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Multi-Generational Stewardship of Plutonium

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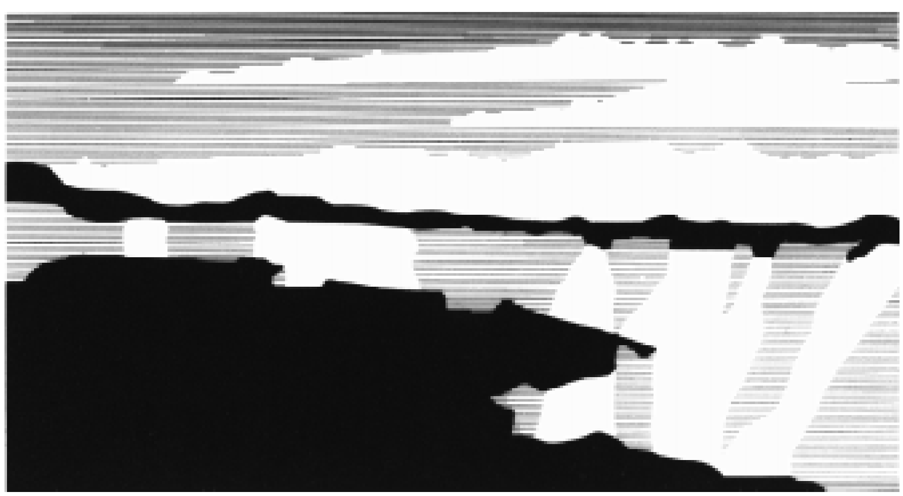

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MULTI-GENERATIONAL STEWARDSHIP OF PLUTONIUM

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ABSTRACT

The post-cold war era has greatly enhanced our interest in the long-term stewardship of plutonium. The management of excess plutonium from proposed nuclear weapons dismantlement has been the subject of numerous high-level intellectual discussions during the past several years. Issues relevant to long-term management of all plutonium as a valuable energy resource are also being examined. Although there are differing views about the future role of plutonium in the economy, there is also recognition of environmental- and health- related problems and proliferation potential of weapons-grade plutonium. If we are to be responsible for retaining the option of using plutonium as an energy resource for future generations, we need a new stewardship strategy.

I. INTRODUCTION

One of this century's scientific discoveries that made a major impact on world affairs was the discovery of plutonium in 1941. During the past 56 years, the world inventory of plutonium has increased from 0.5 microgram to 1400 metric tons (Mt), and the inventory continues to increase at the rate of about 70 Mt/year. Because all plutonium is man-made, we have a reasonable accounting of its presence throughout the world. More than 70% of the world's plutonium is locked up in the spent nuclear fuels that are produced by nuclear reactors. Most of the separated plutonium is in nuclear weapons establishments of Russia, the US, France, China, and Britain, and smaller quantities are produced in the civilian fuel cycles of France, Russia, Britain, Japan, Germany, Belgium, The Netherlands, Switzerland, and India. Although plutonium is most often associated with nuclear weapons, it is important to remember that plutonium is a recognized nuclear fuel for the future.

Despite differing views about the future of plutonium, there is consensus on the proposal to establish a comprehensive protection and management strategy for plutonium of all origins. Both near- and long-term objectives require a variety of technologies and institutional innovations to secure and safeguard plutonium for an indefinite future. This paper addresses some of the important technical and institutional issues and identifies key elements of a pragmatic strategy for maintaining stewardship of all plutonium for the near future as well as for generations to come.

II. EXCESS WEAPONS PLUTONIUM

Most of the open literature on weapons-grade plutonium (WPu) focus on US stockpiles, inventories, and technologies. The issues relevant to the management of Wpu in the US include the stability of materials, safety of workers and the environment, and security of current inventories. Similar safety and security issues are undoubtedly applicable to all WPu world-wide.

Since 1946, there have been numerous proposals to de-escalate the nuclear arms buildup. However, the buildup and production of weapons-useable fissile materials did not stop until the two superpowers voluntarily decided to terminate production because of a glut of nuclear materials in their inventories. In recent years, in anticipation of bilateral and multilateral arms control agreements, numerous scholarly examinations proposed alternative regimes for the disposition of excess fissile materials from nuclear weapons reductions.[1-6] Several of these discussions have also included issues related to long-term management of the rapidly increasing inventories of plutonium in spent fuels world-wide. Unfortunately, these studies have yet to propose a coherent strategy for preserving and using plutonium as a valuable energy resource for the future.

A. Disposition Options and Issues

In 1992, the National Academy of Sciences initiated a detailed examination of issues relevant to the management and disposition of plutonium removed from national inventories through arms reduction agreements. A series of reports from the Academy during the past three years discussed all known options and recommended several "preferred approaches," including the use of excess plutonium in reactor fuels.[1-4] After reviewing some 37 options, in January 1997, the US DOE selected two options for further examination:[7]

(1) the use of plutonium as a mixed oxide fuel in existing reactors and converting plutonium-bearing fuels into spent fuels, and

(2) vitrification of plutonium as glass (or in ceramic forms) and disposing of the stabilized material in geologic repositories.

The fundamental objectives of the weapons plutonium disposition program in the US and Russia can be achieved only when the two nations agree to carry out a disposition program in parallel. The considerable differences between the nuclear fuel cycle policies of the US and those of Russia are delineated in the Programmatic Environmental Impact Statement Implementation Plan issued by the US Department of Energy and the joint US/Russian Plutonium Disposition Study.[8, 9] In general, Russian authorities have objected to WPu disposition options, such as vitrification and deep borehole burial, because of their strong conviction that plutonium is a valuable resource and a "national asset." In the interest of moving forward with excess plutonium disposition, the US has accepted the idea of Russia disposing of plutonium by burning of MOX (mixed oxide) as reactor fuel while we adopt a combination of domestic options that satisfy various political constituencies. The divergence between the two nations' disposition strategies has encouraged some to argue the potential for future recovery of weapons-grade plutonium from immobilization alternatives.[10]

Other issues that influence the disposition of excess weapons plutonium include environmental safety and health issues, strategic needs, nuclear nonproliferation, and the growth of nuclear energy production world-wide. The world community should examine these issues objectively, as we pursue the desirable goal of reducing nuclear weapons. The objective of nuclear weapons reduction or elimination should not prejudice the potential peaceful uses of plutonium as a valuable energy resource for the future. It is appropriate at this time to develop a long-term strategy to manage plutonium, recognizing the needs of future generations.

B. Extended Storage of Plutonium

In order to prevent the reentry of fissile materials removed from weapons dismantlement, there have been numerous proposals for the management of excess fissile materials. In 1993, a bilateral agreement between US and Russia included the decision to use excess enriched uranium to fuel civilian nuclear reactors. Discussions about the disposition of excess plutonium have yet to find a common approach because of Russia's insistence on using excess WPu for energy production only and US efforts to retain options for discarding plutonium as a waste. Irrespective of the approach chosen for eventual disposition of excess plutonium, there will be long periods during which stabilized plutonium must be stored. Properly stabilized plutonium may be stored for extended periods under international safeguards in critically safe configurations in sealed containers after independent verification of declared quantities.

Two issues concerning the form of the plutonium being placed in storage – the physical and chemical characteristics of plutonium – are being considered in all safety analyses. Source terms for dispersion favors storage as a large solid mass rather than a fine powder; liquid and gaseous forms are the most undesirable.

The chemical reactivity of plutonium and its compounds with its immediate environment is a major factor when considering environmental impact and safety. Pressurization of the storage container through helium buildup, radiolytic and chemical interactions with its environment, and desorption of adsorbed gases such as moisture, carbon dioxide, and oxygen is obviously undesirable during long-term storage. Similarly, the potential for pyrophoric reaction of metals or hydrides with oxygen should be eliminated through proper design of storage scenarios. There is a sufficient knowledge base to address the issues of stabilization and storage and to develop a satisfactory solution for problems of long-term storage of plutonium; however, both economic and technical decisions will impact the final selection of storage forms for excess plutonium.

III. STEWARDSHIP OF PLUTONIUM FOR THE FUTURE

The unprecedented agreements between the US and the states of the former Soviet Union (FSU) to dismantle large quantities of their nuclear arsenal and establish a new international security regime have resulted in the new focus on plutonium. Although these agreements are still awaiting final approval, there is already considerable effort to develop plans for implementing the decision to dispose of excess fissile materials so that they will not reenter the weapons fuel cycle. Plutonium is also the focus of many on-going discussions on transuranic waste management and the long-term management of spent nuclear fuels. Plutonium presents both short- and long-term stewardship issues associated with WPu and military/ civilian plutonium, respectively.

Long-term management of our rapidly increasing world-wide inventory of civilian plutonium includes: (1) the rapid depletion of fossil fuels contrasted with the world's growing energy resource requirements; (2) the world community's desire to recover and reuse plutonium as an energy resource; (3) the policies of a few nations to dispose of spent nuclear fuels that contain large quantities of plutonium within geologic formations; (4) the nonproliferation perspectives of fuel cycles; and (5) the burden on future generations to manage the discards of this generation.[11]

A. Fossil fuels and future energy resource requirements

The world is consuming energy resources at a dramatically increasing rate. Demographers estimate the world population will double in 50 years, and the World Energy Council (WEC) has estimated our energy needs will double in 20 years. These realities mean we must make efficient use of all known energy resources, including the recovery and recycle of spent nuclear fuels resources.[12]

During 1996, the US joined the United Nations Framework Convention on Climate Change and agreed to stabilize CO_2 and greenhouse gas emissions at 1990 levels by the year 2000. According to the US Energy Information Administration, the projected 55% increase in demand for energy by 2015 will increase greenhouse gas emissions by 54% if these energy resources are from fossil fuels.[13] During the same period, 40% of the US's nuclear power generating capacity will be retired. As a consequence, the demand for electrical energy generation from fossil fuel will raise CO_2 emissions from 53 million tons per year to 620 million tons/year. To meet the combined goals of energy requirements and environmental compliance, the US may have to depend more on electrical energy generated from nuclear fuels, including plutonium.

Our nuclear fuel resources are natural uranium as a source of fissile uranium in the near-term and as fertile uranium for the future. In addition, fissile plutonium and ^{233}U produced from natural uranium and thorium, respectively, are necessary for the long-term generation of nuclear power. According to the WEC, if plutonium is not recycled, the cumulative demand for natural uranium will exceed the world's current known resources by the year 2030; therefore, commercialized use of plutonium in existing reactors and other advanced reactor systems are necessary for the long term. In addition to conventional MOX fuels, metallic, nitride, and carbide fuels of mixed plutonium and uranium are being developed in anticipation of the future large-scale need for nuclear fuels.

B. Recovery and use of plutonium as an energy resource

The use of nuclear energy and the use of plutonium for power generation will increase as fossil fuel resources are depleted and alternatives are unable to satisfy the growing international demand. Thirty-two nations of the world now operate a total of 443 nuclear power plants that generate 17% of the world-wide electrical energy consumption.[14] To extend the continued beneficial uses of nuclear energy, it is necessary to use plutonium as a fuel. Therefore, we must continue to develop technologies for more efficient use of plutonium as a nuclear fuel.

Because production of plutonium through commercial reprocessing has outpaced its consumption as MOX fuel in reactors, the inventory of separated plutonium in the civilian sector grows steadily. The world community is committed to using plutonium as a nuclear fuel and near-term plans for the use of MOX fuels will continue to reduce the inventory of separated plutonium.

C. Disposition of spent nuclear fuels in geologic formations

The current policies of at least three nations – the US, Canada, and Sweden – to discard spent nuclear fuels containing large quantities of fissile and fertile materials in geologic formations will create large concentrations of plutonium and uranium at few locations. As the radioactivity of the spent fuel decreases with time, the repositories will become attractive sources of plutonium, uranium, and a host of other strategically important materials.[15] Future generations looking for new energy resources will recover and reuse these resources, irrespective of the degree of difficulty created in the design of these repositories. Technologies for the safe recovery and reuse of the spent fuel resources for future energy production will be among the challenges for nations planning geologic disposal.

D. The nonproliferation aspects of fuel cycles

The National Academy Sciences' (NAS) detailed examination of reactor options for the disposition of WPu concluded that MOX fuel containing varying amounts of plutonium can be successfully burned as nuclear fuel in a number of nuclear reactor designs.[2] The most attractive options to complete the burning of excess plutonium in reactors would choose US light water reactors, Canadian CANDU reactors, and Russian VVER-1000's. Additional alternatives include the potential use of accelerator-based conversion of WPu. Although all these options have both advantages and limitations, some of the alternatives have more significant problems.

One of the NAS's reasons for promptly disposing excess fissile materials is the potential for diversion and/or theft of these materials, which could lead to clandestine use in nuclear weapons.[1] To minimize nuclear proliferation risks, the inventory of separated plutonium must be minimized by having a strategy to consume all excess plutonium on a regular basis. The nonproliferation advantages of the once-through fuel cycle and the closed fuel cycle have been discussed intensely for almost two decades. Proponents of the once-through fuel cycle argue that their approach will deplete fissile uranium and isolate the fertile and fissile materials contained in spent fuels. Proponents of the closed fuel cycle point out the need for sensible management of nuclear energy resources to meet the energy needs of future generations. The realities of future energy consumption require efficient uses of all known energy resources, including recovering and recycling the resources of spent nuclear fuels. The concern over nuclear proliferation is used as an argument in support of both alternatives mentioned above.

The nonproliferation argument for terminating the use of nuclear technologies in energy production has very limited support world-wide. The International Atomic Energy Agency (IAEA) estimates that at the end of 1996, 443 nuclear reactors were generating 350 TW(e) energy. Thirty-six nuclear power plants were under construction, with a projected electrical energy generating capacity of 28 Tw(e). Although the construction of new reactors in the western world has stabilized, the expansion of nuclear power in Asia and China continues.[14]

The uranium-fuelled nuclear reactors now in operation generate approximately 100 Mt of plutonium annually. Between 40 and 50% of this plutonium is consumed in-situ for energy production, and the remainder is released as part of nearly 10,000 Mt of spent fuels. Another IAEA estimate shows that at the end of 1995, some 52,000 Mt of spent fuels from nuclear power plants had been chemically processed to recover plutonium. The world-wide reprocessing capacity will increase from 5,500 Mt/year to 5,700 Mt/year by the year 2010, generate 60-70 Mt of separated plutonium annually.[16] To reduce the risk of proliferation, the inventory of separated plutonium should be kept at a minimum through continued consumption of the excess plutonium

E. Transfer of burden to future generations

The transfer of burden to future generations to manage the discards of this generation is an issue of great significance in the overall scheme of managing nuclear energy resources. Proponents of the once-through fuel cycle are requiring that the spent fuels be protected and safeguarded for an indefinite future, even after they are placed in geologic repositories. Both the US and the IAEA have policies that insure the safeguards of geologic repositories of spent fuels for an indefinite future.[17] Assigning this burden to future generations is contrary to all human experiences in the past and will continue to be a problem for the future.[11] A logical alternative is to store spent fuel retrievably as an energy resource for the future and to provide protection and safeguards in the interim.

IV. KEY ELEMENTS OF A LONG-TERM STEWARDSHIP STRATEGY

In recognition of prevailing controversies associated with plutonium disposition, it would be prudent to take the steps below.

(1) *Agree on a strategy to secure all plutonium inventories in enduring configurations under IAEA safeguards.*
Irrespective of the origin, plutonium is a valuable energy resource. In case of plutonium from weapons dismantlement, the US has already begun to place excess materials under IAEA safeguards. It is likely that the US will place 50 Mt of plutonium under IAEA safeguards, and similar response is expected from the Russians. Equally important are the enormous resource of spent nuclear fuels, including plutonium. They should be treated as valuable assets and maintained so that they are readily accessible and useable when fossil fuel resources have been depleted and the radioactivity levels of spent fuels are reduced.

(2) *Develop strategies for all nuclear weapon states to reduce or eliminate nuclear weapons stockpiles.*
It is obvious to any casual observer that although the US and Russia are making efforts to reduce nuclear stockpiles, other weapons states are sharpening their technologies, conducting more tests, and settling down for a continuation of the traditional nuclear proliferation. If the eventual objective of arms reduction is to eliminate all nuclear weapons, all nuclear weapons states must participate.

(3) *Establish achievable goals and eliminate the need for perpetual safeguards for spent fuels and plutonium repositories.*
Proposals, such as “eliminating plutonium from the biosphere” and “putting the nuclear genie back in the bottle” are cynical attempts to limit the energy choices of future generations. These arcane concepts should be quickly abandoned in favor of responsible stewardship of plutonium, eliminating the need for perpetual safeguards for geologic repositories.

(4) *Develop a strategy for multigenerational resource management, including the use of plutonium in energy production.*
Most important to future energy security is to develop a long-term strategy to invest in responsible management of all energy resources, especially plutonium, which holds great promise as a long-term energy resource. This husbanding of resources may at least partially compensate for the large financial liabilities we will pass on to future generations.

(5) *Delay the decision on final disposition and avoid the ethical dilemma of transferring major liabilities of this generation to future generations.*

Even after the US and Russia agree on a common strategy for the disposition of excess WPU, it will take several decades to achieve those goals. Therefore, it would be prudent to continue storage of excess materials under IAEA safeguards, without stipulating its future. Because the present generation have been reluctant to manage plutonium as a resource for the future, the next generations should have the opportunity to reevaluate the future of plutonium. Similarly, the long-term management of spent fuels and its resources should be designed as a multi-generational effort. Financing such an effort showing potential benefits to future generation is the challenge. Maintaining safeguards and security for the spent fuels is a major project and will require long-term investments. Financing major projects by borrowing against future revenues is a system used in international market place. A similar plan should be developed and implemented for multi-generational financing to generate needed resources to maintain safety, security, and safeguards for the long-term stewardship of spent nuclear fuels.

V. SUMMARY AND CONCLUSIONS

Plutonium is a unique material with characteristics of both toxic and radiation hazards. There are genuine safety and security concerns associated with the use of plutonium in military and civilian applications alike. However, ever since the discovery of plutonium, people have devised methods to work with it in safe environments; there have been very few mishaps associated with such operations. Almost all the technologies developed for safely handling plutonium are now available in open literature and are being used extensively for both nuclear and hazardous materials world-wide.

Although there is no international consensus on the future management of plutonium, a decision to destroy or discard plutonium would limit the energy options of future generations. Plutonium, the most famous among man-made materials deserves a reprieve. It is quite clear that the generation responsible for creating plutonium in such abundance may not be objective enough to choose the most appropriate means of managing this material for the benefit of mankind. Therefore, it is more appropriate for the present generations to safely store this valuable material and let future generations, who will inherit the real costs of dealing with this material as a national debt, decide on a disposition option. In the meantime, we should make a concerted effort to stabilize and store all plutonium in enduring chemical and physical configurations and in secure and safeguarded regimes.

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