Background Paper **BP-461E**

MILITARY PLUTONIUM DISPOSAL AND THE MOX FUEL OPTION

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April 1998

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INTRODUCTION

At the Moscow Summit on Nuclear Safety and Security in April 1996, the Prime Minister, the Honourable Jean Chrétien, announced that Canada had agreed in principle to the concept of using plutonium from dismantled nuclear weapons as fuel in Canadian nuclear reactors. By making use of surplus military plutonium in this way, Canada could make a significant contribution to nuclear disarmament and to reducing the risk of illicit trafficking in plutonium and the possibility that terrorists or rogue states could gain access this material.

Burning plutonium in civilian power reactors is one of the two main options that have emerged as the most feasible methods of disposing of weapons plutonium; the other option is immobilization followed by geological disposal. Neither option is without problems and choosing between the two could prove difficult. This paper briefly outlines the technical aspects of these solutions and discusses major issues raised by the disposal of military plutonium.

THE ARMS RACE LEGACY

The United States exploded the world's first nuclear bomb at Alamogordo, New Mexico, on 16 July 1945. That explosion triggered an arms race between the two superpowers of the time, the U.S. and the USSR, which resulted in the accumulation of a staggering 55,000 nuclear warheads(1) in their combined arsenals.

As a result of the second Strategic Arms Reduction Treaty (START II), signed in 1993 (but not yet ratified), the U.S. and the USSR (now the Commonwealth of Independent

(1) Frans Berkhout *et al.*, "Plutonium: True Separation Anxiety," *The Bulletin of the Atomic Scientists*, November 1992, p. 30.

States - CIS) agreed to begin dismantling as many as 45,000 nuclear warheads in their arsenals. These states have now started to reduce their numbers of warheads, from 35,000 to 3,000 and the U.S. from 20,000 to 2,000.[(2)]

It is estimated that about 90 tonnes of plutonium and 450 tonnes of highly enriched uranium (HEU) will eventually be liberated from CIS warheads and approximately half those amounts from U.S. warheads. In addition, each country is assumed to have several tens of tonnes of plutonium and several hundreds of tonnes of HEU in the form of weapons components, scrap, and unprocessed, irradiated fuel.[(3)]

Although the dismantling of warheads represents a very welcome change in the direction of the arms race, it creates an entirely new and difficult challenge: how to dispose safely of the 100 – 200 metric tonnes of plutonium from the dismantled warheads. By contrast, disposing of the 500 – 1,000 tonnes of HEU is relatively straightforward.

HIGHLY ENRICHED URANIUM AND PLUTONIUM

Uranium occurs in nature as two isotopes:[(4)] uranium-235 (^{235}U), representing 0.7%, and uranium-238 (^{238}U), representing 99.3%. Only ^{235}U, however, supports the nuclear chain reactions that make possible the massive release of energy in both nuclear bombs and nuclear reactors. In order to sustain the fast-neutron chain reaction required to generate a nuclear explosion, the ^{235}U has to be separated from the bulk of the ^{238}U. In a sufficiently purified state, it is known as highly enriched uranium (HEU).

At a low level of enrichment, about 4%, uranium will not support the fast chain reaction of a nuclear explosion but it will support the slow chain reaction in a nuclear reactor. Low enriched uranium (LEU) is the fuel used in most of the world's light-water reactors. The Canadian CANDU system, which uses the more efficient heavy water moderator, is fuelled with natural (unenriched) uranium.

(2) *Ibid.*

(3) *Ibid.*

(4) Isotopes are forms of an element that differ only in the atomic mass of their nuclei. Consequently, the chemical behaviour of isotopes is virtually identical but physical properties differ slightly.

^{235}U and ^{238}U can be separated only with great effort by processes, such as gaseous diffusion, that exploit the minute physical differences between chemical compounds of the isotopes. Generally speaking, only technologically advanced states have the resources to employ these types of technology.

Plutonium, on the other hand, is found only in trace amounts in nature but it is produced in nuclear reactors by the interaction of ^{238}U with neutrons. Plutonium-239 (^{239}Pu) is the first isotope formed. As the fuel spends longer in the reactor, additional plutonium isotopes, ^{240}Pu, ^{241}Pu and ^{242}Pu are produced and the proportion of ^{239}Pu decreases. Military reactors are designed and operated to optimize the production of "weapons-grade" plutonium, which consists mostly of the isotope ^{239}Pu. In civilian power reactors, the fuel remains in the reactor much longer so that it can be used efficiently; as a result, "reactor-grade" plutonium obtained from spent power reactor fuel contains a higher proportion of the plutonium isotopes other than ^{239}Pu.

A fundamental difference between plutonium and uranium is that nearly all mixtures of plutonium isotopes can be used to produce nuclear explosives. Reactor-grade plutonium can be used to fashion nuclear weapons. Although the yield and efficiency of devices made with reactor-grade plutonium would be lower and less certain, the effects of such devices would still be devastating. Many in the field believe that terrorists could build crude but effective weapons from reactor-grade plutonium,[(5)(6)] while sophisticated experts could use it to build even more destructive devices.

The other important difference between plutonium and HEU is that plutonium can be separated from irradiated fuel using comparatively less difficult chemical processing. It is the intense radioactivity of irradiated fuel, rather than the separation process *per se*, that makes separation of plutonium difficult.

To a large extent, these technical issues lie at the heart of the challenge of how to dispose of excess military plutonium. Highly enriched uranium, HEU, can be "denatured" simply by diluting it with ordinary uranium to make the low enriched uranium used to fuel civilian reactors. Low enriched uranium cannot be converted back into weapons grade uranium without access to technologically sophisticated and costly enrichment facilities. The U.S. and

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(5) John P. Holdren, "Dangerous Surplus," *Bulletin of the Atomic Scientists*, May/June 1994, p. 40.

(6) Wolfgang K.H. Panofsky, "No Quick Fix for Plutonium Threat," *Bulletin of the Atomic Scientists*, January/February, 1996, p. 59.

the Russian Federation agreed in 1993 that the U.S. would purchase 500 tonnes of excess HEU from dismantled nuclear weapons which would be blended down to LEU in Russia and imported into the U.S. by the United States Enrichment Corporation.(7) The arrangement was amended in late 1996 to accelerate the drawdown of Russian HEU.(8)

It is not, however, possible to denature military plutonium with reactor-grade plutonium in the same way. Thus plutonium presents a much more difficult security problem. Still, blending military plutonium into fuel for civilian reactors is one of the two principal options under consideration. The challenge is to convert plutonium into a form that will be very difficult to divert to weapons use without creating other unacceptable security, health or environmental risks.

THE MAIN OPTIONS

Two main paths have emerged as the most promising options for disposing of surplus weapons plutonium. One is "immobilization." This involves mixing the plutonium with high-level nuclear waste and incorporating it into molten borosilicate glass in a process known as vitrification. The glass, which provides a very stable host, is cast into the form of a "log."

The other option is to blend several percent plutonium oxide with depleted uranium oxide to produce a mixed oxide (MOX) fuel that could be consumed in commercial nuclear reactors. As spent MOX fuel is similar to spent conventional fuel, its disposal would also be essentially the same. Although this is not without difficulties, these will have to be solved whether or not the MOX option is selected. The ultimate fate of both vitrified plutonium and spent MOX fuel would be some form of containment and burial in a deep geologic repository.

Although neither option actually destroys the plutonium, both would render it much less accessible for weapons use. Deep burial provides a substantial measure of physical security and the high radioactivity of the spent isotopes would make moving and handling impossible without heavy shielding and specialized handling equipment. Only with

(7) R.T. Whillans, *1993 Canadian Minerals Yearbook*, p. 53.11.

(8) Craig Cerniello, "U.S., Russia Amend HEU Deal, Accelerating Implementation Pace," *Arms Control Today*, November/December 1996, p. 16.

sophisticated chemical and engineering technology would it be possible to recover plutonium disposed of by either method for weapons use.

In fact, there is little practical value in attempting to destroy weapons plutonium completely while a much larger inventory of plutonium continues to exist in spent civilian fuel. A more realistic objective, dubbed the "spent fuel standard" by the (U.S.) National Academy of Sciences,[9] is to convert weapons plutonium to a form that would be as difficult to reprocess as civilian plutonium. Both vitrification and MOX would effectively meet this level of security.

On 9 December 1996, the U.S. Department of Energy (DOE) announced that it would follow a dual-track approach that includes both the immobilization and MOX options for the disposal of 52.5 tons of excess military plutonium.[10] The DOE decision has generated a great deal of controversy, much of which reflects differences of opinion over the technical merits of the two options. More fundamental and serious differences emerge, however, over the implications of the MOX proposal with respect to non-proliferation and the plutonium fuel economy.

ISSUES

A. Global Security

As long as stocks of plutonium remain in existence, they pose a threat to national and international security. In the U.S., where surplus weapons material is subject to very high security, risks are relatively low; however, in Russia and other republics where the social, economic and political systems have been destabilized following the collapse of the USSR, the security of weapons materials is a major concern. In particular, the low morale and poor discipline of Russian security forces guarding stockpiles of weapons and weapons materials prompt fears these materials could be stolen or diverted for weapons use by terrorist organizations or "outlaw" nations.[11]

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(9) Holdren (1994), p. 43.

(10) Bette Hileman, "U.S. to Test Two Paths to Dispose of Nuclear Weapons Plutonium," *Chemical & Engineering News*, 16 December 1996, p. 10.

(11) For a discussion of the potential threat of illicit traffic in nuclear materials see: Phil Williams and Paul N. Woessner, "The Real Threat of Nuclear Smuggling," *Scientific American*, January 1996, p. 40-44.

Clearly, finding a timely solution to the disposal problem is of the essence, as the longer the stockpiles remain in existence, the greater is the risk that plutonium will come into the wrong hands. The U.S. National Academy of Sciences, in its report "Management and Disposition of Excess Weapons Plutonium," has described surplus of plutonium and HEU as "a clear and present danger to national and international security."(12)

B. Russia

If disposal of its own stockpile of surplus military plutonium were the only consideration, the U.S. would be free to select either immobilization or the MOX option; however the principal concern of U.S. plutonium disposal policy is not the potential misuse of U.S. stocks but of Russian. The Russian stockpile of surplus plutonium has been amassed with enormous economic and social sacrifice, not to mention devastating environmental effects. Consequently, the Russians regard these stocks as a national treasure and an economic resource, which they assume, however mistakenly, to have a value comparable to the conventional fuel that they would displace.

A primary reason for the U.S. pursuit of the MOX option appears to be the belief that if the U.S. burns plutonium as MOX the Russians will be encouraged to do likewise. The Russian nuclear establishment is known to be strongly in favour of using both civilian and excess weapons-grade plutonium as reactor fuel (13) and it has so far dismissed the idea of mixing Russian plutonium with waste,(14)as would be required for the immobilization option. There appears, therefore, to be little hope that Russia will accept immobilization. Many arms control experts believe that the Russians will not dispose of their excess weapons plutonium if the U.S. implements immobilization only.(15)

At least one expert dismisses this view as "bizarre," however, in light of the lack of cooperation by the Russian nuclear agency, MinAtom, over bilaterial monitoring procedures

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(12) Arjun Makhijani, "Let's Not," *Bulletin of the Atomic Scientists*, May/June 1994, p. 45.

(13) International Institute for Strategic Studies, "Eliminating Excess Plutonium Stockpiles: A Dual-track Disposition Strategy," *Strategic Comments*, Vol. 3, No. 2, March 1997.

(14) Edwin S. Lyman, "Just Can It," *Bulletin of the Atomic Scientists*, November/December 1996, p. 49.

(15) Hileman, (1996), p. 11.

for plutonium storage and its refusal to accept international safeguards on MOX fabrication facilities built in Russia. [16]

C. Timeframes

There is still significant technical uncertainty about both methods and a good deal of scientific and engineering research remains to be done before either immobilization or the MOX option can be implemented.[17] Opinion is also divided on the important issue of which option will provide the timeliest solution. There is a consensus that time is of the essence. The longer stocks of plutonium remain in their original form, the greater is the chance of their diversion. One of the advantages cited in favour of the dual-track approach is that it would increase the likelihood of proving at least one of the options workable, which would help to ensure that disposal began sooner rather than later.

Not everyone agrees with this view, however. Some observers have claimed that the DOE’s own data reveal that “even under the most optimistic scenario for MOX disposal, immobilization could begin sooner, complete the job more rapidly, and require fewer facilities to manage and safeguard.”[18] Moreover, they argue that the technical and environmental risks associated with immobilization are far smaller than those associated with MOX and that spreading limited resources through pursuing a dual track could delay disposal. Other experts disagree with this assessment, arguing for example that, “if time is of the essence…vitrification [immobilization] is not the best choice for the 50 metric tons of excess warhead plutonium expected from warhead dismantlement,” although it might be useful for part of the 33 tons of other plutonium found around the weapon production complex.[19]

This is another argument against MOX, and by extension, the dual-track approach. Since not all the plutonium is sufficiently pure for conversion into MOX (only about 33 of the 50 tonnes of U.S. plutonium), the immobilization route will have to be developed for

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(16) Lyman (November/December 1996), p. 49.

(17) International Institute for Strategic Studies (March 1997).

(18) Edwin S. Lyman and Paul Levinthal, “Bury the Stuff,” *Bulletin of the Atomic Scientists*, March/April 1997, p. 46.

(19) Luther J. Carter, “Let’s Use It,” *Bulletin of the Atomic Scientists,* May/June 1994, p. 43.

the remaining plutonium in any case. Thus, it is argued, it makes better sense to dispose of all the plutonium by immobilization.[20]

Although it has been suggested that immobilization as described above could take longer and would not begin until 15 years after a "go" order,[21] a quicker and less costly immobilization option (referred to as "can-in-canister") might be possible. In this method, cans of plutonium would be placed in the canisters prior to their being filled with vitrified waste. Initial cold testing of the process was reported to be sufficiently encouraging for the DOE to plan to accelerate development. It is estimated that processing the full 50 tonnes of plutonium would add only one additional year of operation to the 25-year operating lifetime of the recently completed vitrification plant at the DOE's Savannah River facility in South Carolina.[22]

On the other hand, the feasibility of burning MOX fuel in light water reactors, the most prevalent type around the world, has already been demonstrated in Europe.[23] Nearly all of the U.S. plants, which are of the light water type, would require modification in order to consume MOX; however, the Canadian CANDU reactor, which uses a heavy-water moderator, could burn MOX fuel without physical modifications and therefore could, in principle, be available within a relatively short timeframe. A plausible date for beginning to burn MOX in a CANDU reactor would be around the year 2004.[24]

The MOX approach could be delayed somewhat by the need to construct new fuel fabrication facilities or to modify existing ones. Although it would be technically feasible to have initial MOX fuel supplies processed at European MOX fuel fabrication facilities, the transatlantic shipment of weapons-grade plutonium might be politically unrealistic.

D. Security

Extracting plutonium from spent fuel requires a great deal of expertise in order to minimize the radiation hazard from fission products; however, the same is not true of MOX fuel. Weapons grade plutonium can be extracted back out of MOX fuel using relatively

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(20) Lyman (November/December 1996), p. 49.

(21) Luther J. Carter, "Let's Use It," *Bulletin of the Atomic Scientists,* May/June 1994, p. 43.

(22) Lyman (November/December 1996), p. 49.

(23) Holdren (May/June 1994), p. 41.

(24) A. Ian Smith, briefing note prepared for the NATO Parliamentary Association, 8 May 1997.

straightforward technology. Therefore during fabrication, transportation, and storage at a nuclear power facility, in fact until it has been loaded into a reactor and irradiated, MOX represents a significant security risk.

In addition, as it is the radiation hazard rather than isotopic mix that represents the real barrier to re-use, both main options are primarily short to medium-term security measures. This is because much of the radioactivity of the waste decays relatively rapidly (within the first few decades to centuries) relative to the half-life of plutonium, which is measured in thousands of years. In the longer term, the effectiveness of radioactivity as a deterrent to re-use is significantly reduced. This, however, is also true of conventional reactor fuel wastes.

E. Costs

The (U.S.) National Academy of Sciences estimated that the cost of disposing of 50 tons of excess U.S. military plutonium for both the MOX and immobilization options would be between $0.5 billion and $2 billion. More recent estimates by the DOE for the least expensive immobilization and MOX options put the life cycle costs of both at about $1.8 billion (undiscounted 1996 dollars). [(25)]

It might seem at first sight that some economic benefit could be derived from using surplus plutonium to replace conventional uranium fuels in civilian reactors. The plutonium would be essentially free, as it would already have been paid for through defence spending, while depleted uranium is a by-product of uranium enrichment with few other uses.

Unlike HEU, which can readily be diluted to make LEU and which has substantial value as fuel for civilian reactors, however, plutonium-derived fuel is more expensive than LEU. MOX is not economically competitive at present and is unlikely to become so in the near future.[(26)] For example, the German company Siemens AG, which has proposed building an MOX fabrication plant in Russia, estimates that it could produce MOX at a cost as low as $1,000/kg (compared to current West European prices for MOX fabrication of $1,300 to $1,600/kg and the current cost of LEU at about $1,000/kg). At this rate, the fuel fabrication costs alone for 50 tons of plutonium would be of the order of $1.2 billion.[(27)]

(25) Lyman (November/December 1996), p. 50.

(26) Holdren (May/June 1994), p. 39.

(27) Berkhout (1992), p.32.

Furthermore, contrary to the DOE's earlier assumption that the utilities would reimburse the government at a rate equivalent to the cost of conventional fuel i.e. "a fuel displacement credit," it now appears more likely that they would expect to receive an incentive for using MOX. One estimate puts the subsidy to the utilities at about $500 million, which could increase the cost of the dual-track option over immobilization alone by 30%.(28) Another estimate suggests that the minimum incentive expected by the utilities (a discount or even fuel received free of charge) would eliminate the $1.4 billion fuel displacement credit assumed by the DOE, thereby nearly doubling the life cycle cost of MOX.(29)

AECL is reported to have estimated the total gross cost of using MOX in Canadian CANDUs at over US$2.2 billion. However, this figure does not include the cost of rebuilding the Bruce A reactors or of upgraded security measures at the Bruce site. The cost of plutonium fuel production and shipping is estimated at $70 million a year, about three to four times the cost of CANDU fuel.(30)

The cost of security measures could be quite significant. For example, one estimate puts the capital cost of safeguard equipment in nuclear facilities where MOX is being processed, such as reprocessing plants and MOX fuel fabrication plants in the range of 1-2% of the total capital cost of the facility, an order of magnitude higher than the cost of security requirements for a new nuclear power station using conventional fuel.(31)

It has been argued that some U.S. nuclear utilities have expressed an interest in burning MOX primarily as a way of defraying the cost of operating increasingly uncompetitive plants in an increasingly deregulated market. For keeping facilities operating in order to burn MOX, the utilities would expect to receive subsidies to keep them competitive with other forms of electricity generation, such as more efficient combined-cycle gas turbine plants. Such subsidies could potentially add billions of dollars to the cost of MOX even before full scale use began.(32) In addition, since utility shareholders would probably require some assurance of a

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(28) Hileman (1996), p. 11.

(29) Lyman (November/December 1996), p. 51.

(30) Nuclear Awareness Project, "U.S. DOE Considers Plutonium for CANDUs," *Nuclear Watchdog Bulletin*, No. 3, April 1996, p. 2.

(31) Gerald Clark, IAEA Bulletin, 38:25-8, Dec. 1996, p 28.

(32) Lyman (November/December 1996), p. 51.

guaranteed return before agreeing to an MOX program, the DOE could be faced with additional costs from unanticipated increases in operating costs or major capital expenditures.

Ontario Hydro may be in a similar position to the U.S. utilities. The reactors at Bruce A, potentially the site of MOX consumption, are no longer competitive and in need of extensive repairs. Ontario Hydro mothballed Unit 2 in 1995 rather than investing in upgrades to repair its damaged steam boilers. One observer has alleged that Ontario Hydro has been considering use of MOX as a way of subsidizing the cost of refurbishing the reactor:

> Although Hydro said in its proposal that it was planning to have the work done, it is now clear that it no intention of paying the nearly $1 billion cost and was hoping to charge it to the plutonium disposal program.(33)

F. The Plutonium Economy

One of the main objections to the MOX option is that it may help to legitimize a plutonium fuel cycle:

> Among specialists on the nuclear nonproliferation issue, the tendency is to favour vitrification on the grounds that *any* use of plutonium as a reactor fuel is bad, because it may in some measure legitimize plutonium recycling and renew past dreams of a plutonium economy.(34)

There is some risk that U.S. selection of the MOX option might appear to sanction the French, British and Japanese reprocessing programs, thereby setting the wrong example for potential proliferators and posing risks of nuclear theft and terrorism.

Although selection of the MOX option could appear to reverse a long-standing U.S. policy of not burning plutonium in commercial power plants,(35) the U.S. has said use of this option would not represent such a change in its policy against civilian reprocessing and recycling of plutonium. According to U.S. officials, any MOX facilities built for the purpose of

(33) *Ibid*., p. 52.

(34) Carter (May/June 1994), p. 42.

(35) Hileman (1996), p. 11.

disposing of excess plutonium would be licensed for this purpose only and would be dismantled once their mission was completed.[36]

Despite U.S. assurances, however, there may be some legitimacy to these reservations. For example, Russia's Ministry of Atomic Energy (MinAtom) may be looking at international concern as an opportunity to obtain aid to finance a new generation of plutonium-burning reactors.[37] Russia's reprocessing industry is in difficulty. It had been earning some foreign exchange by reprocessing fuel for Finland and Hungary, but Finland has been reported to be about to cancel its contract and Hungary has also been considering cancellation. U.S. or Western Europe financial support for an MOX plant in Russia could provide the only means of keeping the Russian reprocessing program afloat.[38]

In addition, European MOX fabricators - British Nuclear Fuels, Cogema (France), and Belgonucléaire - have been lobbying for the business of converting both U.S. and Russian plutonium stockpiles into MOX, not only for the financial opportunity but "also because they think that the process might bestow the imprimatur of nuclear disarmament on their operations, which have often been criticized for their proliferation potential."[39]

CANADA'S ROLE

A. Use of MOX Fuel in Candu Reactors

The Canadian government has stated that in principle it supports the use in Canadian nuclear reactors of MOX fuel incorporating plutonium from dismantled nuclear weapons, provided that all federal and provincial health, safety and environmental regulations can be satisfied. In addition, such a scheme would have to meet with public acceptance and would have to be carried out under a commercial arrangement between the fuel supplier and the Canadian nuclear utility. The federal government has said it would not subsidize the use of MOX in Canadian reactors.

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(36) International Institute for Strategic Studies (1997), p. 2.

(37) *Ibid.*

(38) Hileman (1996), p. 11.

(39) Lyman (November/December 1996), p. 50.

The Canadian CANDU reactors appear to be well suited to MOX fuel; they would not require physical modification and MOX fuel could be burned within existing operating and licensing envelopes. Furthermore, it is anticipated that existing safety standards governing the exposure of workers to radiation could be met or exceeded. The most significant change would be the implementation of enhanced security for the storage of new fuel prior to loading it in the reactors.

Feasibility studies carried out by the U.S. subsidiary of AECL on behalf of the U.S. DOE estimate that two of the four reactors at Bruce A could consume 50 tonnes of plutonium in 25 years. With a more advanced core design and the new, but as yet unqualified, "Canflex," fuel bundle, the time could be shortened to 12.5 years.

The studies also concluded that the required quantities of fuel could be fabricated at existing plants, either the Fuel and Materials Examination Facility (FMEF) at the Hanford Nuclear Reservation, Washington, or alternatively at the Barnwell Nuclear Fuel Plant next to the DOE's facility at Savannah River, South Carolina. Fuel would be transported monthly from the U.S. fabrication plant, using U.S. Safe and Secure Transports, to Canada, where the spent MOX fuel would remain.

The more pressing issue from the point of view of global security is the disposal of Russian plutonium. CIDA has funded a study to look at the fabrication of MOX in Russia. The U.S. is subsidizing preliminary fuel qualification tests for fuels using both U.S. and Russion plutonium to be carried out by AECL in its NRU reactor at Chalk River. The program, known as "Parallex," consists of irradiating a limited number of fuel elements manufactured in both the U.S. and Russia for confirmation of MOX fuel requirements. The program, which was originally scheduled to be run in early 1997, has now been delayed until later in 1998.

There are some evident advantages to the CANDU scenario. The use of a single fuel fabrication facility and site would simplify security requirements. Using unmodified CANDU reactors, operating within existing operational and licensing envelopes, and existing fuel fabrication and transportation facilities would minimize costs and technical risks. The use of existing facilities would also shorten the overall timeframe, as a lead-time of only four to five years would be required. Since, for all practical purposes, spent MOX fuel would be very similar to conventional spent fuel, no additional waste management or disposal facilities would be needed beyond those required for the current nuclear generation system. In fact, it is estimated that the volume of spent MOX would be 10 to 15% less than that of the spent fuel produced from conventional fuel for the same amount of energy.

AECL representatives appearing before the Nuclear Fuel Waste Management and Disposal Concept Environmental Assessment Panel, however, were reported to have said that the disposal of MOX and its effects on the disposal concept had not been examined in detail and would require further study. One technical issue that arose was that, owing to the greater burn up of the MOX fuel, the heat output of MOX fuel would be greater than that of conventional fuel. MOX would therefore require longer cooling periods in storage or additional space in the repository. Although the increased need for space could be offset by a reduced amount of waste per unit of electricity generated, the higher temperature of the waste container could affect buffer and backfill performance.(40)

It has also been suggested that MOX would provide a long-term, economic fuel supply for the Canadian utility and, since it would displace the use of conventional uranium fuel, would, in principle, reduce the environmental impact of mining and refining approximately 6,000 tonnes of uranium ore.

B. Criticism of the CANDU/MOX Proposal

The CANDU/MOX proposal and the shipment of MOX to Canada for testing has met with severe criticism from a number of public interest groups, including the Nuclear Awareness Project, the Sierra Club of Canada, the Campaign for Nuclear Phaseout, the Canadian Coalition for Nuclear Responsibility, the Nuclear Control Institute, Greenpeace International, and the Natural Resources Defence Council.

Some of the concerns raised are general; for example, that a program of this type would help to encourage a global plutonium economy and that civilian traffic in plutonium would enhance rather than decrease the risk of theft or diversion. This would create "unprecedented security problems to prevent the theft of plutonium," which would have an adverse effect on the civil liberties of Canadians. The groups also cite safety and health concerns, arguing, for example, that MOX fuel creates the risk of a "criticality accident" during

(40) Nuclear Fuel Waste Management and Disposal Concept Environmental Assessment Panel, *Nuclear Fuel Waste Management and Disposal Concept*, Canadian Environmental Assessment Agency, February 1998, p. 81.

transportation and handling and that any use of plutonium, one of the most carcinogenic substances known, poses a public health and environmental threat.

Other arguments are more specific to Canada. It is claimed, for instance, that Canadian use of MOX fuel would constitute an apparent reversal of Canada's longstanding non-proliferation policy of isolation from the nuclear weapons programs of other countries. Such use would set a dangerous precedent of accepting nuclear waste from other countries and could potentially make Canada a dumping ground for foreign military waste. A further objection is that Canadian use of MOX in its own CANDUs might allow non-Canadian owners of CANDUs to justify the use of plutonium in their own reactors.

The Nuclear Awareness Project, among other critics, argues that the MOX option would in fact be substantially more expensive than using natural uranium fuel. While conceding that U.S. subsidies to Canada might cover the extra costs of MOX fuel, the Project believes that Ontario Hydro ratepayers would still have to pay for regular CANDU fuel costs while possibly also being expected to pay for re-tubing reactors at the Bruce A plant in order to keep them burning the MOX fuel.

Finally opponents of the MOX option decry the lack of public or parliamentary debate on the issue so far and raise the possiblity that an "exemption to Bruce" could be used to avoid an environmental assessment hearing.

Perhaps the most critical assessment of all is offered by Franklyn Griffiths, George Ignatieff, Chair of Peace and Conflict Studies, at the University of Toronto:

> This study finds that the CANDU MOX initiative is beyond redemption. It is certain to deliver substantial direct costs to Canadians. It is all but bereft of benefits for them. It is grossly inadequate in its capacity to achieve its stated international security purposes.(41)

COMMENTS

Some of these criticisms of the MOX option appear to carry more weight than others. For example, the criticisms based on the reversal of Canada's non-proliferation policy

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(41) Franklyn Griffiths, *MOX Experience: The Disposition of Excess Russian and U.S. Weapons Plutonium in Canada*, July 1997

and the threat that this country might become a dumping ground for other nuclear wastes may largely rely on perception. The former issue seems to revolve around the purpose of the non-proliferation policy and whether the MOX proposal would contribute to non-proliferation by reducing the stockpile of weapons-grade plutonium. In other words, does the end justify the means? The wastes, would be, for most practical purposes, the same as conventional spent fuel and there has been no suggestion so far that this would open the door to any other kind of foreign military radioactive waste.

Natural Resources Canada has said that there is no Canadian policy that would prevent the use of plutonium in CANDU reactors.(42) Nevertheless, Canada has had a long-standing policy of a "once through" nuclear fuel system which does appear to imply an intention of not using plutonium in Canadian reactors.(43) The MOX proposal suggests at least a subtle shift in that position.

Other concerns regarding health, safety and particularly security may well be justified. The issue of costs is significant since the government has said that any firm proposal to use MOX fuel in Canadian CANDUs would have to be carried out under a commercial arrangement without Canadian government financing. This raises the question of who would be liable in the event of increased operating costs or the need for major repairs to a CANDU reactor bound by a contractual arrangement to burn MOX.

This issue has been intensified by a recent internal review of Ontario Hydro's nuclear operations that prompted the utility to shut down seven of its operating reactors,(44) including the remaining units at Bruce A, which had been the likely site for MOX consumption. While Ontario Hydro has stated that it intends to bring these reactors back on stream, many observers believe that this is unlikely. Ontario ratepayers may be dubious about refurbishing a reactor whose reliability may still be uncertain in the timeframe required to dispose of the plutonium stockpile, and which, even without MOX, may be increasingly uncompetitive to operate.

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(42) Natural Resources Canada, *Plutonium MOX Fuel Initiative*, *Use of Plutonium in CANDU*, http://www.es.nrcan.gc.ca/WWW-data/uneb/moxfuel/mox_pg05.html, February 1997.

(43) See Atomic Energy Control Board Regulatory Document R-104, Ottawa, 5 June1987, which says "For the long-term management of wastes, the preferred approach is disposal, a permanent method of management in which there is no intention of retrieval…"

(44) News Release, Ontario Hydro, "Statement by William Farlinger, Chairman and Interim Chief Executive Officer," 13 August 1997

The threat posed to global security by the stockpile of excess military plutonium is clearly an issue of the utmost importance. Since "time is of the essence" one of the most important questions is whether MOX or immobilization will provide the faster solution. On the surface at least, the MOX/CANDU proposal seems attractive. There are no major technical difficulties. A CANDU reactor would not require physical modifications, all the MOX could be burned at a single site and, provided that AECL's deep disposal scheme won eventual approval, there would be a ready-made solution for the final waste. Such approval, however, is considerably less certain in view of the conclusion of the Nuclear Fuel Waste Management and Disposal Concept Environmental Assessment Panel that:

> As it stands, the AECL concept for deep geological disposal has not been demonstrated to have broad public support. The concept in its current form does not have the required level of acceptability to be adopted as Canada's approach to managing nuclear fuel wastes.[45]

Many questions still need to be answered, including those with respect to the health, safety and security aspects of the proposal as well as its implications for Canadian nuclear policy and liability for future costs. The MOX proposal deserves extensive, open and informed public debate.

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(45) Nuclear Fuel Waste Management and Disposal Concept Environmental Assessment Panel (1998), p. 2.