VIEWPOINT: GETTING TO BURN WEAPONS PLUTONIUM: PRINCIPAL ISSUES AND OBSTACLES

by Charles N. Van Doren

The closing months of 1996 are a crucial period for U.S. decisionmaking on how best to dispose of tens of tons of plutonium expected to be recovered from the dismantlement of U.S. nuclear weapons and determined to be surplus to national security needs. By the end of the year, a U.S. government decision is scheduled to be made—on the basis of consideration of the various studies and reviews—as to which of the available options (or combination thereof) the United States should pursue and begin to implement.[1]

One option would use weapons plutonium (WPu) declared to be surplus to U.S. national security needs to fabricate mixed-oxide ("MOX") fuel for burning in a few designated nuclear power reactors of existing types. Notably, this is the option that appears to be preferred by Russia for the disposition of its surplus WPu. Because some of the WPu in each country is in forms not readily adaptable to such use, this option may well be coupled with the application of another of the available options (such as vitrification) to such other material.[2]

This essay reviews the principal policy issues involved and the obstacles yet to be faced in implementing reactor-based options. In doing so, it discusses the technical issues, proliferation concerns, current Russian policy, and, finally, the various remaining practical obstacles. It concludes by arguing that burning plutonium—despite admitted hurdles—makes sense, and the sooner the better.

TECHNICAL BACKGROUND

The underlying concept of reactor-based options is an appealing one: buttoning down nuclear arms reductions by having the United States and Russia transfer the fissile ingredients of dismantled nuclear weapons to use as safeguarded fuel for the production of civilian electric power. This concept dates back to the late 1950s, when President Eisenhower proposed a mutual cut-off of the production of fissile materials for weapons use and the transfer of such materials (from a substantial number of weapons) to peaceful uses. Considerable progress in that direction has recently been made with respect to highly enriched uranium (HEU). Both countries have long since ceased producing HEU for weapons purposes, and the blending down of HEU recovered from weapons dismantlement to low-enriched uranium (LEU) for fabrication into fuel for light water reactors (LWRs) has already commenced.[3] But plutonium options have not proceeded due to the greater technical and political difficulties involved.

Operation of any nuclear reactor with fuel containing natural uranium or LEU produces plutonium. A substantial fraction of this plutonium is consumed ("burned") during such operations, accounting for as much as one-third of the energy produced in an LWR. Several West European countries and Japan have had extensive experience in the fabrication and use of MOX fuel in place of LEU (in up to 30 percent of a reactor's fuel).

According to industry sources, while an LWR fueled with LEU:

> produces 20 to 30 kg of plutonium per TWh [billion kilowatt hours], a 30 percent MOX-loaded reactor produces practically none, and a 100 percent MOX reactor, that is, a completely loaded MOX fuel reactor, burns approximately 60 kg of plutonium per TWh generated.[4]

The plutonium remaining in the spent fuel is mixed with uranium and highly radioactive fission products and is inaccessible because of this radiation barrier—as well as the size, weight, and high temperature of the spent fuel assemblies in which it is contained. Such residual plutonium is also somewhat degraded in quality (i.e., the proportion of the fissile isotopes Pu^{239} and Pu^{241} to total plutonium, which also includes such non-fissile isotopes as Pu^{238} and Pu^{240}), making it comparatively unattractive for use in sophisticated weapons (though still capable of

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being used for weapons purposes if optimal performance is not required).

Before the plutonium remaining in spent fuel can be used either for recycle in a nuclear reactor or to make weapons, it requires separation in a reprocessing facility, which yields separated Pu free of fission products.[5] But reprocessing is not required to make MOX fuel out of WPu, which is uncontaminated with fission products.

Despite the anxieties of the U.S. and other governments (as well as various non-governmental organizations), burning WPu in a small number of existing reactors was one of the leading alternatives suggested in the landmark study published by the National Academy of Sciences in 1994[6] for dealing with the "clear and present danger" presented by WPu by making it at least as inaccessible as spent fuel from a commercial power reactor (the so-called "spent fuel standard"). It was the alternative strongly preferred by the distinguished international panel subsequently convened by the American Nuclear Society.[7] Many major North American nuclear utilities have expressed an interest in having some of their reactors considered for participation in such an undertaking, and the Russians have made clear their determination to make use of the energy value of WPu by burning it in reactors.

Relationship to the Controversy Over Recycling Commercial Plutonium

Since the mid-1970s, there has been an impassioned policy debate, primarily in the United States, over commercial plutonium recycling, which is the path being pursued by several major European countries and Japan. Proponents stress the energy value of plutonium ("one gram of recycled plutonium in a MOX fuel assembly generates the same quantity of electricity as burning 1 to 2 tons of oil"[8]) and insist that it is a valuable resource that should not be discarded.[9] Meanwhile, opponents stress its toxicity, longevity, and the fact that its acquisition is one of the principal pacing items in acquiring a nuclear weapon capability and urge that its commercial use be avoided and that it be treated as a waste to be isolated from the biosphere.

A serious concern is the need to avoid the emergence of widespread reprocessing under national control. Large commercial reprocessing plants currently exist only in three countries (Russia, France, and the United Kingdom)—all of which are nuclear weapon states parties to the Non-Proliferation Treaty (NPT). The latter two countries provide reprocessing services to advanced nuclear industrial countries such as Japan,[10] Germany, Belgium, and Switzerland. Such reprocessing has separated considerably more plutonium than is needed for near-term commercial use, amounts that far exceed the amounts of WPu to be released from dismantled warheads.[11]

As Berkeley Nobel Laureate Glenn Seaborg has explained:

> Reprocessing technology has now been in the public domain for a number of decades and its performance on a small-scale is well within the capabilities of virtually any country that can operate a nuclear power plant. We cannot rely on the difficulty of reprocessing as an effective barrier to proliferation any more than we can rely on the difficulty of fabricating a nuclear weapon by those who come into possession of enough fissionable material.[12]

Construction of a small reprocessing facility that could extract enough plutonium to make several nuclear weapons is considerably easier than building a successful commercial reprocessing plant (though it might present a significant hurdle to a subnational group). In most cases, the principal protection against doing so is the fact that most countries have decided that acquiring nuclear weapons would not be in their interest, and have made legal and political commitments not to do so. It seems clearly desirable to discourage the construction of reprocessing facilities in countries without such commitments or whose dedication to such commitments is unclear, or whose physical protection is unreliable.[13]

The other main concern of those who oppose a "plutonium economy" relates to the multiplicity of locations where separated plutonium might be exposed to the risk of theft or seizure by unauthorized persons or groups if plutonium recycle became widespread. Separated plutonium would be exposed at the product end of the reprocessing facility, in transit to the fuel fabrication facility, and in the latter facility. MOX fuel (whose plutonium content could be recovered by means simpler than reprocessing, since no fission products would have to be coped with) would be present at the output end of the fabrication plant, in transit to each reactor planning to use it, and at the input end of such reactors.

While there may be little risk of *national* diversion of such plutonium in an advanced nuclear industrial state with good nonproliferation credentials (for which access to ample fissile material by more direct means would pose no problem), critics also express concern that condoning commercial recycling of plutonium in such a country could increase the difficulty of resisting its adoption in less reliable neighboring countries (where it might present a more substantial risk of national diversion). For those concerned about a "plutonium economy," the question thus becomes whether, and, if so, to what extent, the burning of WPu might create a "slippery slope" toward such an economy.

Several differences between the two situations should help prevent its having that effect. First, in the case of burning WPu, no reprocessing would be involved, since WPu is already separated plutonium. Instead of being converted into a form that is *more* proliferation-sensitive, the conversion would be in the opposite direction, since it starts out in the form of actual metal weapons "pits"—which are even more directly usable in weapons than separated plutonium oxide powder. Second, it is likely that the burning of WPU will be confined to a small number of designated reactors in a very limited number of locations. Third, the expectation is that WPu will be made available to the reactor owners at no cost (in fact, the owners are expected to be paid a fee for burning it), whereas commercial MOX is quite costly (involving expenses incurred for reprocessing and for fabricating MOX fuel, which are higher than that for fabricating nuclear fuel that does not contain plutonium—since plutonium requires remote handling).

These differences narrow the "slippery slope" question down to whether and to what extent the burning of MOX made from WPu might stimulate the establishment of a MOX fuel fabrication industry whose interests would be to encourage the use of commercial MOX *or* demonstrate some advantages of MOX fuel (e.g., in CANDU reactors, as discussed below) and thus stimulate a broad demand for MOX made from commercial plutonium, notwithstanding the cost differences mentioned above.

Groups hostile to recycling commercial plutonium nevertheless seem likely to try to prevent or delay both the making and implementation of a decision to pursue reactor options for disposing of WPu.[14]

PROLIFERATION RISKS AND RELATIONSHIP TO RUSSIAN POLICIES

Two distinct types of proliferation risk are involved: 1) the vulnerability of the WPu to theft, seizure, or smuggling, and acquisition by subnational groups of terrorists or criminals or by rogue states; and 2) the risk of break-out (i.e., its re-use in nuclear weapons by one of the disarming superpowers if it decided to flout its undertakings to reduce its nuclear arsenal).[15]

Both the United States and Russia have recognized the first as of top initial priority, and are making progress toward achieving the safe, secure storage of WPu,[16] pending its conversion into a less accessible and reusable form. But only the latter step would also reduce the risk of break-out. On the production side, the United States terminated all production of plutonium for weapons use several years ago, and it seems to be making good progress in negotiating with the Russians arrangements to secure a similar termination of such production in the last few remaining Russian dual-purpose reactors. But, while the United States has also been promoting negotiation of a world-wide convention against further production of plutonium for weapons or in unsafeguarded facilities, it has not yet made visible progress in this area. On the other hand, progress has been made in U.S.-Russian cooperative efforts to manage their own stockpiles of weapons plutonium.

In the joint declaration from their January 1994 summit meeting, Presidents Clinton and Yeltsin announced that they had agreed to establish a joint working group to consider:

> steps to ensure the transparency and irreversibility of the process of reduction of nuclear weapons, including the possibility of putting a portion of fissionable material under safeguards. Particular attention would be given to materials released in the process of nuclear disarmament and steps to ensure that these materials would not be used again for nuclear weapons.[17]

On March 1, 1996, President Clinton announced that he had ordered that "200 tons of fissile material—enough for thousands of nuclear weapons—be permanently withdrawn from the United States nuclear stockpile. Two hundred tons of fissile material that will never again be used to build a nuclear weapon."[18] It was subsequently revealed that this included 38.2 metric tons of weapons-grade plutonium that had been determined to be excess to national defense needs. A Department of Energy (DOE) publication in July 1996 stated that "Additional inventories of plutonium are expected to bring the total amount of [U.S.] plutonium that is surplus to approximately 50 metric tons."[19]

The joint declaration issued at the April 1996 Moscow Nuclear Safety and Security Summit[20] included a pledge by the G-7 economic powers plus Russia to support "efforts to ensure that all sensitive nuclear material (separated plutonium and highly enriched uranium) designated as not intended for use for meeting defense requirements is safely stored, protected and placed under IAEA safeguards...as soon as it is practicable to do so." The declaration mentioned several options: "safe and secure long-term storage, vitrification or other methods of permanent disposal, and conversion into mixed-oxide fuel (MOX) for use in nuclear reactors." The two sides agreed to share information on such options and to convene an international meeting to discuss them.[21]

Negotiations on achieving transparency (with respect to the size of inventories of WPu, and to provide assurance the plutonium involved is in fact derived from weapons programs and not freshly produced for this purpose) have also been underway, but have been hindered by delays in concluding an agreement for cooperation that will permit release of the requisite U.S. information, which is currently classified.[22]

Nevertheless, the United States has been cooperating under the Nunn-Lugar Cooperative Threat Reduction Program to help ensure the safe, secure storage of Russian WPu and to protect it against subnational threats (theft, seizure, or smuggling). Among other activities, the United States has been helping to improve physical security at relevant Russian facilities and build a safe, secure storage facility. Continued progress in this sector will be influenced by possible Kremlin leadership changes, Russian action on ratification of the Strategic Arms Reduction (START II) Treaty, and the extent to which the Russians continue down the nuclear disarmament path.

But what Russia will do about getting its excess plutonium into a form that meets the "spent fuel standard" and disposing of it depends also on U.S. progress on the disposition of its WPu. Russia has made it clear that it will move no further or faster than the United States does. Another issue is the apparently firm Russian conviction that plutonium is a valuable energy resource that must be used and not discarded.

Russia initially stated that its preference has been for burning WPu in fast breeder reactors. Such reactors *could* be operated to consume more plutonium than they use or produce. But, this plan would postpone the disposition step for many years, require enormous investments of funds it is unlikely to have available, and greatly prolong the period in which the WPu remains stored in the form of metallic weapons "pits"—the form that most readily lends itself to re-incorporation into weapons.

Russia has, however, shown some interest in three other reactor options. It realizes that some of its WPu is not in a form that could readily be used to fabricate MOX fuel, and thus would have to be disposed of by other methods. There have been technical exchanges between the United States and Russia already on all of these matters, which will doubtless be further discussed in the coming months.

The three reactor options (other than the fast breeder) in which the Russian side appears to have shown some interest are:

1. A Canadian proposal to burn WPu as 100 percent MOX in designated CANDU[23] reactors in Canada (on which Russia is engaged in a joint study with Canada);
2. A proposal, which Russia is studying with France, to burn WPu as MOX in Russia's VVER-1000s, the type of LWR most similar to U.S. LWRs; and
3. A proposal by the U.S. company General Atomics to complete the development of a Gas Turbine Modular Helium Reactor (GT-MHR)(in which the Ministry of Atomic Energy (Minatom) has reportedly invested $1 million of its own funds for a study, and the French company Framatome has also invested some).

The CANDU option is the only reactor proposal under consideration by both the U.S. and Russia and is discussed more fully in the next section.

The GT-MHR is not among the reactor options being considered by the U.S. government for the disposition of U.S. WPu, even though it promises results that go beyond the "spent fuel standard" by more completely and efficiently consuming the WPu and by leaving a smaller and more degraded waste product. The main reason is that the GT-MHR is still in the developmental stage, and would require substantial time and investment to bring into operation. Russia, on the other hand, appears to see it as an attractive possibility for a new generation of passively safe power reactors and, as in the case of the breeder possibility, seems less bothered by the probable delay. Moreover, DOE recently granted General Atomics permission to transfer the technology to Russia.[24] This transfer suggests that the process is beginning to move forward, but coordination with developments in other international settings will be crucial to achieving real progress.

REMAINING PRACTICAL OBSTACLES

Where to Fabricate the MOX Fuel?

The pacing item for the reactor-based options appears to be the availability of facilities for the fabrication of the MOX fuel from WPu. The National Academy of Sciences study noted the possibility of using DOE's nearly completed Fuel and Material Examination Facility (FMEF) at Hanford (Washington) for this purpose. Advantages of doing so include avoidance of the greater delays and costs of building a new facility in the United States from scratch, and its location on a physically protected Federal reservation. The downside is that its annual capacity to consume WPu would be limited unless major additions were made to it.

One alternative would be to build a new MOX fuel fabrication facility in the United States.(If located at Hanford, it could either complement the use of FMEF, or fill the entire fuel fabrication need.) Fabrication at the DOE's PANTEX facility in Texas, where the weapons dismantlement occurs, is another possibility under consideration. British Nuclear Fuels Limited (BNFL), the French company COGEMA, and Belgonnucleaire have each indicated their willingness to help design and construct such a U.S. facility, drawing on their considerable expertise and experience.[25]

A third possibility—which these European fuel fabricators also expressed their willingness to accommodate—would be to fabricate the special MOX in Europe, either using their existing MOX fuel fabrication capacity or adding to it. The problem this would raise is the need to transport the weapon-grade PuO_2 by sea from the United States to Europe, which could encounter all the safety and security objections that accompanied the 1992 return of plutonium from Europe to Japan.[26] But such transport is obviously no more of a risk than transporting U.S. nuclear weapons, for which military transport has been used.

Of these choices, completion of the FMEF seems potentially the quickest, cheapest, and safest alternative for fabricating MOX fuel from U.S. WPu, though its operation would presumably be subject to the licensing hurdles discussed below (which could delay it). It would also be the least likely to create the "slippery slope" feared by opponents of commercial plutonium recycle. In most of these respects, construction of a special facility at PANTEX might also be an attractive alternative, and have the advantage of avoiding the need to transport the WPu before its fabrication into MOX.

The West European fuel fabricators are also possibilities for fabricating MOX from Russian WPu, if they are not too fully booked. (The prospects of using the idled German facility at Hanau for this purpose seem to have disappeared, both because its owners decided against it and because of some apparent reluctance of the Russians to ship weapon-grade plutonium to Germany.) But some consideration is being given to German assistance in the construction of a MOX fuel facility in Russia. If the Russians decide to pursue the GT-MHR, fabrication of MOX would not be required, and fabrication of the ceramic coated plutonium fuel involved would be expected to take place in Russian facilities.

How Many and Which Reactors?

In response to a request by DOE for expressions of interest by U.S. nuclear utilities in the possible use of some of their existing reactors for burning MOX made from WPu, positive interest was expressed in early 1996 by 15 utilities, with respect to more than 34 existing reactors.[27] In deciding how many and which reactors should be used to burn WPu, the major policy problem is to strike the best balance between performing the task at a faster rate (thus shortening the time needed to complete it) and avoiding the putative risks of a "plutonium economy." A faster rate could obviously be achieved by using a larger number of reactors and/or those that can burn 100 percent (rather than only 30 percent MOX fuel) without significant design modification. But confining the task to a small number of selected reactors, as suggested by the National Academy study, would minimize the risk of stimulating a "plutonium economy."

Responses by North American nuclear utilities to the DOE request included submissions by the two largest U.S. nuclear utilities—Commonwealth Edison and Duke Power in conjunction with a team that included the French companies COGEMA and Electricite de France, BNFL, and others—that would involve the use of up to eight PWRs and two BWRs, following Lead Test Assembly demonstration programs. Another interested utility is Washington Public Power System (WPPS), which has been examining the matter in depth for several years both for its WNP-2 plant (located within the U.S. government's Hanford Reservation) and as a possible member of a consortium. Others include Arizona Public Service Company, with respect to its three Palo Verde reactors, which are capable of burning 100 percent MOX cores without modification of their design; and a Canadian proposal to use Ontario Hydro's "Bruce" A CANDU reactors to burn MOX fuel fabricated from WPu. (Without modification, these reactors could burn 100 percent MOX cores, and the Canadians would take responsibility for the spent fuel The rate at which they could burn WPu would be substantially increased if a special new type of fuel—now being developed—were used. Canada has conducted a joint study with DOE of the technical feasibility and advantages of this approach, assembled a supporting team (including BNFL and Bechtel), and is carrying out a joint study of this option with the Russians, who, as noted above, have expressed some interest in this option.) Given Canada's stability and outstanding nonproliferation credentials, concerns about national diversion of the fuel and safeguards difficulties seem negligible for CANDU reactors located within Canada.[28]

Negotiation of the contractual terms for actual participation in the use of existing U.S. reactors is expected to be tough. For example, PECO (formerly the Philadelphia Electric Company) made clear its expectation that DOE would bear the costs associated with such participation:

> including, but not limited to the costs for: facility modifications, security enhancements, health physics and industrial health and safety enhancements, fuel handling, fuel fabrication, lead test assembly program, spent fuel handling, storage, packaging, transportation, and the costs of any lost generating capacity caused by reactor shutdowns, or outage extensions necessitated by the MOX fuel program.[29]

It also argued that DOE would be contractually obligated to provide an acceptable, guaranteed, net benefit to PECO (such as irradiation fees, tax deductions or exemptions). Several respondents to the DOE request noted the need for a sustained federal commitment to the program, and for public acceptance (although WPPS, the CANDU team, and PECO claimed progress in securing the latter).[30]

Regulatory Hurdles

If the fabrication of WPu into MOX is to be performed in the United States, the fuel fabrication facility would presumably require licensing by the Nuclear Regulatory Commission (NRC). In preliminary meetings at the NRC in early 1996, the need for the NRC to reacquire the expertise needed to perform such a function was identified, and was estimated to take some 18 months following a decision to do so.

Once it has reacquired such expertise, the NRC would presumably have to perform a safety analysis of the use of MOX fuel made from WPu (which could draw on extensive European experience in using 30 percent MOX fuel loadings, but would also have to address any potential differences attributable to the use of a higher grade of plutonium, and the possibility of 100 percent MOX fuel loadings). It would also have to act upon proposed license amendments authorizing the operation of the designated reactors to burn MOX fuel. While there would probably be some special extra safety and physical protection measures required at those reactors, there would not appear to be a need for a generic study of the acceptability of using MOX in U.S. LWRs, such as the NRC's Generic Environmental Statement on Mixed Oxide (GESMO) fuel use proceedings aborted in the 1970s. Such proceedings would probably not be necessary because few reactors would be involved in burning WPu.

There would, of course, be a risk of intervention in the proceedings by hard-core opponents of commercial plutonium use, as well as related National Environmental Protection Act litigation and, perhaps, even attempts to get state regulatory bodies involved. Transfer of MOX containing WPu to Canada could also face regulatory hurdles.

CONCLUSIONS

To overcome the many obstacles mentioned in this essay (almost certainly an incomplete list) will clearly take time, sustained and dedicated effort, and substantial funding by the U.S. government over a number of years.[31] Meanwhile, the WPu is likely to remain in a form (metallic weapons "pits") from which it could all too easily be incorporated into nuclear weapons again, either by Russian or U.S. leaders who might decide to break out of their nuclear reduction commitments, or by others (quite possibly including a "rogue" state) if the physical protection accorded it proves inadequate against theft or seizure. There is an appreciable risk that before the burning or equivalent disposition of WPu begins or is completed, the political situation in Russia could deteriorate and Russian cooperation in weapons reductions cease.

Although the U.S. government funding needed to implement the reactor option is bound to be substantial (at least a billion dollars),[32] it is minuscule compared to the trillions of dollars spent to build up the U.S. and former Soviet nuclear arsenals,[33] or the many billions needed to clean up facilities that were involved in that build-up.[34] Nevertheless, it may well be extremely difficult to obtain the necessary funding from successive budget-cutting Congresses that may not appreciate how vital appropriate disposition and destruction of WPu actually is to national and global security.

[1] The primary documents in this connection are: Department of Energy (DOE), *Technical Summary Report for Surplus Weapons-Usable Plutonium Disposition* (DOE/MD-0003)(Washington, D.C.: DOE, July 17, 1996), and DOE, *Storage and Disposition of Weapons-Usable Fissile Materials, Draft Programmatic Environmental Impact Statement* (DOE/EIS-0229-D) (Washington, D.C.: DOE, February 1996), the final version of which is scheduled to be released during the fall of 1996. The first of these is the shorter and, in this author's judgment, by far the more useful. The second, in its current draft form, is a 2,350-page document that deals in minute detail with estimated environmental impacts of the numerous alternatives and subalternatives still under consideration, and does not designate any preferred alternative. While legally necessary, this document essentially indicates that the incremental environmental impact of none of the programmatic options considered is severe enough to rule it out, or to provide a decisive basis for choosing among them. Following a decision on which programmatic options to pursue, site-specific environmental impact statements will also presumably be prepared and submitted for public comment.

On relevant nonproliferation issues, see also DOE, *Draft Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material Storage and Plutonium Disposition Alternatives* (Washington, D.C.: DOE, October 1, 1996) (available on the Internet at "http://www2.dp.doe.gov/www.nn.doe.gov/nn/index.html"). A proposed outline for this study was published in 61 *Federal Register* 33909 (July 1, 1996), and public meetings to discuss that outline were subsequently held in each of the major regions of the United States.

[2] For a report that the DOE is likely to make such a "hybrid" decision, see Dave Airozo, "DOE to Opt for Dual Path Approach for Plutonium Disposition Effort," *Nucleonics Week*, September 12, 1996, p. 6.

[3] More than a dozen shipments of LEU derived from the blending down of part of the 500 MT of former Russian weapons HEU purchased by the United States have already been received in the United States. In late June 1996, the DOE published the pertinent environmental analysis (DOE *Final Environmental Impact Statement on the Disposition of Surplus Highly Enriched Uranium* (DOE/EIS-0240-DS) (Washington, D.C.: DOE, June 1996)), which designated maximum commercial use of the blended down HEU as the preferred option, and a Record of Decision to pursue that option was published in July (DOE, *Record of Decision for the Disposition of Surplus Highly Enriched Uranium Final Environmental Impact Statement* (Washington, D.C.: DOE, July 29, 1996). On the related subject of proposed sales by the DOE of surplus natural and low-enriched uranium, see the following very informative Energy Department Record of Decision entitled *Draft Environmental Assessment on DOE Sale of Surplus Natural and Low Enriched Uranium* (DOE/EA-1172) (Washington, D.C.: DOE, July 29, 1996). The U.S. Enrichment Corporation (USEC) distributed to the press a useful *Progress Report* on September 25, 1996.

[4] British Nuclear Fuels Ltd., COGEMA, and Japan Nuclear Fuel Co. Ltd., *Nuclear Recycling* (Paris: Nusys, February 1996), p. 10.

[5] There have, however, been recent proposals for utilizing unreprocessed spent fuel from LWRs (whose residual U^{235} content is higher than that in natural uranium) in CANDU reactors, and promising research has been reported on a new technology for removing uranium from spent fuel without traditional reprocessing; see "International Research Effort Aimed at Extracting U Without Reprocessing," *Nuclear Fuel*, August 12, 1996, p. 8.

[6] Committee on International Security and Arms Control, National Academy of Sciences (NAS), *Management and Disposition of Excess Weapons Plutonium* (Washington, D.C.: NAS Press, 1974), followed by a supplemental subcommittee report on *Reactor-Related Options* published in 1995. These will be referred to collectively as "the National Academy study."

[7] American Nuclear Society Special Panel, *Protection and Management of Plutonium* (La Grange Park, Ill.: ANS, August 1995).

[8] British Nuclear Fuels Ltd., *et al.*, p. 10.

[9] Another facet of the resource argument concerns the possibility of using plutonium in fast breeder reactors. Though commercial use of breeders is conceded to be at least several decades in the future and would involve large shipments of separated plutonium, its advocates point out that current reactors utilize only a tiny fraction of the energy potential in uranium, which could be increased nearly 100-fold in a fast breeder reactor by converting the plentiful isotope U^{238} into fissile Pu^{239}. It would also be possible to operate breeders as net consumers of Pu.

[10] Although Japan has long planned construction of a large commercial reprocessing plant of its own, such plans have met with considerable domestic resistance and may be delayed. It has declared its policy against accumulating separated plutonium in excess of that needed for its civil nuclear program, and advocated "transparency" that will make clear to the international community how its plutonium is being used.

[11] For a useful discussion of world inventories of plutonium, see Albright, Berkhout, and Walker, *World Inventory of Plutonium and Highly Enriched Uranium 1992* (London: Oxford University Press, 1993), a revised and updated version of which is expected to be published by SIPRI this year.

[12] Guest editorial by Dr. Glenn Seaborg, in British Nuclear Fuels Ltd., *et al.*, p. 2.

[13] In this editorial, Dr. Seaborg writes: "Plutonium should be separated and used with great care under strong international safeguards and *only in locations where it makes technical, economic and political sense to do*. This means that in place of the "plutonium economy" that some forecast, we need to develop a 'spent fuel economy' in which, as it acquires economic value, spent fuel is transferred from countries that lack the technical background and economic justification for reprocessing to those that do." (Emphasis added).

[14] They may, for starters, initiate protracted litigation over alleged deficiencies in the DOE's environmental impact analyses.

[15] On October 1, 1996, the DOE released for public comment by November 6 an analysis of the nonproliferation and arms control implications of the principal options for disposing of weapons plutonium and of possible ways of mitigating those that are adverse. See DOE, *Draft Nonproliferation and Arms Control Assessment of Wepaons-Usable Fissile Storage and Plutonium Disposition Alternatives.*.

[16] As for storage in Russia, this has been a major focus of efforts under the Nunn-Lugar Cooperative Threat Reduction program, and of related efforts of the U.S. DOE and the National Laboratories. The most recent publication on U.S. government consideration of storage options in the United States is the DOE, *Technical Summary Report for Long-Term Storage of Weapons-Usable Fissile Materials* (DOE/MD 004) (Washington, D.C.: DOE, July 17, 1996).

[17] Office of the Federal Register, 30 *Weekly Compilation of Presidential Documents* 81 (Washington, D.C.: GPO, January 24, 1994).

[18] Office of the Federal Register, 32 *Weekly Compilation of Presidential Documents* 343 (Washington, D.C.: GPO, March 6, 1996).

[19] DOE, *Technical Summary Report* (July 17, 1996). While most of that plutonium is in metallic form, the remainder is in oxides, reactor fuel, irradiated fuel or other forms, some of which could not readily be converted into MOX fuel. Thus, somewhat less than the 50 tons would be likely to be used for that purpose, and the remainder might well have to be disposed of in one of the alternative ways identified in the National Academy and DOE reports.

[20] The text of the declaration is reprinted in "Programme for Promoting Nuclear Nonproliferation," *Newsbrief No. 34* (Southampton, United Kingdom: University of Southampton Press, June 1996).

[21] At press time, this meeting was still scheduled to take place in France in late October.

[22] Sec. 144.d of the U.S. Atomic Energy Act (42 U.S.C. Sec. 2164d) as added by Sec. 3155 (b) of P.L. 103-337 (October 5, 1994) and most recently modified by Sec. 3160 of P.L. 104-201 (September 24, 1996) which extended until October

1, 1997, the legal authority to enter into such a special agreement for cooperation without a Congressional review period.
[23] CANDU reactors are unusually adaptable to different uses, but normally produce a greater quantity of plutonium than LWRs of comparable size, and are online refueled (theoretically making them more difficult to safeguard, in view of the ease with which fuel could be removed after relatively brief irradiation, when its plutonium content would be of a higher grade). However, Canada has provided the International Atomic Energy Agency (IAEA) with technologies to safeguard these reactors effectively.
[24] Michael Knapik, "DOE Likely to Give GA Approval to Transfer Technology to Russia," *Nucleonics Week*, September 12, 1996. An executive officer of General Atomics advised the author that the authorization was in fact received on September 13.
[25] "DOE Seeks MOX Makers' Advice on Conversion of Old Facilities," *Nuclear Fuel*, September 23, 1996, p. 12.
[26] In that case, an armed escort vessel was required by the United States, and protests were met from a number of countries along the route, as well as harassment by Greenpeace vessels that tracked the shipment, publicized its movement, and thus compromised its security.
[27] For an excellent article by a U.S. industry executive advocating a reactor-based option and explaining utility perspectives, see William F. Naughton, "Disposition of Weapons-Grade Plutonium in Commercial Light-Water Reactors," *Nuclear News*, August 1996, p. 24.
[28] See Joanne Charnetski and Tariq Rauf, "Let Canada Cremate Nuclear Swords," *Defense News*, October 3-9, 1994, pp. 23-24.
[29] Letter to DOE from Hugh Diamond, director, Fuel and Services Division of PECO Nuclear, February 26, 1996, p. 4, Public Documents Room, DOE, Washington, D.C.
[30] Since WPu *does* present a "clear and present danger," the author was surprised by the National Academy panel's estimate of six years as the minimum plausible time before reactor burning of WPu could commence, and of many more years to complete it (depending on the number of reactors and percentage of MOX fuel used). But this review of the hurdles ahead has persuaded him that the Academy study's estimate was probably correct, if not optimistic.
[31] The earliest estimated starting time for reactor-based options given in the DOE's *Technical Summary Report* (July 17, 1996) was 10 years after authorization for the CANDU option (or up to four years earlier if European MOX fuel fabrication plants are used initially), and "several years longer for other reactor types"; and the "time to complete" was estimated at 24 years for the CANDU option and up to seven years longer for the other reactor options considered.
[32] DOE, *Technical Summary Report* (July 17, 1996), and Susan Kopte, Michael Renner, and Peter Wilke, "The Cost of Disarmament: Dismantlement of Weapons and the Disposal of Military Surplus," *The Nonproliferation Review* 3 (Winter 1996).
[33] A Nuclear Weapons Cost Study Project Committee, chaired by Stephen Schwartz of The Brookings Institution, has been analyzing the real cost (in 1995 dollars) of the U.S. nuclear weapons program since its inception. Its preliminary conclusions were summarized in an article by Schwartz in the issue of *The Bulletin of the Atomic Scientists* (November/December 1995) entitled "Four Trillion Dollars and Counting." A book updating and providing greater detail on their findings is expected to be published this winter. Although no comparable study of the cost of the Russian nuclear weapons program appears to have been done, their program was even more extensive, and the environmental damage from it even more devastating.
[34] Cf. DOE, *Closing the Circle on the Splitting of the Atom: The Environmental Legacy of Nuclear Weapons Production in the United States and What the Department of Energy is Doing About It* (Washington, D.C.: DOE, January, 1995).