# International MOX Assessment Project

## Conclusions and Recommendations

Plutonium is essentially a man-made radioelement which occurs in nature only in very minor quantities in a handful of locations on this planet. Every uranium fuelled commercial size nuclear reactor (1,000MW) produces roughly 200 kg of plutonium per year. Initially, plutonium-239, the most important fissile isotope of plutonium with a half life of 24,000 years, had been produced in a sizable quantity to fabricate weapons of mass destruction, which showed its terrible efficiency at Nagasaki in 1945.

### One of the Most Toxic Elements Known to Man

Plutonium-239 is a well-known carcinogenic (cancer-causing) substance, but reactor grade plutonium, which consists of a combination of various isotopes of plutonium and is commonly used in civil plutonium programs, is eight to ten times more toxic by weight than pure plutonium-239. *One gram of reactor grade plutonium oxide* corresponds to the cumulated annual *limit of inhalation* for as many as *40 million people*. This order of magnitude should be kept in mind when discussing plutonium production and stocks in the order of dozens of metric tons.

### Fast Breeder Reactors Abandoned-MOX Fuel Prompted

Beyond military uses, plutonium separation had been originally justified by the development of fast breeder reactors. However, fast breeder reactor programs have been abandoned entirely in the USA and Europe. The French government has acknowledged the failure of the program and shut down definitely the Western world's only industrial scale fast breeder reactor Superphenix. In Japan the Monju reactor has been shut down since a sodium fire devastated the plant in December 1995. There are no realistic perspectives for any significant future breeder program in Japan. As a consequence, MOX (uranium-plutonium mixed oxide fuel) is being prompted to absorb vast plutonium stocks arising as a consequence of earlier decisions on plutonium separation.

### Plutonium Stockpiles Still Growing

By year 2000 the US-Russian *stockpile of separated weapons plutonium* (outside weapons) will be roughly *160 tons.* In addition, the civil plutonium stocks continue to rise, especially in Europe. In 1996, worldwide about 22 tons of plutonium were separated and only 8 tons were used as MOX and in FBR programs. The total stock was estimated by the IAEA to be about *160 tons* at the end of 1996. The Japanese stockpile was about 16 tons at the end of 1995, according to the Japanese government, or roughly *10% of the world's stockpile*, it will increase its share and reach 30 tons and 70 tons in 2000 and 2010 respectively, according to an estimate by the Group.

### Any Plutonium is Potential Primary Bomb Ingredient

There are various "qualities" of plutonium. However, the Group's analysis has clearly established that: *Plutonium of almost any isotopic composition*, and in particular plutonium separated from spent fuel of *any nuclear reactor* currently operating in Japan, can be used for the manufacturing of a *nuclear explosive device*. Reactor grade plutonium in the form of oxide crystals in spherical shape has a critical mass of about 35 kg. The radius of this sphere would be about 9 cm, the *size of a cantaloupe*. The transformation of plutonium oxide into metal - a straightforward chemical process - reduces the critical mass to 13 kg which would be still reduced if a neutron reflector like natural uranium was used. Persistent statements by the plutonium industry as to the inadequacy of reactor grade plutonium for the manufacturing of an explosive device are misleading and scientifically incorrect.

### Weapons Plutonium to MOX: A Counterproductive Proposal

In a 900-MW(e) light-water reactor which can use MOX in a third of the core, about 170 kg of weapons plutonium could be absorbed a year. Besides the build-up of an entire plutonium alloy conversion and MOX fabrication infrastructure, it would take 30 of these reactors operating for at least 30 years to handle the 140 t of military plutonium to be removed from dismantled nuclear weapons in the next ten years. This activity would contribute to the dispersion of plutonium to a large number of facilities over a long time span and thus encourage nuclear proliferation rather than prevent it.

### Safeguards: Not up to the Challenge

Independent experts have calculated that, in the case of a large reprocessing plant (capacity of 800 tons of spent fuel per year), even if the error margin in the operator's computer calculation is as low as 1%, the minimum amount of diverted plutonium which could be detected with a probability of 95% and a false alarm probability of 5% is about 220 kg, enough to produce 6 to 10 crude nuclear bombs.

Problems of safeguarding of MOX fuel fabrication plants and fresh MOX fuel at reactor sites have been rated "high priority" by the IAEA as early as 1987. However, in 1994 it was disclosed that 70 kg of plutonium were held-up (stuck to surface) in remote-handling equipment at the Tokai Plutonium Fuel Production Facility.

It is chemically of no difficulty to extract plutonium from fresh MOX fuel. With the storage of fresh MOX fuel, the reactor sites thus become direct weapons use material storage sites. In 1996, the IAEA was confronted with the problem of the refusal by the operator of a German nuclear power plant of MOX fuel verification.

### Physical Protection: Defeatable

Detailed descriptions of current physical protection concepts are, for obvious security reasons, not in the public domain. However, independent experts have had a good insight into containment and surveillance systems and estimate that these systems can be defeated or circumvented. In particular the spectacular increase in plutonium and fresh MOX transports as well as MOX storage at reactor sites is of great security concern. The US

Department of Energy suggests that a special protection system guarded with "deadly forces" be necessary for MOX irradiation of weapons plutonium in commercial reactors.

### Nuclear Terrorism: An Increasing Threat

Increasing availability of plutonium and the existence of highly trained terrorist organizations make the escalation to nuclear terrorism more likely than ever. Some of these organizations have shown an unprecedented level of cruelty and the use of means of mass destruction. There can be no doubt that some of these groups would be in a position to manufacture a crude nuclear device or to deliver a credible equivalent threat.

### Safety of MOX Fuel Production and Use Questionable

The industrial experience with MOX is very limited as compared to UO2 fuel. The number of MOX assemblies used worldwide represents less than 0.2% of the total LWR fuel assemblies and even in Germany which, besides Japan, is the largest foreign reprocessing client of the French and English plutonium industries, the share does not exceed 4% (200 t of MOX against 5,000 t of UO2 fuel).

Certain properties of MOX fuel can have a negative impact in the reactor use, in particular in case of certain transients:

- The melting point of MOX is lower by 20-40 °C as compared to uranium fuel.
- The thermal conductivity of MOX fuel decreases systematically with increasing plutonium content.
- Reduction of neutron absorbing capacity of the control rods.
- Change of certain reactivity coefficients takes place, making a MOX-loaded reactor core more difficult to control under certain conditions.
- Power peaks are increased.
- The delayed neutron fraction is reduced, making the control more difficult.
- The neutron spectrum is hardened.

In general, MOX fuel lowers the safety margin of a light water reactor. In addition, there are considerable uncertainties in regard to safety-related aspects of MOX burning in light water reactors, particularly at large plutonium enrichment and high fuel burn-up.

### MOX Would Make a Severe Accidents Even Worse

In case of a severe reactor accident with containment failure, the dose at a given distance *would generally be 2.3 to 2.5 higher in the case of the MOX fuelled reactor*, implying that health effects of the radioactivity release would increase by the same factor. In other terms, the distance of various health impacts increases so that the actual increase in social impacts would be 3.2 to 4 times higher if social impact is assumed to be proportional to the affected area (since the area is proportional to the square of the distance).

### MOX Fuel Chain Introduces Risks at All Steps

The necessary manipulation of plutonium in all steps of the MOX fuel chain including reprocessing, fuel fabrication and handling of spent fuel makes each operation potentially more hazardous than in the case of the uranium fuel chain. Particularly, intensive radioactive discharges from a reprocessing plant cannot compare with other nuclear facilities and pose serious environmental and health risks.

### MOX Increases Fuel Costs Significantly

The Group's own economic analysis shows that the introduction of *MOX* to a third of core *will raise the fuel costs of LWRs by a factor of about 2.5*. There is no economic justification for the MOX use in light water reactors. Some cost overrun in Japan can be attributed mainly to high construction costs in Japan. While this disadvantage can be avoided by commissioning reprocessing and MOX fabrication to European companies, this would not result in net cost reduction since the long distance shipments of radioactive materials have a net negative economic effect.

### Cask Dry Storage Best Available Interim Storage Option

As far as technical conditions are concerned and if compared with wet pool type and can type storage systems, the cask storage is considered to be the best option for the direct storage strategy from the safety point of view, because it relies mostly on relatively simple and cheap passive safety features.

### Direct Fuel Disposal Preferable Option for an Optimum Backend Policy

The direct spent fuel storage option is the preferable path if compared to reprocessing for a large number of reasons, and in particular according to the following criteria:

- *Waste volumes*: The reprocessing path generates at least six times more waste than the direct disposal path, probably even significantly more.
- *Radioactive discharges*: Reprocessing facilities release very large quantities of liquid and gaseous discharges, the Direct Disposal option virtually none.
- *Transports of radioactive materials:* More than 200 waste shipments between Europe and Japan associated with the reprocessing option are expected to be carried out in the coming decade.
- *Interim storage*: Reprocessing is certainly not a credible path to combat insufficient interim storage capacity; technically it can be increased without difficulty.
- *Waste heat management*: The thermal output of spent MOX fuel is by a factor of two to more than three higher than that of UO2 spent fuel.

### Severe Societal and Legal Implications of MOX Use

Currently, the citizens in Japan are virtually deprived of the rights and power to intervene effectively as an equal party in legal procedure and decision-making process in regard to nuclear issues and freedom of information is not guaranteed. Recent developments indicate that through the administration of local governments the public participation could perform an effective function. However, because commercial and security-related secrets possessed by the enterprise are always justified in regard to a plutonium program on the ground of "safety and security of the public" and thus contradict with any principle of public participation, a MOX program will always tend to contradict democratic, participatory and transparent decision-making processes.

### What if the Japanese Official Plutonium Long Term Plan Went Ahead? - A Security Scenario

If the Japanese Long Term Program on plutonium went ahead, around 90 plants including plutonium stocks and fuel fabri-

cation plants would have to be protected. About 400 shipments of MOX fuel, may be 40% of them from Europe, would be needed. Roughly 30 to 60 shipments of HLW from Europe to Japan also have to be protected. The protection of the 90 plants would need about 5,400 security guards (15 guards in 4 shifts around the clock).

Reactive steps to a nuclear crisis have to be planned well ahead. Technical elite units like the Nuclear Emergency Search Team in the US have to be established. Additional police forces have to be trained in particular to deal with such a nuclear emergency.

If society uses plutonium, it will come under pressure to intensify security. If the threats beyond its control increase society has no choice. Its security measures will restrict civil liberties.

### Plutonium and MOX Transports - Security and Safety at Stake

The case of the planned MOX program for Fukushima I-3 illustrates well a typical case of transport scheme. Nuclear materials and wastes go several times back and forth between Europe and Japan. Even if one considers only one transport per type of shipment, the distance to be travelled by nuclear materials totals some 100,000 km or more than twice around the world: a nightmare for security officials and insurance-companies.

**The Co-Researchers of the IMA-Project conclude that the disadvantages of the Plutonium-MOX path versus the Direct Fuel Disposal option are overwhelming whether on the level of industrial, economic, security, safety, waste management and societal implications. In other words, there is no reasonable justification or identifiable social benefit in the continuation of plutonium separation and the launch of a MOX fuel program for light water reactors.**

## Recommendations

### On Transparency

The classification of information concerning nuclear matters should be entirely reviewed by a Commission, set up under the auspices of the Diet, its members should stem from civil society and be independent of any nuclear interests. The Commission should elaborate recommendations as to relevant future restrictions of access to information. The principle to be achieved is that information on nuclear matters is a priori public, and confidentiality, if ever necessary, has to be justified on a case by case basis.

### On the Weapons Usability of Reactor Grade Plutonium

The Japanese Government should make a solemn statement recognizing the weapons usability of light water reactor plutonium thus ending any further misleading speculations.

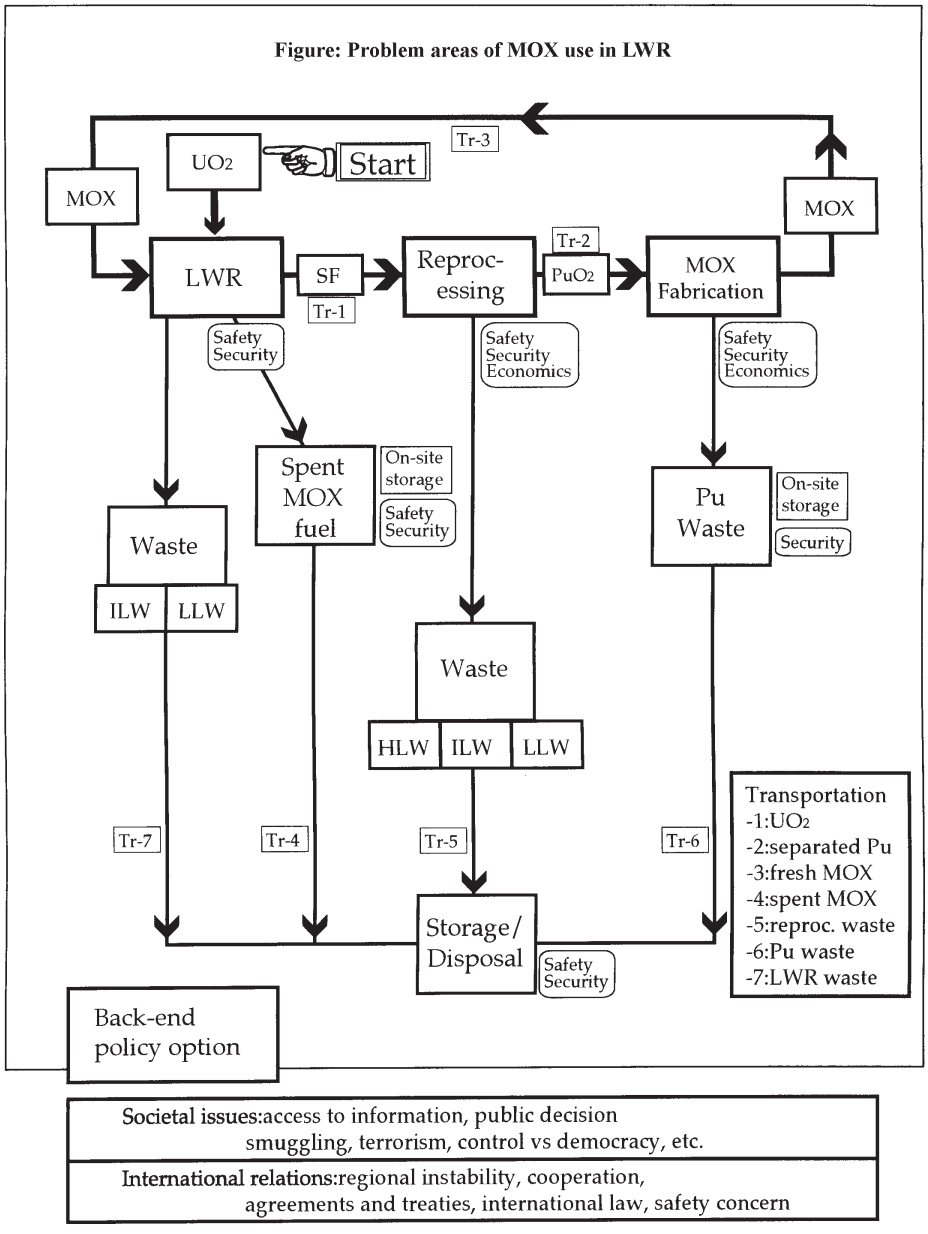
### On Reprocessing

Considering the strategic value as well as the extreme toxicity of plutonium and taking into account the fact that the total stockpile of "civil" plutonium was about 160 tons at the end of 1996 of which more than 10% belonged to Japanese utilities, further separation of plutonium should be immediately halted.

Existing reprocessing contracts with foreign reprocessors should be cancelled. This implies:

- The non-reprocessed spent fuel–800 tons or 27% of the LWR (light water reactor) spent fuel under contract with COGEMA and 2,300 tons or 90% of the spent fuel under contract with BNFL (exact figures not available from BNFL) have to be shipped back to Japan. Only about 1% of the spent fuel under contract has not been shipped yet and should of course be kept in Japan (all figures as of March 1997).
- The reprocessing wastes corresponding to the throughput already carried out

**Figure: Problem areas of MOX use in LWR**



under Japanese contracts have to be shipped back from Europe to Japan. Prior to any further shipments there should be an in depth impact assessment and potential adaptation of the shipment mode.

- The Japanese utilities and the Japanese government should make a public statement that Japan will take back *all* corresponding wastes, category by category as they are conditioned by the reprocessing service, and to cancel any other potential agreement with European reprocessors. They should also make public the calculation according to which Japan takes back what quantities of what kind of waste.
- Plutonium already separated should stay at European plants for the time being. The Japanese Government should immediately enter negotiations with the French and British Governments as to the possibility of conditioning the plutonium with high level radioactive waste into a final waste package–transforming plutonium separation into plutonium conditioning services. These plutonium bearing waste packages could then be shipped back to Japan.
- The Japanese Government should announce the permanent closure of the Tokai Reprocessing plant, whose operation is jeopardized by the fire/explosion in March 1997.
- The Japanese Government should announce the abandoning of the Rokkasho Reprocessing plant, which is still in its early construction phase, before any significant capital is wasted (as was the case in the late abandoning of the German Wackersdorf plant).

### On the Fast Breeder Reactor Program

The Fast Breeder Reactor Program should be abandoned. The Monju reactor should be shut down forever. The Japanese Government and industry should consult with their French counterparts–France took the decision to shut down the Western world's only industrial scale fast breeder reactor Superphenix–as to the final shut down and dismantling procedures.

### On Plutonium and MOX Transports

Current plutonium and MOX fuel transport schemes lead to unacceptable risks. These transports should be minimized to the level necessary for conditioning and final disposal as waste.

### On Interim Storage of Spent Fuel

Consultations should be engaged immediately with local governments and residents of potential intermediate storage sites for spent fuel. These locations include reactor sites as well as away-from-reactor facilities. The prior aim of the consultations should be the evaluation of the conditions for the acceptability of interim storage for spent fuel currently covered by reprocessing contracts.

Additional intermediate spent fuel storage capacity should be evaluated in a second step preceded by the elaboration of alternative energy scenarios, including the phase out of the operation of a given nuclear plant.

### On Nuclear Material Accountancy and Physical Protection

The standards of nuclear material accountancy and control should be significantly increased, in particular in Japanese plutonium handling facilities. The standards of physical protection for plutonium handling facilities should be upgraded at least to the US standards.

### On MOX Fuel Fabrication

The Japanese utilities have signed contracts with European MOX fabricators *before* any impact assessment of its use in Japanese light water reactors has been accomplished and *before* any license for its use has been granted. These agreements should be cancelled, the utilities should not be permitted to build up a fait accompli in the debate over plutonium production and use in Japan.

### On MOX Fuel Use

The Japanese utilities are invited to publish a comprehensive analysis of MOX use in light water reactor covering technical, economic and social issues. Such a report should make all the basic assumptions public and be subject to a full check and review process involving a wide spectrum of the general public.

### On the Present Report

We invite the Japanese Government, utilities and industry to analyze the present report and submit their comments to the director of the project. The members of the Group are ready to give evidence on the results of the report to the Japanese Parliament, Government and any committee dealing with the issues raised.

We also invite the government, utilities and industry of any country, which is engaged in, has plans for or has a concern over using MOX in light water reactors, to analyze the present report and review its nuclear policy on the basis of the present findings.

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### Alternative Nobel Prize for Takagi and Schneider

The 1997 Right Livelihood Award–commonly known as the 'Alternative Nobel Prize'–was given to Jinzaburo Takagi, director of the non-profit Citizens' Nuclear Information Center (CNIC), which he founded in Tokyo in 1975, and to Mycle Schneider, director of the Paris office of the World Information Service on Energy (WISE). Both have collaborated closely for the past six years, e.g. in the International MOX Assessment Project. They were honoured for their remarkable partnership in efforts to overcome the threat to humanity posed by the manufacture, transport, use and disposal of plutonium. The Award jury said their work had "served to alert the world to the unparalleled dangers of plutonium to human life" and had enabled many people to challenge the secrecy and misinformation of the nuclear industry. The two will share about USD. 60,000 from the total cash award of USD. 240,000. Other recipients of the 1997 Right Livelihood Award are:

- Joseph Ki-Zerbo (Burkina Faso), renowned African historian and political philosopher,
- Cindy Duehring (USA), for putting her appalling experience of pesticide poisoning at the service of others and becoming a recognised international authority on chemical injury, and
- Michael Succow (Germany), for safeguarding important ecosystems and areas of special natural value in Russia, his native East Germany and several former Soviet republics.