FORUM ON THE NUCLEAR FUEL CYCLE

Senate Science and Technology Caucus

Senate Nuclear Caucus

Foundation for Nuclear Science

Senate Russell Building 385

November 16, 2005

Ernest J. Moniz

Cecil and Ida Green Professor of Physics and Engineering Systems

Co-Director, Laboratory for Energy and the Environment

M.I.T.

Source Materials:

- The Future of Nuclear Power – An Interdisciplinary MIT Study, co-chairs: J. Deutch and E. Moniz (Cambridge MA, 2003), available at http://web.mit.edu/nuclearpower/

- Making the World Safe for Nuclear Power, J. Deutch, A. Kanter, E. Moniz, D. Poneman (Survival, vol. 46, no. 4, Winter 2004-2005, pp. 65-80)

- Nuclear Power and Proliferation Resistance: Securing Benefits, Limiting Risks – Report by the Nuclear Energy Study Group of the American Physical Society Panel on Public Affairs, chair: R. Hagengruber (APS 2005), available at http://www.aps.org/public_affairs/proliferation_resistance/

FRAME OF REFERENCE

- Global electricity demand growth and potentially stringent constraints on greenhouse gas (GHG) emissions have reawakened interest in nuclear power.
    - Any technology pathway that seriously addresses both challenges must provide “carbon free” electricity at the terawatt (TW, or million megawatts) scale or greater, globally, by mid-century; this corresponds roughly to avoidance of a billion tons of carbon emissions (nearly four billion tons of CO_2) annually relative to “business-as-usual”.
        - Staying below a doubling of pre-industrial atmospheric GHG concentrations is a formidable challenge, requiring multiple TW contributors.
        - We cannot succeed if we do not start down this path now with commitment.

- For nuclear power, the TW scale means tripling current global capacity.
    - Economic, safety, waste, and nonproliferation tests must be met if nuclear power is to reach the TW scale by mid-century.
    - If it is realized, there would inevitably be a spread of nuclear power to new regions, including some with low security standards and considerable risk from terrorists, organized crime, and/or unreliable regimes with difficult regional relationships. Technical and institutional nonproliferation measures need to be in place before such expansion takes off.

- A move to reprocessing fundamentally links waste and nonproliferation considerations because actinides in spent nuclear fuel (SNF) can pose very long term waste management challenges and, if removed from the SNF through reprocessing, can pose nonproliferation challenges because of their usability in nuclear explosives; benefits and risks must be weighed in both domains simultaneously.

  - o The proliferation risks lie primarily with enrichment and reprocessing plants.
  - o Today, 240 tons of separated plutonium have accumulated in several countries from civil SNF reprocessing (the MOX fuel cycle) without qualitatively altering waste management challenges; the U.S. should continue to vigorously discourage further deployment of the MOX fuel cycle, even as it pursues R&D on more proliferation-resistant fuel cycles.
  - o More advanced reprocessing/fuel form options that lead to recycle of virtually all actinides hold the possibility of qualitatively simplifying long term waste management, but considerable R&D is needed to determine whether such approaches will prove technically and economically feasible.

- Long term geological isolation of SNF/high level waste (HLW) appears to be scientifically sound; consequently, the open fuel cycle (no reprocessing, geological isolation of SNF), given the adequacy of uranium resource estimates, has a strong technical foundation at least into the second half of this century.
  - o However, sound implementation and public acceptance are equally important and have proved elusive.
  - o A TW global deployment in the open fuel cycle will produce enough SNF to fill a Yucca Mountain about every 3.5 years.

- Storage of SNF for a considerable period (say, for 50-100 years) should be explicitly built into waste management plans

- POPA, pg 22: “There is no urgent need for the U.S. to initiate reprocessing or to develop additional national repositories. DOE programs should be aligned accordingly…”. POPA pg 20:

- "…interim storage of spent fuel in dry casks, either at current reactor sites, or at a few regional facilities, or at a single national facility, is safe and affordable for a period of at least 50 years."
- "… any spent fuel that would be emplaced at Yucca Mountain would remain available for reprocessing for many decades"; the same is clearly true for dry cask storage.
- There is "time to determine the best path for the next phase of the expansion of nuclear power… It is important, however, to use that time effectively to explore the options more thoroughly than has been done to date."

- Advanced reprocessing/full-actinide-recycle fuel cycles, with their associated reactor and fuel fabrication technologies, will not contribute substantially for decades, and their ultimate contribution at scale is not assured in the competition among future energy sources later in this century. However, the same is true for other technologies as well, and research on "carbon-free" options that might meet economic and security goals and that have TW scale potential by mid-century is important and, given the relatively small number of such options, should be a defining characteristic of the Federal R&D portfolio (along with technologies for greatly improved efficiency).

NEAR-TERM PRIORITIES

1. Realize nuclear power plant “first-mover” initiative.

- EPACT05 provides support (production tax credits,…) for 6 Gwe, addressing market imperfections (regulatory uncertainty, unresolved waste management, absence of a carbon emissions “price”)
- Risk to “first mover” initiative from an early reprocessing decision needs to be recognized and factored into consideration

2. Pursue international fuel cycle arrangements based on “fuel leasing” concept (fresh fuel supply, spent fuel return).

- major issues: security of supply; political asymmetries and incentives
- Administration first steps on security of supply are a good start, but effort also needed on “back end” of fuel cycle (which poses more difficulties until waste management issues are resolved in supplier states)
- One example of a more comprehensive approach: Assured Nuclear Fuel Services Initiative (ANFSI) in Survival article (notes appended)

3. Establish process and program plan for moving SNF as soon as possible from reactor sites to one or more Federal locations for interim storage and security

- Federal government takes SNF ownership, satisfying NWPA requirements for ultimate disposal
- Major impetus for “first movers”

4. Initiate substantial R&D program that will develop and evaluate multiple options for nuclear power deployment and nuclear fuel cycle development up to mid-century, and beyond

- R&D for both open and closed fuel cycles is important

- Early emphasis on “basic” research and laboratory-scale experiments, supported by strong systems analysis and extensive modeling/simulation, so as to explore reactors/fuel forms/fuel cycles well beyond the limited range of investigations that has been possible to date with very limited and highly channeled R&D funding
- Important areas include: uranium resource inventory; alternative SNF/HLW geological isolation concepts (e.g. deep boreholes) and engineered barriers; high temperature gas reactors; modular reactors with long-lived cores; “actinide-burner” reactors and fuel forms; advanced reprocessing concepts; fuel cycle simulation tools;…
- Early commitment to large demonstration projects has, at best, a mixed record for various energy technologies and runs the risk of being counterproductive.

ADDENDUM: Assured Nuclear Fuel Services Initiative

Survival vol. 46, no. 4, Winter 2004-2005, pp. 65-80

- recognition of "supplier states" and "user states"
    - such division of suppliers and customers already exists as a marketplace reality
    - US, EU, Japan, Canada, China, Russia about 85% of nuclear capacity
    - This is unlikely to drop below 80% even in robust growth scenario
        - i.e., robust growth to mid-century realized only with lots of new nuclear power in current fuel cycle states
    - fuel cycle not economic for small programs
    - quick start possible without negotiations of "permanent" criteria
- stay-put period of 10 to 15 years
    - long enough for stability and security
    - not so long as to ask for sacrifice of long-term options should nuclear power grow dramatically
    - little growth of nuclear power anticipated over 10-15 years, with ample fuel services available already; growth would come later
    - note: NPT started with fixed term
- during stay-put period, cradle-to-grave fuel services with attractive arrangements
    - specifically, fresh fuel supply and spent fuel removal
- fuel-service transactions between commercial entities negotiating commercial contracts, as today
- non-NPT signatories excluded from ANFSI, and ANFSI members do not receive nuclear materials or services from or supply services for new nuclear power plants to non-members
- advanced fuel cycle technology R&D within ANFSI

CHALLENGES

- security of supply
- technological leadership
- asymmetries and incentives

- while difficult and perhaps impossible to resolve at the level of principle and theory, may be far more tractable if addressed pragmatically

ASYMMETRIES AND INCENTIVES

- incentives appropriate since user states go beyond NPT requirements
- removal of SNF to country of origin or designated third party
  - commercial terms/inexpensive
  - acceptability in supplier states?
    - If growth robust, implicitly have made substantial progress
    - Principle of SNF return for proliferation reasons established (e.g., RERTR program in US)
    - Russia has declared interest and legal framework
    - User state fuel not more than 20% increment for half-century; manage as domestic fuel is managed with no qualitative impact
- fresh fuel incentives – discount against market price for enrichment
  - scale: robust growth scenario of 200 Gwe in user states in 2050 has associated enrichment cost of only $2B/year!
  - Approaches not requiring direct outlay of public funds
    - Agreed tax credit for enrichment services to ANFSI user states
    - Government insurance and export market credit institutions in supplier states restricted to ANFSI state transactions
    - Carbon trading credits

- Nuclear power currently not included in international "trading" mechanisms
- Proposal: as carbon credit trading regimes established, assign carbon credits to new nuclear plants in ANFSI user states
    - Presumably displace fossil fuels
    - At $50/tonne-C, with credits pegged at average of avoided emissions from coal and NGCC plants, credit worth 0.8 cents/kWh – more than entire fuel and SNF disposal cost combined!
    - European market currently trading close to $100/tonne-C!