# Advanced Nuclear Fuel Cycle Research and Development

# Testimony to

# U.S. House of Representatives Committee on Science and Technology

**Mark T. Peters, Argonne National Laboratory**

**June 17, 2009**

## <u>Introduction and Context</u>

World energy demand is increasing at a rapid pace. In order to satisfy the demand and protect the environment for future generations, including reduction of greenhouse gas emissions, future energy sources must evolve from the current dominance of fossil fuels to a more balanced, sustainable approach to energy production that is based on abundant, clean, and economical energy sources. Therefore, there is a vital and urgent need to establish safe, clean, and secure energy sources for the future on a worldwide basis. Nuclear energy is already a reliable, abundant, and "carbon-free" source of electricity for the United States and the world. In addition to contributing to future electricity production, nuclear energy could also be a critical resource for "fueling" the transportation sector (e.g., electricity for plug-in hybrid and electric vehicles and process heat for hydrogen and synthetic fuels production) and for desalinating water. However, nuclear energy must experience significant growth to achieve the goals of reliable and affordable energy in a carbon-constrained world.

There are a number of challenges associated with the global expansion of nuclear power. Such a global expansion will create potential competition for uranium resources for fuel, the need for increased industrial capacity for construction, the need for integrated waste management, and the need to control proliferation risks associated with the expansion of sensitive nuclear technologies. Moreover, domestic expansion of nuclear energy will increase the need for effective nuclear waste management in the United States.

Any advanced nuclear fuel cycle aimed at meeting these challenges must simultaneously address issues of economics, uranium resource utilization, nuclear waste minimization, and a strengthened nonproliferation regime, all of which require systems analysis and investment in new technologies. In the end, a comprehensive and long-term vision for expanded, sustainable nuclear energy must include:

- Safe and secure fuel-cycle technologies;
- Cost-effective technologies for an overall fuel-cycle system; and
- Closed fuel cycle for waste and resource management.

## Spent Nuclear Fuel Management

The nuclear fuel cycle is a cradle-to-grave framework that includes uranium mining, fuel fabrication, energy production, and nuclear waste management. There are two basic nuclear fuel-cycle approaches. An open (or once-through) fuel cycle, as currently planned by the United States, involves treating spent nuclear fuel as waste, with ultimate disposition of the material in a geologic repository (see Figure 1). In contrast, a closed

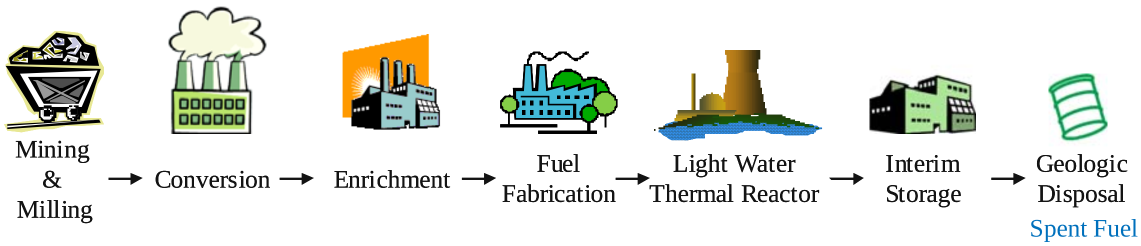


Figure 1. Open (or once-through) nuclear fuel cycle

(or recycle) fuel cycle, as currently planned by other countries (e.g., France, Russia, and Japan), involves treating spent nuclear fuel as a resource whereby separations and actinide recycling in reactors work with geologic disposal (see Figure 2).

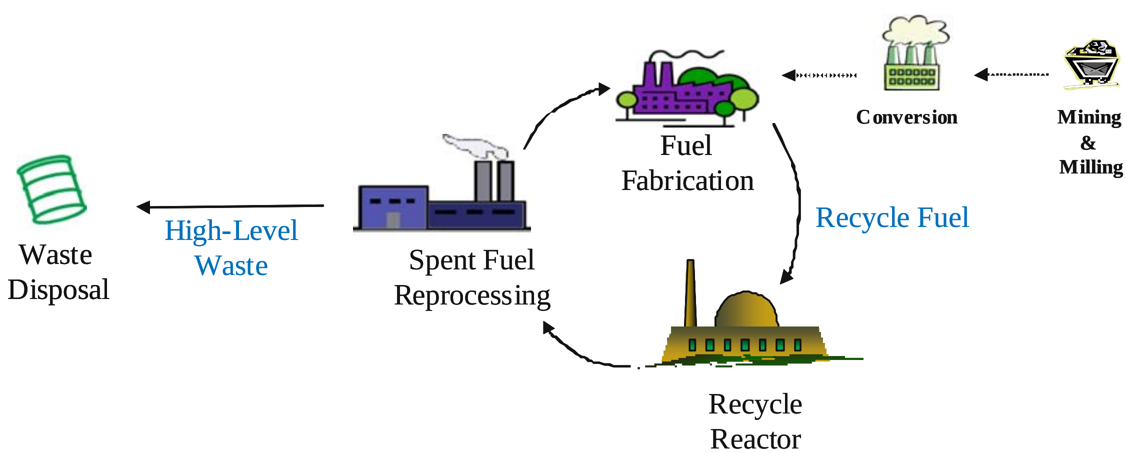


Figure 2. Closed nuclear fuel cycle (or reprocessing/recycling)

One of the key challenges associated with the choice of either option is spent nuclear fuel management. For example, current United States policy calls for the development of a geologic repository for the direct disposal of spent nuclear fuel. The decision to take this path was made decades ago, when the initial growth in nuclear energy had stopped, and the expectation was that the existing nuclear power plants would operate until reaching the end of their design lifetime, at which point, all of the plants would be decommissioned and no new reactors would be built.  While it may be argued that direct disposal is adequate for such a scenario, the recent domestic and international proposals for significant nuclear energy expansion call for a reevaluation of this option for future spent fuel management (see Figure 3).  While geologic repositories will be needed for any type of nuclear fuel cycle, the use of a repository would be quite different for closed fuel-cycle scenarios.

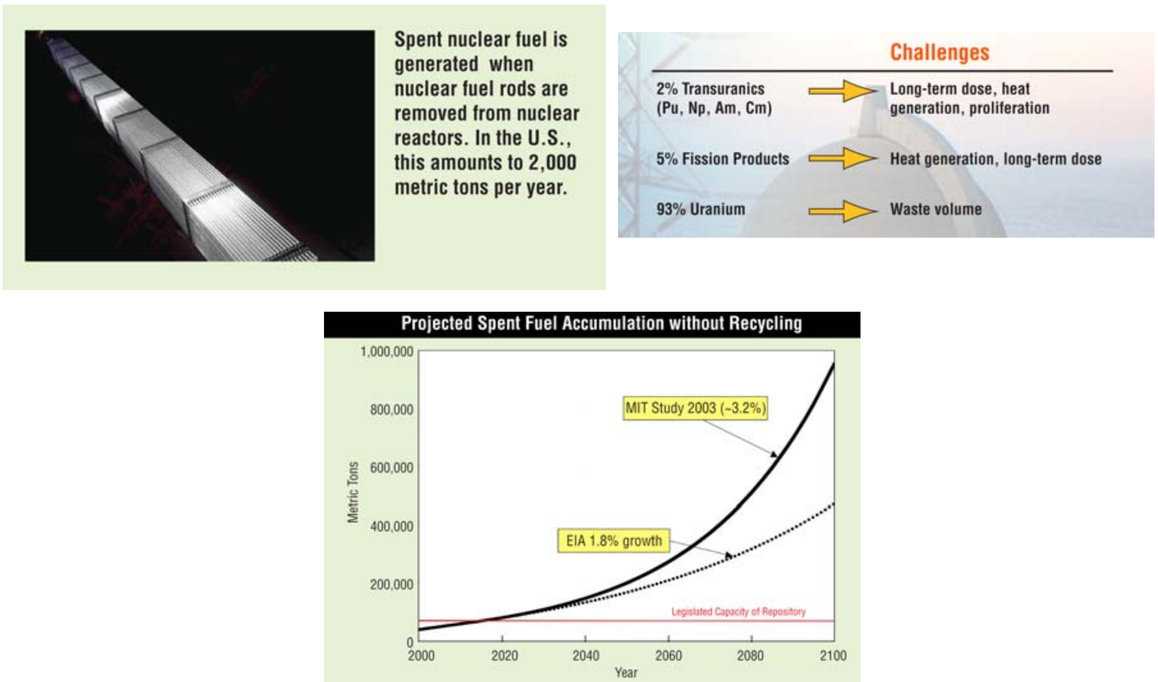


Figure 3.  Spent nuclear fuel generation and management

For reprocessing to be beneficial (as opposed to counterproductive), it must be followed by recycling, transmutation, and fission destruction of the ultra-long-lived radiotoxic constituents (for example, plutonium [Pu], neptunium [Np], americium [Am]; the Pu-241 to Am-241 to Np-237 chain is the dominant one).  Reprocessing (with Plutonium and Uranium Recovery by Extraction [PUREX]) followed by Pu mono-recycling (mixed-oxide [MOX] fuel in light water reactors [LWRs]) is well established, but is only a partial solution.  It is not at all clear that we should embark on this path, especially since the United States has not made a massive investment in a PUREX/MOX infrastructure. (Although, the United States is proceeding with a plan to reduce excess-weapons Pu inventory using MOX in LWRs.)  In contrast, advancement of fast reactor technology for transuranic [TRU] recycling and consumption would maximize the benefits of waste management and also allow essential progress toward the longer term goal of sustainable use of uranium (and subsequently thorium) with fast reactors.

There is no urgent need to deploy recycling today, but as nuclear energy expands, a once-through fuel cycle will not be sustainable. To maximize the benefits of nuclear energy in an expanding nuclear energy future, it will ultimately be necessary to close the fuel cycle. Fortuitously, it is conceivable that the decades-long hiatus in United States investment circumvents the need to rely on a dated recycling infrastructure. Rather, we have the option to develop and build new technologies and develop business models using advanced systems.

## Advanced Fuel-Cycle R&D Program

To reduce cost, ensure sustainability, and improve efficiency, safety, and security, significant investments (several hundred million dollars per year) in a sustained nuclear energy research and development (R&D) program are needed. Such a program must effectively support and integrate both basic and applied research and use modeling and simulation capabilities to address both near-term evolutionary activities (e.g., life extensions of the current nuclear fleet) and long-term solutions (e.g., advanced reactors and fuel-cycle technologies and facilities). As the nuclear industry pursues evolutionary R&D to further improve efficiencies along each step of the current fuel cycle, it is incumbent upon the government to implement long-term, science-based R&D programs for developing transformational technologies and options for advanced nuclear fuel cycles. Including nuclear regulators in the research and evaluation of results will facilitate the licensing and regulation of future nuclear facilities and technologies.

The growth of the scientific basis for nuclear energy and its translation into design concepts and technology advances will enable expanded, sustainable use of nuclear energy to meet energy needs worldwide in a safe, secure, and cost-effective manner through:

- Discovery and understanding of relevant phenomena;
- Creation of innovative concepts;
- Science-based approaches involving theory, experimentation, and modeling and simulation followed by demonstrations of new technologies; and
- Optimization of future nuclear energy systems in the context of technological, environmental, nonproliferation, security, and socioeconomic factors.

Planning the R&D required to support future implementation requires consideration of not only domestic nuclear energy development needs, but also an understanding of the global context in which nuclear energy will continue to grow. This requires a forward-looking program to conduct R&D defined by consideration of a broad range of planning assumptions for future nuclear energy use and effective approaches for improving waste management, nuclear non-proliferation, resource utilization, and economics. In summary, an advanced fuel-cycle R&D program, including fundamental R&D and technology development, is needed to examine a range of possibilities to determine the most important aspects, identify what the risks may be, and define what steps may be needed to successfully leapfrog existing technologies.

An essential part of the overall program supporting nuclear energy is the fundamental R&D that addresses long-range development issues.  These include:

- Timelines for potential nuclear energy deployment strategies to identify possible nuclear energy infrastructures, both global and domestic, and the science and technology development needs and timing of availability;
- Understanding the current technical status (including industry, the national laboratory complex, and universities) and planning for a reasoned development;
- Fundamental development of key technologies to resolve existing or anticipated issues related to waste management, non-proliferation, resource utilization, and economics; and
- Identify the need for research and development facilities, including utilization of existing infrastructure, for development and testing of the key technologies, including determining the deployment times for these facilities.

In the very near term, we recommend that the United States advanced fuel-cycle program develop a *Science and Technology Development Roadmap.*  Based on a comprehensive set of options for fuel-cycle technologies and overall systems, the roadmap should describe the technical readiness, risks, and potential benefits of each option and the required R&D plan for each.  This should be followed by implementation of a robust, science-based R&D program involving advanced reactors, separations, transmutation fuel, and waste management to enable timely identification of the technology options for a sustainable closed fuel cycle, identify what the risks may be, and define what steps are needed to successfully leapfrog existing recycling technologies.

In the long term, the required basic and applied R&D includes:

- Science and discovery contributions to technology/design;
- Increased role of modeling and simulation in nuclear energy R&D and design of nuclear energy systems;
- Improved systems analysis of nuclear energy deployment strategies;
- Advances in separations and fuel technologies to close the fuel cycle, e.g.,
  - Develop and demonstrate aqueous-based technologies;
  - Develop and demonstrate pyroprocessing technologies; and
  - Develop and demonstrate transmutation fuels.
- Advances in nuclear reactor technology and design to generate electricity and close the fuel cycle, e.g.,
  - Develop advanced reactor concepts;
  - Develop advanced reactor component testing facilities; and
  - Develop a demonstration fast reactor.
- Advancement of safe and secure use of nuclear energy on an international basis, e.g.,

- Enhance safety assurance capabilities in countries newly adopting nuclear power; and
- Improve safeguard technologies and practices.

- Education and training of future nuclear energy professionals; and
- University programs and partnering with institutions that have nuclear energy programs.

Finally, there is sufficient time to analyze the technology options, choose the paths to investigate, and conduct the science-based R&D and technology demonstrations that would be needed in the future for making decisions about the nuclear fuel-cycle infrastructure in the United States. However, it is imperative to begin now to build the R&D infrastructure that is needed for science and technology development, which must include advances in theory; modeling and simulation; new separations, fuel, and waste management technologies; and advanced reactor concepts.