Re-Assessing Methods to Close the U.S. Nuclear Fuel Cycle

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The current once-through nuclear fuel cycle in the U.S. and much of the rest of the world was a direct result of commercialization of water-cooled thermal spectrum reactor technologies developed for nuclear propulsion of submarines. Studies have consistently shown that a continuous recycle fuel cycle should be much more efficient, theoretically reducing uranium usage by ~99% and reducing waste requiring geologic isolation by ~95%. This paper explores different potential pathways to establish a continuous recycle fuel cycle system should a decision be made to do so. Nothing in this paper implies any DOE policy decisions.

The continuous recycle fuel cycle requires fast spectrum reactors to breed fissile fuel material from fertile material, so implementation would require a fleet of new reactors. Most of the current thermal reactors in the U.S. were built around the same time in the 1970s and 1980s and are anticipated to need replacement in the next 20-40 years. This presents a unique opportunity to transition to a continuous recycle fuel cycle by replacing some or all of the retiring reactors with fast reactors and initiating used fuel recycling.

The U.S. Department of Energy Office of Nuclear Energy's Systems Analysis & Integration Campaign, formerly known as the Fuel Cycle Options Campaign, has completed a multi-year effort on nuclear fuel cycle transition analysis focusing on potential pathways to transition from the current nuclear infrastructure to a closed fuel cycle based on fast spectrum reactors that continuously recycle their own fuel. These studies were conducted using subject matter expertise and the fuel cycle systems codes DYMOND, ORION, and VISION, along with numerous reactor physics and economics calculations. The goal was to better understand how to phase out the current nuclear infrastructure that would no longer be needed if such a transition were to occur, while phasing in a fleet of fast reactors and the associated fuel cycle facilities for fuel fabrication and recycling.

The key findings in terms of physics, materials, and infrastructure requirements will be summarized. Some of the major highlights include:

Assuming the continued use of nuclear power in the U.S., transition to a closed fuel cycle based on continuous recycle is feasible to achieve during the time period when the current fleet of reactors need replacement.

The transition requires development of a significant inventory of fissile material to initially fuel the reactors. Once recycle is established, the ongoing resource requirements would be a less than 1% of current requirements and high level waste mass would be only ~5% of current generation for the same level of energy production.

Two methods for producing the fissile material inventory are from recycle of the used fuel from current thermal reactors or the use of High Assay Low Enriched Uranium (HALEU). The recycle of thermal reactor used fuel is the traditional approach and used fuel separations facilities are currently operating in France and Russia. However, this study found that the use of HALEU may be more favorable because it is less constrained and may be more economical.

The presentation will include more information on the differences in scenario flexibility when doing startup with recycled materials versus with HALEU and implications for other scenario analyses and the supporting tools.