A New Paradigm: Near-Complete Recycling of Spent Fuel—A Path to Sustainable Nuclear Energy

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INTRODUCTION

Nuclear energy represents a large and economical source of clean energy without carbon emissions, and its track record regarding safety and reliability continues to improve. The only remaining major obstacle to its widespread public acceptance is concern over what to do with the spent fuel.

A responsible and sustainable deployment of nuclear energy should be based on a life cycle that maximizes the use and reuse of resources and minimizes the amount of wastes generated, particularly those requiring geological disposition.

BACKGROUND

Conventional reprocessing as presently practiced in light-water reactors (LWRs) recycles less than 1% of the spent fuel mass as Pu mixed oxides. The bulk of the spent fuel plus the secondary wastes generated in the process remain as high-level wastes to be disposed of in geological repositories. In addition, because the spent fuel used is processed after a relatively short cooling period, the Pu can be recycled only once. This approach is hardly an acceptable solution.

A new paradigm of near-complete recycling where more than 95% of the spent fuel is recycled is quite possible at a reasonable cost.

Under this scenario, only a small amount of waste would need to be disposed in geological repositories such as Yucca Mountain. This new approach of near-full recycle along with minimization of emissions and secondary wastes (both geological and low-level wastes) should promote public acceptance and encourage consensus building in the environmental community and among political bipartisan leaders.

DESCRIPTION OF THE ACTUAL WORK

The following figure shows the average composition of the spent fuel that has accumulated from commercial reactors in the United States thus far. As can be seen, the bulk of the mass is represented by the remaining uranium and cladding materials. The fissile fraction and the collective fission products represent a small fraction of the mass but contain the bulk of the radiotoxicity. The recovery of more than 95% of the spent fuel mass while minimizing emissions and maximizing repository capacity requires (1) separation and purification of uranium, transuranics, cladding, and possibly noble metals for reuse; (2) capture of volatile species and long-lived fission products; and (3) management of major heat sources to maximize repository capacity.

At present, spent fuel is being stored at the reactors sites. During this prolonged cooling period, a significant decay of activation products, fission products, and heavy actinides—notably ^{241}Pu and ^{244}Cm—takes places, which facilitates the subsequent, processing and unlimited recycling of major constituents back to the existing fleet of reactors at a lower cost.[1,2] This practice of relatively inexpensive interim storage (e.g., 40 to 60 years) followed by simplified processing for recycle should minimize the lifetime cost of the fuel cycle by large-scale processing, maximizing reuse, and minimizing the use of precious geological space**.**

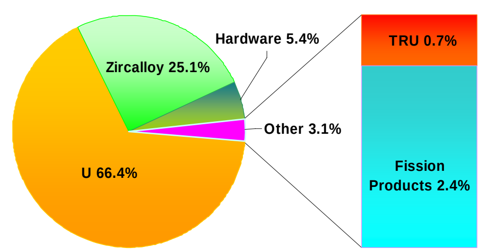

Fig.1. Average composition of spent fuel accumulated in the United States.

RESULTS

Uranium can be recycled into existing heavy-water reactors (HRWs) or into future breeder reactors, or it can be re-enriched for use in existing LWR. Zircaloy cladding can be refined and purified for the fabrication of new cladding, high-integrity containers for nuclear wastes, and repository components. Fissile transuranics can be recycled into the existing fleet of reactors (LWRs) and into planned future reactors such as the dual-use gas reactors (hydrogen generation, electricity) and fast reactors. Other selected fission products such as the noble metals (Ru, Rh, Pd, Ag) and Xe can potentially be recycled economically.

The approach proposed is a gradual deployment using initially the existing fleet of LWRs but with the implicit flexibility to accommodate future types. Significant costs savings can be realized by using a very large plant to minimize the unit cost and by taking advantage of the unique situation in the United States of having a very large inventory of aged fuel. Proliferation resistance and cost reductions can be achieved by close-coupling of separation and fuel fabrication along with strong site security and safeguards. Potential industrial partners and significant details will be presented in the full paper.

REFERENCES

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