evaluation of assumed accidents based on the safety evaluation guidelines, it is possible to assure safety to the required standards. However, at this stage, Japan lacks technical knowledge in regard to direct disposal that takes into account Japan´s natural conditions. It is necessary to accumulate this knowledge.”*

The criterion used in the Interim Report is absolutely insufficient to compare safety aspects of the different scenarios. Of course, all facilities must fulfil the required safety standards, but there are significant differences in the possibility of severe accidents beyond the requirements and their radiological consequences.

[11] see, for example, IMA-Report, chapter 3.2 and 3.3

The different parts of reprocessing facilities have very high inventories of radioactivity. There are storing pools for spent fuel, storing (and vitrification) facilities for the high-active fission product solution, storing facilities for plutonium etc. All mentioned facilities have inventories of radioactivity that are much higher than those of a nuclear power plant. Compared to a dry storage of spent fuel there are lots of scenarios which cause a release of high amounts of radioactivity from a reprocessing facility (fire, severe earthquake, terrorist attack etc.). The real problem of accidents in reprocessing facilities results from accidents beyond the design and required standards. It was impossible to evaluate these differences to dry storage facilities for spent fuel in the Interim Report because an insufficient criterion was used for the evaluation.

Remark to the "closed-loop economy": The waste storage facilities at reprocessing sites are necessary for the interim storage of the wastes from reprocessing. After reprocessing the volume of radioactive waste is larger than before. Only a negligible part of the radioactivity in the spent fuel is separated for reuse, the major part remains in waste that must be disposed of. Therefore, the following statement in Annex (tables) of the Interim Report is absolutely wrong: *"Reducing the quantity of resources used and waste produced, reusing and recycling create a closed-loop economy. Reprocessing is consistent with this philosophy."*

Regarding the final disposal there is an additional inventory of plutonium in it, if spent fuel is not reprocessed. However, some aspects should not be ignored:

- Every final disposal for high-level radioactive waste will contain plutonium and other fissionable material. The absolute inventory depends mainly from the number of cycles in which plutonium is reused, considering that the quality of the plutonium (fissile part of its isotopes) is reduced with every reuse and separation.
- The reuse of plutonium causes additional problems in respect to the final disposal. There is a significantly enhanced heat production in spent MOX fuel compared to spent uranium fuel and the inventory of some long-lived transuranium nuclides grows up. The enhanced heat production creates a need for long-term cooling. For example, spent MOX fuel elements with a burn-up of 33 GWd/tHM after about 100 years have dropped to a heat output of spent uranium fuel elements with the same burn-up after a cooling period of 10 years[12]. With higher burn-up this effect grows up and the time, when the same heat production is reached, can be several hundreds of years. Reprocessing of spent MOX fuel cannot significantly reduce this effect, because the major part of the enhanced heat results from transuranium nuclides.

4. Proliferation Risks Related to Separated Plutonium and Spent Fuel

The Interim Report states, that *"there is no significant difference between the scenarios on the issue of non-proliferation"*. The reasons, presented to support this conclusion, are:

- In the case of reprocessing, MOX is fabricated from the separated plutonium and this is done in accordance with technical procedures agreed with the US.
- In the case of direct final disposal the temptation for diversion of nuclear fuel will be increased in the period between hundreds and tens of thousands of years after disposal, so that a monitoring and physical protection system must be developed and implemented.

Due to its suitability for weapons plutonium especially must be carefully observed in order to avoid proliferation (misuse of civil plutonium for military purposes), or at least to discover it early on. For this control the so-called safeguard measures are used. Inspectors from international organisations (IAEA and in Europe also Euratom) control the civil nuclear plants using certain methods. The methods must be

[12] for details, for example see the figures in IMA-Report, chapter 5.4.1 or IPPNW-Report, chapter 7.2.

adapted to the prevailing technical processes in the observed plant and to the proliferation resistance of each handled material containing plutonium. The isotopic composition is not considered because of plutonium's fundamental suitability to weapons on examination of proliferation resistance.

Safeguards can relatively easy be implemented as long as countable items containing fissile materials are handled. Regarding fuel, this is done by measuring the fissile material content. As long as this element is not dismantled it can be surveyed easily during handling, storage or transportation, because only the methods of containment and surveillance have to be applied. Sealed containers are, in view of safeguards, similar countable "items" as fuel. Interim storage sites are, therefore, relatively easy to survey if safeguard aspects were considered during construction.

One main weakness of the safeguard concept is exposed through all the so-called "bulk-handling facilities". These are plants where plutonium (and other fission products) are handled in great amounts in their free-flowing separated form, for example, reprocessing facilities and MOX fuel fabrication facilities. As long as the plutonium is packed and kept together (e.g. in fuel assemblies), it can be accurately counted using the methods mentioned above. If, however, material containing plutonium appears in a non countable form (powder, solution, pellets, abrasive dust and other scrap material) accuracy is not guaranteed during counting - up to 1% inaccuracy is unavoidable with every check carried out. The calculated material balance differs then from stock-take to stock-take. This can lead to considerable amounts of material unaccounted for (MUF).

The IAEA states[13]: For item material balance areas (MBAs), MUF should be zero, and a non-zero MUF is an indication of a problem (e.g. accounting mistakes) which should be investigated. For bulk handling MBAs, a non-zero MUF is expected because of measurement uncertainty and the nature of processing. The operator's measurement uncertainties associated with each of the four material balance components are combined with the material quantities to determine the uncertainty of the material balance.

Should there appear a MUF greater than zero, the safeguard organisations are faced with the problem of not being able to distinguish between a real proliferation and a statistical inaccuracy. The bigger the inventory handled in a plant, the greater the inaccuracy. This in turn means that the absolute amount of MUF which can be tolerated is greater- due to this inability to distinguish between real proliferation and inaccuracy.

Dealing with these inaccuracies, the IAEA defines a "detection probability" and a "false alarm probability". The detection probability is the probability, if diversion of a given amount of nuclear material has occurred, that IAEA safeguards activities will lead to detection. The values of accountancy detection probability currently in use are 90% for 'high' and 20% for 'low' probability levels[14]. False alarm probability is the probability that statistical analysis of accountancy verification data would indicate that an amount of nuclear material is missing when, in fact, no diversion has occurred. It is usually set at 0.05 or less, in order to minimize the number of discrepancies or false anomalies that must be investigated[15].

So-called significant quantities are used in establishing the quantity component of the IAEA inspection goal. The quantity value currently in use for plutonium is 8 kg[16]. The combination with the above mentioned detection probability and false alarm probability results in the fact that the amount of plutonium diverted from a reprocessing facility with high through-put that can be detected is much higher than the significant quantity of 8 kg, for example 50 to 100 kg.

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[13] International Atomic Energy Agency, IAEA Safeguards Glossary, 2001 Edition, International Nuclear Verification Series No. 3, Vienna, section 6.43.
[14] IAEA Safeguards Glossary, section 3.16.
[15] IAEA Safeguards Glossary, section 3.17.
[16] IAEA Safeguards Glossary, section 3.14.

This cannot be avoided by using "near real time accountancy (NRTA)". This is a form of nuclear material accountancy for bulk handling material balance areas in which itemized inventory and inventory change data are maintained by the facility operator and made available to the IAEA on a near real time basis so that inventory verification can be carried out and material balances can be closed more frequently than, for example, at the time of an annual physical inventory taking by the facility operator[17]. However, it inevitably includes the estimation of in-process inventory by calculation because the plant operation cannot be stopped at each time. Therefore, NRTA does not mean that the material balance data are available nearly continuously, but for shorter time periods than one year.

Due to the fundamental problems of balancing as a measurement technique, the proliferation risk of free-flowing plutonium is high. It is therefore preferable to keep plutonium in spent fuel from the view-point of non-proliferation. The Interim Reports referred to *"internationally agreed safeguards"* and *"accordance with technical procedures agreed with the US"* to argue that there is no major proliferation risk associated with reprocessing spent fuel. This evaluation ignores the insufficiencies of physical measurements and the inherent inaccuracy on which the safeguards are based. Obviously, these physical facts cannot be substituted by international agreements or agreements with the US.

Regarding plutonium in a final disposal the following facts must be considered:

- In a final disposal with irradiated fuel elements, the protective effect of the fission products remains over very long periods. Should an interest in a clandestine military use arise after several hundreds or thousands of years, the opening of the final disposal and salvage of the fuel elements would still be a massive operation. Substantial radiation shielding measures would still be necessary, and the centuries-old fuel elements would still have to be manipulated by remote control. Due to the extensive measures necessary, the recovery of such old irradiated fuel elements could hardly pass unnoticed. A lot of concepts exist for the monitoring of a final disposal site, see, for example papers of the IAEA[18].
- It is highly questionable whether plutonium and nuclear weapons will still have the same military importance in the more distant future than today. It is rather to be expected that the relevance of plutonium will be that of flint stones to us, which also had a key military function several thousand years ago.
- The future effort required to salvage plutonium from a final repository must also be viewed in comparison to the effort required for new production. It is technically simpler to create plutonium in a small special reactor and separate this plutonium from the fresh spent fuel than to salvage irradiated fuel elements from a final disposal and to reprocess the salvaged elements, which will be in a very "undefined" condition.

5. Overseas Trends

Only some short comments will be given here to the overseas trends as they are described in the Interim Report.

The Interim Report states in its Annex (tables), that Germany, Switzerland and Belgium are examples of countries following scenario 2 (reprocess spent fuel, but directly dispose of that quantity which exceeds reprocessing capacity). This is not comprehensible at all because all these countries do not operate national reprocessing facilities (at least since a lot of years) but had spent fuel reprocessed abroad. The decision for a phase-out of reprocessing was not drawn because of missing reprocessing capacity abroad.

[17] IAEA Safeguards Glossary, section 6.3.
[18] see, for example, A. Fattah. 1999. Safeguards Policy and Strategies. An IAEA Perspective for Spent Fuel in Geological Repositories. International Atomic Energy Agency (IAEA)/Department of Safeguards, EPR-55. Vienna.

The French and British reprocessing facilities can offer a lot of capacity to foreign customers. Therefore, the classification in the Interim Report is not correct.

The evident disadvantages of reprocessing spent fuel lead to the German decision to stop the transport to reprocessing at July 1st, 2005. This was fixed in the atomic law as a result of an agreement between the German federal government and the German operators of nuclear power plants. Another important change in the atomic law was the definition of a remaining plant-specific amount of electricity that is allowed to be produced in the nuclear power plants. Meanwhile, the Christ democrats proclaimed that they would change the atomic law again, if they will be the winners of the next federal elections (probably taking place in autumn 2005), so that the nuclear power plants can run for a longer time-period. But there is no wish to restart transports to reprocessing in Germany.

6. Conclusions

The main conclusions can be summarized as follows:

- The higher the quantity of reprocessed fuel in a scenario is, the higher will be the radiation exposure of workers and the public. The difference in radiation exposure between the scenarios is several orders of magnitude.

- The higher the quantity of reprocessed fuel in a scenario is, the higher will be the risk resulting from accidents. These accidents can occur at the reprocessing facility, during fabrication of MOX fuel and during the use of the MOX fuel in a nuclear reactor.

- The higher the quantity of reprocessed fuel in a scenario is, the higher will be the amount of plutonium that is handled in bulk-facilities and not in an itemized status. Due to the corresponding difficulties of possible safeguard measures this results in growing proliferation risks.

Therefore, regarding radiation protection, safety and non-proliferation, scenario 1 (reprocessing of all spent fuel) shows the most disadvantages and scenario 3 (direct final disposal of all spent fuel) shows the most advantages.

The different results in the evaluation by the New Nuclear Policy-Planning Council on nuclear fuel cycle policy in Japan are due to

- generally ignoring optimization below dose limits,
- generally ignoring differences in respect to accidents beyond the design basis,
- generally ignoring differences in the number and kind of facilities where such accidents can occur,
- generally ignoring the physical basis and restrictions of safeguards,
- abandoning the weighting of the importance of different criteria.

Chapter 5

ICRC REVIEW

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1. Introduction

I divide this review into two parts:

2. Domestic considerations: economics, safety and other, and
3. International considerations: the added danger of plutonium diversion by would-be nuclear terrorists and damage to the effort to contain the proliferation of national nuclear fuel-cycle facilities.

As an international reviewer, I focus more on the latter aspects. However, I hope that my comments on nuclear safety issues may have special value as well.

2. Domestic considerations

I divide the discussion of domestic considerations into three subsections:

1. Economics,
2. Safety, and
3. Other considerations.

2-1. Economics

The Interim Report[1] concludes that direct disposal of 32,000 tons of spent fuel instead of reprocessing it and recycling the plutonium it contains would save Japan about:

- 0.6 ¥/kWh of nuclear-generated electricity or
- 173 billion ¥ per year or
- 7 trillion ¥ over the 40-year operating life of the Rokkasho plant.

Comment. This is the only part of the report that contains significant analysis. I agree with its conclusion that the reprocessing/recycle option would be extraordinarily costly.

2-2. Safety

The Interim Report dismisses concerns about a possible accidental or terrorist dispersal of radioactivity from Rokkasho, stating without analysis that the risks to the Japanese population would be no greater from reprocessing than from direct disposal of spent fuel.

[1] CNIC [Internet]. Translation of the AEC Planning Council's Interim Report Concerning the Nuclear Fuel Cycle Policy. [updated 12 November 2004]. Available from: http://cnic.jp/english/topics/policy/chokei/longterminterim.html. (Also attached at the end of this report).

Comment. Most of the danger from spent fuel occurs while it is still in the spent-fuel storage pools associated with the reactors from which it has been discharged.[2] The risks from reprocessing and plutonium recycle therefore are *additive*, *not alternative* to most of the safety risk from unreprocessed spent-fuel.

In 2000, the twenty one radioactive-waste tanks at the United Kingdom's THORP facility contained about 185 Mega-Curies (MCi) of 30-year halflife cesium-137, almost 100 times as much as was released by the Chernobyl accident.[3] The amount of 30-year halflife strontium-90 would have been about the same. The UK Nuclear Installations Inspectorate expressed concern about the possibility of hydrogen or red oil explosions occurring in these tanks and dispersing some of their contents.[4] An explosion in a radioactive waste tank in the Soviet Union's RT-1 reprocessing plant in the Urals ejected about 0.5 MCi of strontium-90 and caused the long-term evacuation of 1000 km^2.[5] The economic damages from hypothetical releases of 3.5 and 35 MCi of Cs-137 from 5 U.S. reactor sites have been estimated at $100-400 billion.[6] The risk of accidental or deliberate dispersal into the atmosphere of liquid high-level waste therefore deserves serious consideration.

Potential large releases of plutonium-oxide aerosol from storage at the reprocessing plant, from the plutonium-fuel fabrication plant or during transport in between must also be considered. Eight thousand kilograms of plutonium oxide powder would be processed annually at Rokkasho and it is likely that a much larger quantity would be stored there. The accidental dispersal of only 10 kilograms of plutonium-oxide aerosol 30 kilometers upwind from Seattle would cause hundreds to thousands of additional cancer deaths.[7]

2-3. Other considerations

The Interim Report concludes that the huge economic costs, the safety issues, and the security and nonproliferation objections to plutonium recycle that I discuss below in the section on international considerations are outweighed by the following considerations:

i. **The lack of experience with the direct disposal of spent fuel.**

Comment. Japan and the world nuclear industry lack experience also with the disposal of the high-level vitrified waste generated by reprocessing, and the transuranic waste from the fabrication of fuel containing plutonium and the decommissioning of the reprocessing and fuel-fabrication facilities. The issues raised by all these radioactive-waste disposal problems have much in common. Therefore, this consideration does not weigh for reprocessing.

ii. **The problem of maintaining the technology base and human skills required for reprocessing if the Rokkasho reprocessing plant and plutonium-fuel fabrication facility are not operated.**

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[2] Robert Alvarez, Jan Beyea, Klaus Janberg, Jungmin Kang, Ed Lyman, Alliston MacFarlane, Gordon Thompson, and Frank N. von Hippel. 2003. Reducing the hazards from stored spent power-reactor fuel in the United States. Science & Global Security 11. 1p.
[3] Gordon Thompson. 2000. High-level radioactive liquid waste at Sellafield: An updated review by Institute for Resource and Security Issues. p. 6. Available from: http://www.irss-usa.org/pages/enpubsum2.html.
[4]2000. The storage of liquid high level waste at BNFL Sellafield: An updated review of safety, HM Nuclear Installations Inspectorate. pp. 37-40.
[5] Thomas Cochran, Robert Norris and Oleg Bukharin. 1995. Making the Russian bomb: From Stalin to Yeltsin. Westview. pp. 109-113.
[6] Jan Beyea, Ed Lyman and Frank von Hippel. 2004. Damages from a major release of ^{137}Cs into the atmosphere of the United States. Science & Global Security 12, p125.
[7] Steve Fetter and Frank von Hippel. 1990. The hazard from plutonium dispersal from nuclear-warhead accidents. Science & Global Security 2. p21.

Comment. Japan developed its current expertise in reprocessing and mixed-oxide fuel fabrication without operating the Rokkasho plant. If these capabilities are needed in fifty or a hundred years, Japan's nuclear-power R&D community could devise programs to preserve and restore them at a cost far less than 170 billion ¥ per year operating cost of the Rokkasho plant. The benefit of embarking on reprocessing for this reason is therefore is far outweighed by the costs.

iii. **The 10-20 percent uranium resource savings that would result from recycling plutonium recovered by reprocessing.**

Comment. At the average uranium price paid by U.S. reactor operators in 2004 ($33 per kilogram[8]) Japan could replace the annual savings of 800-1600 tonnes of natural uranium that would result from reprocessing and recycling plutonium (and possibly uranium) for a few percent of the cost of operating the Rokkasho plant. Therefore, this benefit would be far outweighed by the costs.

Uranium savings are not an argument for operating Rokkasho now, however, because the plutonium separated at Rokkasho would not be used until the 40 tons of separated plutonium that Japan has already stockpiled have been recycled. This is not likely to have been accomplished in less than 15 years.

Furthermore, if Japan chooses direct disposal as its spent-fuel policy and changes its mind later, the fuel value of the plutonium and uranium in today's spent fuel will still be available for recovery until a final decision is made to close Japan's first radioactive waste repository, many decades in the future.

iv. **The problem of finding interim storage sites.**

Comment. Vitrified high-level waste also requires interim storage until geological disposal becomes available. Aomori Prefecture has agreed to provide interim storage for Japan's foreign and domestic high-level reprocessing waste at the Rokkasho plant for up to 50 years. It will also store for decades most of the plutonium that will be recovered there. Thus the Aomori Prefecture has already agreed to supply interim storage for Japan's spent fuel for decades -- only in the form of separated radioactive materials instead of the mixture in spent fuel.

Why would the prefecture not accept the lower risks of interim storage of the intact, self-protecting spent fuel if the same tax revenues and number of jobs were guaranteed? Has this formulation of the question been discussed with the leadership of the prefecture?

3. International considerations

As my comments above suggest, the arguments being made in the Interim Report for the operation of the Rokkasho reprocessing plant evaporate under close and critical inspection. At the same time, the safety issues relating to the storage and processing of liquid high-level waste and plutonium oxide have not been addressed seriously.

If these were the only issues, however, the debate over the operation of Rokkasho would be a domestic matter for Japan. What makes it an issue of international concern is the risk of plutonium diversion to terrorists and the impact of Japan's example on the current effort to stem the spread of nuclear fuel-cycle facilities to countries of proliferation concern. Plutonium separated *anywhere* is a potential threat to cities *everywhere*.[9]

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[8] Energy Information Administration. 2004. Uranium Marketing Annual Report. 2004 Edition.

[9] Japanese reprocessing advocates often argue that power-reactor plutonium, unlike weapon-grade plutonium, cannot be made into a nuclear weapon. This is despite repeated briefings to the contrary from U.S. nuclear-weapon

In the remainder of this review, I therefore discuss the Interim Report's treatment of the diversion and proliferation costs of operating the Rokkasho plant and sketch out some of the issues that should have been analyzed but were not.

3-1. Risks of plutonium diversion

The Interim Report states that the increased risk of diversion of plutonium due to plutonium separation in reprocessing is offset by the danger that plutonium could be mined from buried spent fuel hundreds or thousand of years in the future.

Comment. This is a problematic comparison because no one can predict the type of society that will exist so far in the future. If there are central governments, they ought to be able to keep terrorist groups from recovering plutonium from a central nuclear-waste repository hundreds of meters underground much more easily than a government today could prevent the theft of plutonium in surface storage, processing or transport.

On the surface, diversion resistance comes from two sources:

i. The physical characteristics of a plutonium-containing material, and

ii. Added barriers (guards, barriers, intrusion alarms, etc.)

i. Inherent diversion resistance. The interim report does not and cannot claim that stealing the 8 kg of plutonium that the IAEA considers sufficient to make a crude nuclear explosive, and the 8 kg of uranium diluent in the Rokkasho reprocessing plant product[10] would be as difficult as stealing two half-ton spent-fuel assemblies containing the same amount of plutonium.

The gamma field around an unshielded spent fuel assembly, 20 years after discharge from a reactor, would deliver a lethal dose one meter away in 15 minutes.[11] A cask weighing tens of tons therefore would be required to provide shielding during transport, and the mechanical and chemical separation of the plutonium from the fission products would have to be carried out behind heavy shielding -- i.e. in an improvised reprocessing plant. This makes quite implausible the idea of terrorist theft and reprocessing of spent fuel.

In contrast, the plutonium-uranium oxide mix produced by the Rokkasho reprocessing plant could be transported in lightweight airtight containers. Similarly, a unirradiated mixed-oxide (MOX) fuel

designers. The technical issues relate to the effects of the higher concentrations of Pu-238 and Pu-240 in power-reactor plutonium. Because of its short half-life, Pu-238 generates heat. A kg of power-reactor plutonium generates decay heat at a rate of about 20 Watts per kg vs. about 2 Watts/kg for weapon-grade plutonium. Inside a thick insulating blanket of high-explosive such as in the Nagasaki bomb design, the plutonium would eventually heat up to a level where the high-explosive would start to decompose. However, for safety reasons, the Nagasaki design had the plutonium inserted not long before detonation. This would also avoid the overheating problem. Pu-240 is problematic because it releases neutrons by spontaneous fission that could start the fission chain-reaction before the imploded plutonium reached its maximum supercriticality. This would reduce the yield of a Nagasaki-bomb design but the lowest yield expected from that design would still be equivalent to about 1000 tons of chemical explosive, J. Carson Mark. 1993. Explosive properties of reactor-grade plutonium. Science & Global Security 4. 111p. The yields of modern weapon designs are not sensitive to pre-initiation of the chain reaction.

[10] Uranium/Plutonium Mixed Oxide: Safety in Regard to Fuel Fabrication Facility, Safety Check Investigation Committee Report. 2002. Outline of raw material type and product fuel type. 13p. Table 3.

[11] W.R. Lloyd, M.K. Sheaffer, and W.G. Sutcliffe. 1994. Dose Rate Estimates from Irradiated Light-Water-Reactor Fuel Assemblies in Air. Lawrence Livermore National Laboratory. UCRL--ID-115199. Five Sieverts (500 rem) is a median lethal dose.

assembly containing 30+ kg of plutonium could be placed in the back of a truck without shielding. In both cases the plutonium could be separated later in an unshielded glove box.

ii. Added barriers to diversion. The risks of theft of separated plutonium and MOX fuel are reduced by the addition of physical barriers, access controls, intrusion sensors, and guards. The U.S. spends almost a billion dollars per year on such protections for its military plutonium and high-enriched uranium. Major shortcomings have been identified, however, that make this material vulnerable to theft.[12] Such vulnerabilities are typical of added barriers. Physical self-protection is much more reliable.

The Interim Report points out that the self-protection of spent fuel will die down "in the period between hundreds and tens of thousands of years" and hence "it will be necessary to develop and implement an efficient and effective internationally agreed monitoring and physical protection system." The concern is that spent fuel repositories could become "plutonium mines."

The Interim Report ignores, however, the fact that the buried wastes from reprocessing and MOX fuel fabrication also will contain significant quantities of plutonium. On the order of one percent of the plutonium in the spent fuel ends up in the waste. In 40 years one percent of the 8,000 kg/yr plutonium output of the Rokkasho plant would mount up to enough material for 400 nuclear weapons.

There is also about 2% as much Americum-243 as plutonium in spent fuel. If the spent fuel is reprocessed, the Am-243 is to be buried with the vitrified high-level waste., It decays with a 7400-year half-life into plutonium-239.

Of course, if plutonium is still being separating and recycled in that distant future, it will still be more difficult to protect on the surface than the dilute plutonium stored in a few national repositories under hundreds of meters of rock.

3-2. Effect of Japan's decision upon the proliferation of national fuel-cycles

The Nuclear Policy-planning Commission dismisses with a meaningless sentence the entire issue of the impact on the international nonproliferation effort of a Japanese decision to separate hundreds of tons more plutonium:

> "each country is making a choice between reprocessing and direct disposal in response to geological factors, resource factors, scale of nuclear power generation, and cost competitiveness."

"Resource factors" are irrelevant to the operation of Rokkasho any time in the next decades, however. And, as the Interim Report acknowledges, reprocessing and plutonium recycle are not cost competitive with direct disposal.

The current global concern about Iran's acquisition of a nominally civilian but inherently dual-use fuel-cycle facilities indicates, however, that the proliferation of such facilities is also a major international-security issue.

In the case of reprocessing, it is easy to see that a country that has only spent fuel is much further from possessing nuclear weapons than an otherwise identical country that has a large stockpile of separated plutonium.

Consider a scenario in which the governments of these two hypothetical countries both decide one day that they wish to make nuclear weapons. The government that does not have separated plutonium or a

[12] See e.g. U.S. nuclear weapons complex [Internet]: Homeland security opportunities, Project on Government Oversight. May 2005. Available from: http://www.pogo.org/p/homeland/ho-050301-consolidation.html.

reprocessing plant will require a considerable amount of time to build a reprocessing plant and begin to separate plutonium from its spent fuel. This could give time for domestic anti-nuclear-weapon groups and allied governments to persuade the government to change its mind. This is, in fact, what happened in a number of countries, including Sweden in the late 1960s, and Argentina and Brazil in the 1980s and early 1990s.

Japan, of course, is different. Even without putting Rokkasho into operation, Japan already has over 5 tons of separated plutonium, enough to make 600 first-generation nuclear weapons because of its previous reprocessing activities at Tokai Mura and early imports from the U.S. and perhaps other countries.

The Interim Report does not even consider, however, the fact that Japan's example, as the only non-nuclear-weapon state with a reprocessing facility, undercuts ongoing international efforts to discourage the proliferation of nuclear fuel-cycle facilities.

Recently, I participated in a two-day discussion of Iran's nuclear program with a high-level group of Iranians in Vienna. Repeatedly, the Iranians insisted on their country's "inherent right" under the Nonproliferation Treaty to acquire enrichment technology. Repeatedly the Iranians asked why their country should not acquire the same technology as Japan. When I responded that acquiring the technology would put Iran in a position to very quickly acquire a nuclear weapon. The response was, "Why should not Iran have a nuclear-weapons option like Japan? All we want is the option. Don't worry, we won't use it!" I have had similar discussions with nuclear analysts in Brazil, South Korea and other countries.

The IAEA Director General has proposed multilateral fuel-cycle facilities as an alternative the proliferation of national enrichment and reprocessing plants.[13] The issue mostly concerns enrichment plants, which are required by today's nuclear power plants. Reprocessing plants are neither required nor even economic. In any case, this option is not discussed in the Interim Report.

I criticize my own Government frequently these days for policies that undercut the nonproliferation regime.[14] In this case, Japan too would set a terrible example by insisting on operating a facility that is designed to produce annually enough separated plutonium to make 1000 nuclear weapons. As the discussion above shows, Japan has *no justification whatsoever* for doing this. Its example therefore undercuts those who would challenge the justification of fuel-cycle plants in other countries and urge those countries to explore alternatives such as interim spent-fuel storage.

What makes the situation even more extreme in this case is that the Government of Japan proposes to violate its own commitment to "the principle of no surplus plutonium."[15] It is proposing to launch the operation of a huge domestic reprocessing plant at a time when it already has a stockpile of 40 tons of separated plutonium that it has not yet been able to recycle. These considerations have put the importance of delaying operation of the Rokkasho plant near the top of the international nonproliferation agenda.[16]

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[13] See , IAEA. 2005. Multilateral approaches to the nuclear fuel cycle: Expert group report submitted to the Director General of the International Atomic Energy Agency. INFCIRC 640.

[14] See e.g. Steve Fetter and Frank N. von Hippel. 2005. U.S. Reprocessing? Still unnecessary, uneconomic and risky. Arms Control Today. (in press).

[15] See Japan's submission to the IAEA, "Plutonium utilization plan of Japan," attached to InfCirc/549, Add. 1, March 31, 1998 on the IAEA's web site.

[16] See "A call on Japan to strengthen the NPT by indefinitely postponing operation of the Rokkasho Spent Fuel Reprocessing Plant," released by the Union of Concerned Scientists at the Nonproliferation Treaty Review Conference, May 5, 2005. The 28 prominent scientists who were the first signatories include four winners of the Physics Nobel Prize and Joseph Rotblat, who was awarded the Nobel Peace Prize because of his life-long work for nuclear disarmament starting with his resignation from Los Alamos after the defeat of the Nazis, Available from: http://www.ucsusa.org/global_security/nuclear_terrorism/page.cfm?pageID=1765.

If it is impossible to get Japan, the only country thus far to have cities devastated by nuclear bombs and the home to the world's leading nuclear disarmament movement, to set a good example, what basis is there for hope that other countries will behave responsibly?

4. Conclusion

I can find no basis in the Nuclear Policy-Planning Council's interim report for its conclusion that the benefits of operating the Rokkasho plant and recycling the recovered plutonium would exceed the costs. To the contrary:

- The cited benefits are minor or nonexistent;
- The financial cost to Japan would be huge;
- The increased risks of radioactive contamination within Japan and of nuclear terrorism to all countries would be significant; and
- The damage to the international nonproliferation regime could be severe.

In contrast, if Japan postponed the operation of Rokkasho for at least a decade -- or even for the duration of the 5-year moratorium called for by IAEA Director General ElBaradei -- that action would give hope to nuclear nonproliferation and disarmament advocates worldwide.