COMPARISON OF RECYCLE AND DISPOSAL OPTIONS FOR FISSILE MATERIALS ARISING FROM DISARMAMENT TREATIES

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NEAR-TERM ISSUES

1. Safe and secure storage of fissile material inventories, estimated at:

   <u>CIS</u>: 600-1100 MT HEU; 120 MT Pu

   <u>US</u>: 600 MT HEU; 95 MT Pu.

2. Commitment to non-weapons use, with verification

NEAR-TERM US PLANS

- Currently storing most HEU at Y-12 (Oak Ridge) and most Pu at Pantex (Amarillo)
- Rate of dismantlement expected to reach 2,000 warheads per year between 1993 and 2000
- Plan to consolidate HEU and Pu storage
- **HEU**: expect to use HEU in reactors requiring HEU, e.g. naval reactors
- **Pu**: US DOE now considering ultimate Pu

disposition options. Studies forthcoming from NAS and OTA.

NEAR-TERM RUSSIAN PLANS

- Build large storage facility near Tomsk capable of storing all warhead fissile material. Open in 1997.

- **HEU**: Under recently-concluded agreement, export LEU to the US (500 MT HEU would be converted to LEU as soon as practicable)

- **Pu**: Strong preference for recycling as nuclear fuel. May favor burning MOx in fast reactors, not LWRs.

HIGHLY-ENRICHED URANIUM

- **Warhead HEU, with 90% U-235, may be blended with natural U to produce LEU.**
  - **HEU has substantial economic value**
  - **HEU is relatively easy to convert into a form that cannot be reused in a nuclear weapon**
- **Still, warhead HEU inventories are large. Need to maintain control over HEU. .**
- **Alternative applications: naval reactors; MHTGRs.**

PLUTONIUM VS. HEU:

- **Much harder to convert into a form that could not be used in an explosive device:**

  "...a bare critical assembly could be made with plutonium metal no matter what its isotopic composition might be." (J. Carson Mark, 1990)

- **Pu fuel more expensive than U fuel**

- **Pu toxicity: need to protect public health and environment**

OVERALL PLUTONIUM DISPOSITION OPTIONS

1. Indefinite storage

   - as original metal
   - as oxide

2. Storage followed by recycle in fission reactors

   - LWRs (1/3-core MOx or all-MOx)
   - Gas-Cooled Reactors (MHTGR)
   - Fast Reactors (ALMR)

3. Storage followed by disposal as nuclear waste

4. Other (e.g. accelerators)

PRIORITIES AFFECTING SELECTION OF LONG-TERM PLUTONIUM OPTIONS

1. Disarmament and Physical Security

2. Technical Availability

3. Cost

4. Environment, Health and Safety

5. Political/Public Acceptance

SAFEGUARDS ASPECTS OF PLUTONIUM RECYCLE OPTIONS

- Pu may be used to fuel fission reactors, which convert weapons-grade Pu (>90% 239) into lower grade Pu (around 60% 239).

KEY ISSUES:

☞ How effectively does each reactor lower the grade of Pu? US DOE Plutonium Disposition Study (7/93) finds:

- thermal reactors produce similar Pu isotopic mix to LWR SF
- ALMR would not change fissile content significantly

☞ **What is each reactor's Pu throughput capability?**

GWe-YEARS REQUIRED TO CONSUME 100 MT Pu UNDER VARIOUS RECYCLE OPTIONS

Option	**Initial Load** (MT Pu/GWe)	**Subsequent Throughput/Year** (MT Pu/GWe-Year)	**GWe-Years to Consume 100 MT Pu**
LWR, 1/3 MOx	0.27	0.27	370
LWR, all MOx	2.5	0.84	117
ALMR, recycle	6.6	0.21	446
ALMR, once-through	6.6	1.6	59
MHTGR, PuO_2	1.8 - 5.5	0.92 - 2.7	36 - 108

fuel			

- **Low Pu consumption rate in 1/3-core loadings means that multiple sites would be required, increasing safeguards concern.**

- **Existing LWRs could be modified to accommodate all-MOx (full-core) loadings.**

TECHNICAL AVAILABILITY OF PLUTONIUM RECYCLE OPTIONS

- **Important to disarmament/physical security, cost, and political acceptance**

- **LWR options have advantage:**

  - **1/3-MOx loadings are well demonstrated in civilian nuclear industry**
  - **All-MOx option may be limited to plants with 90 control rod penetrations, rather than 60**

- **Advanced reactors (fast reactors, MHTGR, etc.):**

demonstration may be needed (Russia has one operating fast reactor)

ECONOMIC ASPECTS OF PLUTONIUM RECYCLE OPTIONS

- **Current market conditions: recycle options would likely be a significantly costlier way of generating electricity than continuing to use U fuel**

- **Main reasons: need for new fuel fab. plants; increased production costs (1 to 20 mills/kWh)**

- **Still could be a reasonable approach from an arms control perspective: substantial security benefits for a modest price**

- **Care must be taken to compare <u>added</u>, <u>incremental</u> cost of options:**

ECONOMIC ASPECTS OF PLUTONIUM RECYCLE OPTIONS (continued)

- **<u>Use of existing LWRs</u>: added cost is for fuel fab. plant (Omberg et al: $500 million) and penalty of using MOx rather than UO_2 fuel (1 mill/kWh)**

- **<u>Construction of new facilities</u>: added cost is difficult to define-**

  - **Added electricity revenues offset capital/operating costs**

  - **Net value (+/-) of new facilities should be compared with net value of alternative competitive electric generating option.**

- New facilities may produce net benefits,but ben's may be less than for alternatives pursued if Pu did not need to be burned.

DISCUSSION OF

PLUTONIUM REC

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- Expensive relative to U fuel
- Significant disarmament/security benefits $\Rightarrow$ may be reasonable

approach from an arms control perspective

- **Greatest overall security: options that produce low-grade Pu (LWR, MHTGR) and consume at high throughput rate (all-MOx LWR, MHTGR).**

- **Recent US DOE study concludes: LWRs, GCRs, LMRs could all be used for Pu disposition, but LWRs provide most effective way to achieve desired proliferation-resistance**

- **However, LWR option could require many new large LWRs. This suggests further consideration of modifying LWRs to accommodate all-MOx fuel loadings, allowing faster consumption of warhead Pu.**

DISPOSAL OF PLUTONIUM AS NUCLEAR WASTE

- **Vitrify plutonium in same facilities in use or planned for HLW vitrification**

- **Difficult to recover Pu from glass:**

  - **high radiation fields from the HLW**
  - **very low concentration of Pu in glass**

- **Technical issues:**

  - **solubility**

- radiation damage to glass
- criticality

DISPOSAL OF PLUTONIUM AS NUCLEAR WASTE (continued)

- Safeguards/disarmament aspects:

  - Less movement of Pu than recycle options
  - Pu is immobilized in glass, but is weapons-grade

- Cost: on the order of $1 billion to dispose of 100 MT (von Hippel et al, 1993)

- **Concern over technical availability**

SUMMARY

- **Highest priority should be safeguards/ disarmament**

- **<u>HEU</u>: may be blended with natural U to produce reactor-grade LEU with positive economic value**

- **<u>Pu</u>: there are both recycle and disposal options that are likely to at least meet minimum requirements (some may be better than others)**

- **US and Russia may develop different Pu strategies**

SUMMARY (continued)

- **Russian conditions may favor MOx option:**
  - spent fuel reprocessing
  - small MOx production plant already under construction
  - active breeder program.

  Considering burning in fast reactors.

- **US does not reprocess civilian fuel or use MOx in LWRs or fast reactors:**
  - Obstacles to recycle could be higher. But all-MOx LWR and other options may be acceptable.
  - Disposal of Pu in HLW could be attractive. Appears to have

good economics and prevent re-use as weapons.

SUMMARY (continued)

- **Should not overemphasize economics. However, it may be appropriate to give preference to options requiring the least investment in new facilities that would not otherwise be built. Also, ensure that <u>incremental</u> costs are compared.**

- **Political/institutional: solution that fits with overall nuclear infrastructure, without building many facilities that would not otherwise be built.**