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Processing Incentives for Russian Weapons-Grade Plutonium

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Russian Weapons-Grade Plutonium Processing Incentives

At MIT we are developing strategies that promote the physical processing of weapons-grade plutonium (WGPu) in the near term by guaranteeing Russia the fuel value of her plutonium. Physical forms are being evaluated that would provide a material barrier to proliferation without eliminating future retrieval by the nation state for use as fuel. Financial agreements are also being studied that would guarantee Russia fair compensation for the fuel value of her plutonium, presumably removing her major objection to physical processing.

Borosilicate glass (with or without high-level waste (HLW)) and a ceramic host form that may be used as an indefinite storage form as well as a fuel in standard LWRs, are currently under technical investigation at MIT. In previous work, experimental testing of simulated Pu glass uncovered no fabrication or repository performance problems.[1] The neutronic behavior of the fuel form is undergoing computational evaluation. However, the remainder of this document will outline our basic thinking behind financial agreements that may clear the way for material processing of WGPu.

Observations:

The existence of separated WGPu (particularly in Russia) presents the opportunity for sub-national diversion. Centralized storage, improved material accounting and increased safeguards while needed, provide only institutional barriers to diversion. Solutions that would promote *physical* barriers in the near term are therefore desirable.

Unfortunately Russia is opposed to physically processing its WGPu in any way that would jeopardize the future extraction of its fuel value. If Russian opposition to processing is based solely on fuel value issues, it would appear that financial mechanisms are capable of addressing these concerns.[2] Russia could be guaranteed or outright compensated for the fuel value of her WGPu thereby allowing a corresponding amount to be processed. The all important question is how much would this cost.

Calculating the future value of a commodity is difficult especially when its current value is uncertain. Plutonium is not a freely traded market commodity, therefore determining its current economic value is complicated. Russia would certainly wish to value her Pu roughly based on its energy content. This would make the estimated 50 MT of Russian WGPu in question worth 630 million

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[1] Budlong Sylvester, K., "A Strategy for Weapons-Grade Plutonium Disposition," thesis prepared for a M.S. degree in Nuclear Engineering and a M.S. degree in Technology and Policy, Massachusetts Institute of Technology, Cambridge, MA, September 1994

[2] It is assumed that excess Russian WGPu will not be held as part of a military reserve, therefore the management of this material is open to negotiation.

barrels of oil or approximately $11 billion.[3] However, such comparisons gloss over the costs associated with utilizing Pu's energy.

Another simple approach would be to use the price Russia herself agreed upon for her highly-enriched uranium (HEU). Through negotiations the Russians have assigned a value of $12 billion (over 20 years) for 500 MT of her HEU or $24,000/kg (undiscounted). Fissile plutonium atoms could be used to displace fissile uranium atoms in LEU fuel. Therefore it seems plausible to assign WGPu this same price. This would make the 50 MT of WGPu worth $1.2 billion. This price is generous as 1 kg of Pu-239 displaces only 0.8 kg of fissile U-235.[4] Additional costs of using Pu fuels are also neglected. However this provides a reasoned upper limit on WGPu's value using Russia's own assessment of a similar material.

Indeed, there are numerous ways to 'compensate' Russia for the economic value of her Pu. However, the menu of alternatives is dramatically affected by Russian flexibility in negotiations. If they require physically extracting the energy content of the WGPu itself, intermediate storage or fuel forms would be the only options. However, if Russia is open to receiving reactor-grade Pu (RGPu), other fuels, or cash in exchange for swiftly disposing of her WGPu, the options increase.

We begin by exploring agreements that would involve transferring RGPu to Russia for timely WGPu processing. This situation is treated first as Russia has expressed a desire to physically utilize Pu in its energy future and the US may be hesitant to negotiate direct compensation due to broad disagreement over Pu's value. Finally, other forms of compensation are examined and conclusions presented.

<u>Scenario 1 : Russia accepts RGPu in Exchange for WGPu</u>

- Under these conditions, the US or preferably an international coalition would seek out and finance an agreement with Japanese or European utilities (who possess surplus separated RGPu) to provide Russia with a fixed amount of RGPu at some time in the immediate or extended future.

- In exchange Russia would agree to immediately deposit an equivalent amount of WGPu (on a per fissile atom basis) in an internationally owned and monitored storage facility in Russia or at an agreed upon neutral site. The US would submit an equal amount to a similar facility if Russia requires reciprocity.

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[3]Calculated using: a crude oil price of $17.34 per barrel; energy content of 5.8 million BTU per barrel; 100% of fissile atoms fissioned; 200 MeV per fission

[4]Organization for Economic Co-operation and Development, "Plutonium Fuel: an Assessment, Paris 1989 p.121

- The deposited WGPu would be subject to immediate physical processing (determined by a bilateral or international committee) with the expressed intent of reducing the threat of unauthorized diversion in the near term.

<u>Immediate Delivery - A RGPu Swap</u>
Execution of such a program would depend upon Russian flexibility and utility support. If Russia required up-front delivery of RGPu it could be transported to Russia and safeguarded along with current Russian stocks. On a fissile atom per fissile atom basis, this would require approximately 1.36 MT of RGPu per MT of WGPu disposed (or 68 MT of RGPu for 50 MT of WGPu). It has been reported that by the end of the year 2000 up to 310 MT of civilian RGPu may be in storage worldwide.[5] So supplies would, in theory, be available for such a transfer.

As mentioned earlier the cost of such an arrangement is clearly important. We have examined the Pu price Russia may desire, in this case we are interested in what RGPu owners (Japanese or European utilities) may seek. If they based their price on their own costs of reprocessing, vitrification, storage (to date) and transportation, the amount would be roughly $100 M per MT RGPu or $6.8 B total.[6] This is a considerable amount of money, however this does not reflect the *economic* value of the RGPu.

The utilities could base Pu's value on the cost of its commercially produced substitute, uranium. Uranium enriched to 3.5% costs approximately $970 per kg to produce, or roughly $28,000 per kg fissile material.[7] At this price 68 MT of RGPu (~70% fissile) would be worth $1.~~9~~3 billion. However, the presence of Pu in the fuel increases fuel fabrication costs thereby greatly reducing the value of the Pu.

Currently the direct cost of fabricating MOX fuel alone (assuming none of the reprocessing costs) is roughly equivalent to the entire cost of fabricated uranium oxide fuel of 3.5 % enrichment.[8] This would imply an economic indifference between purchasing LEU fuel and fabricating MOX fuel with free Pu. This implies that Pu has zero value.

Despite the price indifference, MOX fuel (assuming a utility already possesses separated Pu) is chosen in order to avoid added costs. These include RGPu

[5] Albright, D., "World Inventory of Plutonium and Highly Enriched Uranium, " Oxford University Press, Oxford 1992 p.205

[6] Cost data taken from "The Economics of the Nuclear Fuel Cycle", OECD document 1994

[7] Calculation done using $110/SWU and $50/kg natural U feed

[8] Based on a MOX fabrication cost of $1100 and reference low enriched uranium fuel cost data taken from "The Economics of the Nuclear Fuel Cycle", OECD document 1994 p.11

storage costs (~$1500/kg/yr) and the Am-241 processing cost (~$18000/kg).[9] Over ten years of storage, 68 MT of RGPu would incur an undiscounted storage cost of $1.0 B. This material would most likely have to be processed to remove the buildup of Am-241 at a cost of ~$1.2 B, pushing the total cost to $2.2 B or $32,000/kg RGPu. Therefore it makes sense for utilities to utilize their capacity to burn separated RGPu and avoid this seemingly unavoidable cost.

If they had the option to sell the RGPu and avoid at a minimum the $1500/kg/yr costs they would appear to have a financial incentive to do so. If they were able to dispose of the Pu they could also save money. However, as such a disposal facility does not exist, this is not an option (it is most likely politically unacceptable as well). It would seem that if the US offered to purchase the RGPu outright, it potentially could be had for next to nothing.

Purchasing surplus RGPu from utilities would not conflict with utility or national objectives. The MOX fuel cycle does not and will not require maintaining a large surplus of RGPu. The high associated storage costs discourage it. The projected surpluses seem to be an unplanned and unwelcomed phenomenon that is a result of changes in projected nuclear power utilization in these countries. Its removal would represent a commitment to reduce costs and support the disarmament effort. This would appear to support the notion that Japanese and European utilities may be willing to part with their surplus RGPu.

There are proliferation concerns about transporting the RGPu a great distance in pure oxide form. To address this concern, the WGPu could be fabricated into MOX assemblies prior to shipment (potentially with some financial contributions from utilities from their storage savings) to provide a chemical dilution barrier. If this arrangement was still deemed unacceptable, there are several potentially preferable alternatives that would not require any Pu transportation.

Future Delivery - A RGPu Option Contract

One alternative would be to negotiate and purchase an "over-the-counter" option to buy RGPu. The option would allow the US to guarantee delivery of RGPu to Russia in the future in exchange for immediate processing of her WGPu. This would require no immediate RGPu transfers but would satisfy Russia's future Pu needs should they materialize. Figure 1 displays the material and cash flows involved in such a strategy.

An option to buy a specified amount of RGPu at some fixed price during a future time period would be purchased by the US or preferably an international coalition. The future price of the plutonium would be part of the option negotiation but would probably be low (as Pu has no current value).

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[9]Cost data taken from "The Economics of the Nuclear Fuel Cycle", OECD document 1994 pp.40-41

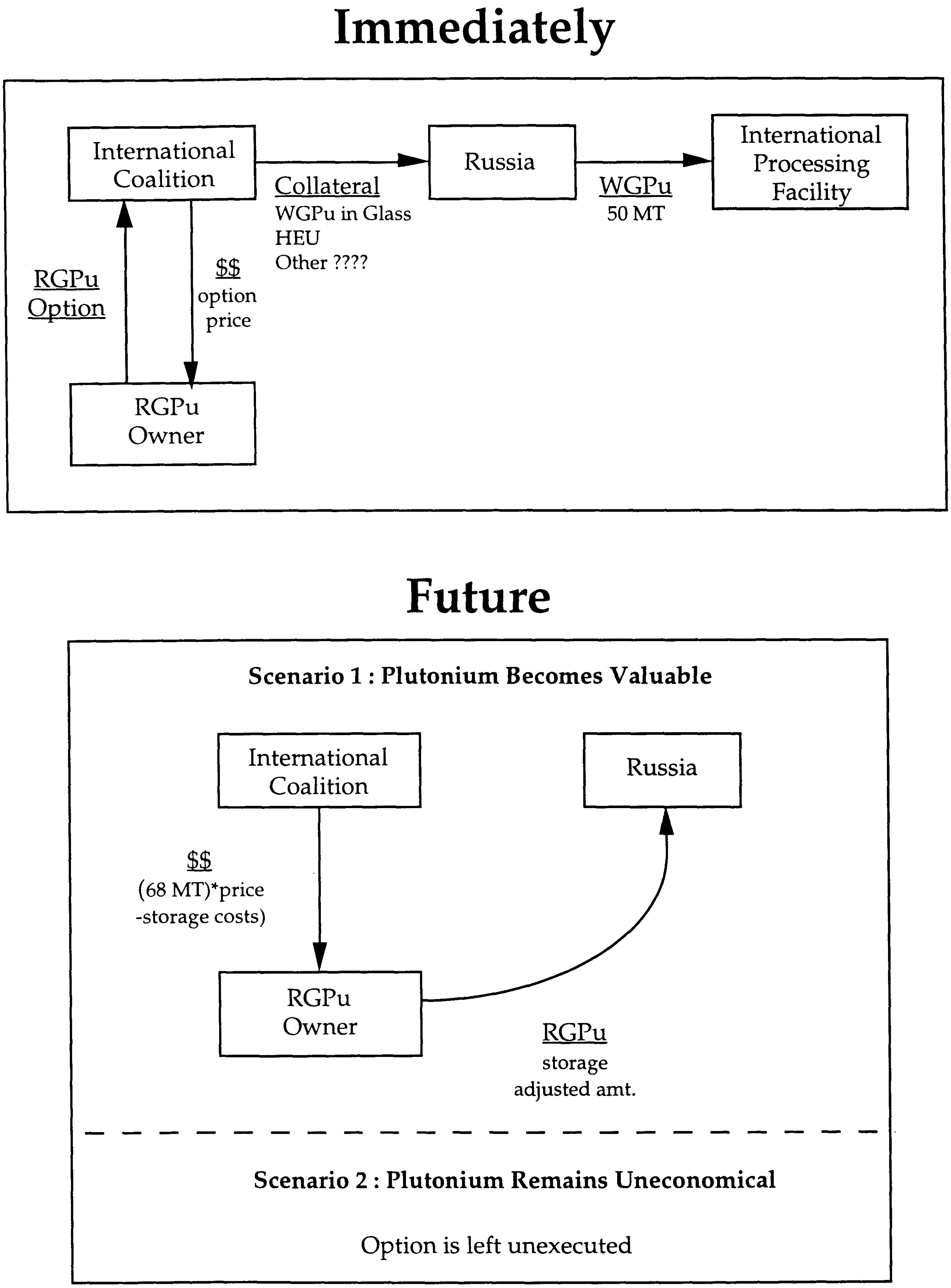

Figure 1 - RGPu Option Strategy

The cost of the option itself would reflect a fraction of the storage costs and Am-241 processing costs in order to be attractive to the utilities who hold reprocessing contracts. The option price must also compensate utilities for potential gains they are foregoing by offering the option. However, this price should not be great, as the above mentioned costs will be unavoidable for the utilities and the prospect of a dramatic increase in Pu value appears slim.

The US would then set a market trigger price for execution of the option. The price would be the difference between fabricated uranium fuel enriched to 3.5% and the sum of MOX fabrication costs and Am processing costs, whatever it may be during the option period. If fabricated low enriched uranium fuel prices rose to a level where MOX fuel makes economic sense in Russia (assuming free Pu), the US would exercise its option and start delivering RGPu to Russia.

The amount delivered should be adjusted to account for the storage costs Russia would have incurred had she retained the WGPu herself. The US is guaranteeing Russia's *potential* for profit and should not compensate Russia for a cost she would have accepted regardless.

If uranium fuel proves itself the more economical fuel choice, the option would be allowed to expire. Should this happen, the US would have paid the amount of the option in exchange for timely WGPu processing and participating utilities would have received funds to offset their storage costs.

Russia would almost certainly insist on some form of collateral to accept this arrangement. The WGPu committed to an international facility in Russia could itself serve such a purpose. The WGPu would be processed into a non-radioactive glass or similar storage form to provide an easily verifiable, material barrier to diversion. Russia would be given the authority to retrieve its chemically altered WGPu for fuel should the US default on its commitments. This also recognizes the de facto ability of Russia to physically reclaim any WGPu on its soil. The US, of course, would maintain the capability to retrieve its WGPu as well.

Another option would be to use the blended down Russian HEU (already purchased under contract with the USEC) as collateral. A certain amount of HEU could be blended to say 20% enrichment and held by Russia until she receives her fuel compensation (should it prove necessary).[10] This arrangement would allow for the immediate removal of WGPu from Russian soil. This would be in the US government's interest as this WGPu could be directly safeguarded in US facilities.

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[10]Twenty percent enrichment would sufficiently denature the uranium but would allow Russia to charge new fast breeder reactors with the material. Thus all commercially useful attributes of WGPu would be retained.

Under the RGPu option alternative, if Pu prices rose, the US could begin delivering RGPu to Russia or preferably facilitate Russian negotiations for the sale of the (now valuable) option to a third party for hard currency. An equivalent amount of WGPu in chemically altered storage would either be mixed with HLW or destroyed in a reactor. Part of the initial agreement could also require that a portion of any Russian profits from her newly acquired RGPu be used to pay for Russian WGPu storage and processing costs. All variations on this idea are subject to negotiation but this displays the flexibility afforded by such an approach.

Russia may still require a certain amount of cash up-front to accept the terms of the deal even though her fuel value concerns would be addressed. What is important is that Russia will not be able to demand tens of billions of dollars up-front for the energy content of its WGPu. This may be important for negotiations. The negotiated settlement would be recognized solely as a reward for timely processing and would presumably garner a much lower payment (especially if the US reciprocates without compensation).

What this arrangement does is remove any economic risk for Russia related to this portion of its WGPu. If there is commercial profit to be made on this material Russia will be assured to reap it. In absence of such an agreement, Russia risks the scenario of assuming large storage costs for an ultimately worthless material. This agreement eliminates Russia's economic risk while reducing global security risks.

There are numerous other benefits if Russia uses the option arrangement to delay increased investment in a Pu fuel cycle. Added reprocessing and MOX fabrication facilities represent huge capital outlays, capital they presently don't have. Such investments may eliminate Russia's ability to utilize the most economic energy sources in the future.

In addition, technology advances may make a Pu fuel cycle more economically attractive. As higher burnup fuel cycles are developed, Pu recycling becomes more economically competitive. By waiting Russia may use cheaper fuels today and enter into Pu fuels when the time is right.

The option alternative is preferable to immediate delivery in that it would not necessitate Pu transfer (only in the case where uranium fuel prices rise which appears unlikely). It may be more costly than a direct swap (as the RGPu option would probably cost something) but it has the potential for achieving the same goal with no physical movement of RGPu.

Both alternatives may have the effect of encouraging additional utility reprocessing to capitalize on the new US demand while meeting waste management goals. This is more of a concern for the direct fissile swap alternative if a large value is placed on the RGPu. However, the US could refuse to accept any price that might have that effect. The uncertainty associated with the RGPu option would probably not encourage an increased rate of reprocessing. The risk of having to accept the added storage costs would seem to be an effective deterrent.

It should be noted that the same arms control goals could be attained by convincing the Russians to mix their WGPu with their own separated RGPu. The Pu would still require safeguarding but would be sufficiently denatured (from a military viewpoint), thereby losing its strategic utility. Theoretically the US could reciprocate by purchasing a small amount of RGPu from the Russians and blending down its own WGPu. Calculations have shown that a mixture of 30% RGPu and 70% WGPu (by weight) could be effective in this regard.[11] There would certainly be political objections in the US to such a proposal, however such actions would seem to fulfill the limited goal of reducing the strategic stockpiles of the two START II signatories.

Scenario 2 : Russia accepts alternate compensation

Under this scenario the economic value of the WGPu would be ascertained and compensated for directly. This may be done in the form of a near term cash payment (arguably not to exceed the $24,000/kg paid for HEU). Alternatively, a date or time period in the future would be agreed upon when the Russians would need the energy derived from its WGPu. The US would agree from the outset to provide Russia on this date with an amount of fuel equivalent to her deposited WGPu (based on its energy content and current extraction efficiency).

The fuel form delivered would be determined by whatever has the lowest free market price at that time. If the free market price of MOX fabrication is more than the price of fabricated uranium oxide fuel, RGPu would clearly be the cheapest fuel (having zero or negative value). The US would negotiate an option contract for RGPu in preparation for such an outcome. However, it is conceivable that Russia may not wish to receive the RGPu due to its high storage and disposal costs.

The US would fulfill its agreement with RGPu unless the material becomes competitive with other fuel forms. If the equivalent amount of coal is cheaper at this time, Russia will receive coal (or the cash equivalent). The US could also give the Russians the market value of other assets such as SWU or low enriched uranium should they prove to be more economical. Once again such an arrangement would allow for WGPu disposal progress while limiting US costs.

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[11]Budlong Sylvester, K., "A Strategy for Weapons-Grade Plutonium Disposition," thesis prepared for a M.S. degree in Nuclear Engineering and a M.S. degree in Technology and Policy, Massachusetts Institute of Technology, Cambridge, MA, September 1994

Conclusions:

Russia is apparently willing to gamble on the future value of Pu. What must be assured is that such speculation is not done at the expense of global security. This analysis has shown that with some creative agreements such a scenario can be avoided.

Timely processing of Russian WGPu can be achieved if Russian/US desires are addressed within requisite time frames. Russia apparently seeks compensation for her WGPu. Whether she desires Pu itself, the energy it provides, or the price it may command, we have postulated mechanisms to accommodate.

The US, seeking security, may provide such compensation. But only if it is done in a fair, realistic manner. Russia is incapable of utilizing her Pu or profiting from it today. They do not currently possess the infrastructure to burn the material and its current market value is zero or negative. Fairness would suggest that any compensation for lost profits/energy should only occur during the time period they would have been realized. In this case perhaps never. If economic compensation is sought today it must be recognized for what it is, purely an incitement for action.

Future Work:

The analysis performed here is admittedly incomplete. Its only objective is to illustrate the potential for such compensating agreements as we see it. A deeper and more thorough analysis is needed to "strengthen the numbers" and to justify the merit of these proposals.

The key economic data used here were taken from the 1994 OECD report "The Economics of the Nuclear Fuel Cycle." The incentive for utility participation hinges on the stated costs of RGPu storage and Am-241 processing, as well as their Pu value predictions. This data should be explicitly investigated to increase our understanding of the utilities' economic position. The fixed costs of the Russians should be studied for the same reason. A more detailed investigation of the magnitude, location and ownership of separated RGPu and RGPu scheduled to be separated must also be included in this analysis.

The analysis lacks direct knowledge of Russian objectives as well. For example, a strong understanding of Russian energy policy is crucial to the design of acceptable alternatives. In addition, an effort should be made to present alternatives that are sensitive to the traditions and culture of the Russian people. Perhaps material exchanges are more readily acceptable in an environment where currency itself possesses transient value. Regarding negotiations with European or Japanese utilities perhaps a more sophisticated option agreement or other financial strategy could be pursued. Nonetheless, the potential positive effects of the strategies presented in this document justify their continued investigation.

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1. Albright, D., "World Inventory of Plutonium and Highly Enriched Uranium, " Oxford University Press, Oxford 1992 p.205

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