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Integrating Fuel Cycles, Spent Fuel Storage, and Repositories

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Nuclear reactors produce spent nuclear fuel (SNF). Until the 1970s, SNF was considered a valuable energy resource. Then SNF was considered a waste. Today we do not know if LWR SNF is a waste or a resource. Historically fuel cycles, SNF storage, and repositories have been considered separately—but the functions they perform can be achieved in different ways to meet different sets of goals. It is time to rethink goals and thus how the backend of the fuel cycle is organized. Four options are described herein—of which for historical reasons only the first option has been seriously examined.

Traditional Approach. There are separate uncoupled fuel cycle facilities. The repository requirement is safe disposal of radioactive wastes. The repository may be coupled to open or closed fuel cycles for disposal of SNF or high-level waste. SNF storage, a technical requirement for disposal, is considered independent of the repository.

Repository with SNF Retrievability. The repository requirements are (1) safe disposal of wastes including SNF and (2) SNF is recoverable for centuries. This option (1) enables disposal of SNF so those who benefit from nuclear energy can minimize liabilities to future generations and (2) maintains for future generations the option to recover and use the SNF as a resource. Retrievability is also a policy statement that if problems are found with a repository site, the SNF can be recovered for disposal elsewhere.

Closed Fuel Cycle with Collocated/Integrated SNF Storage, Reprocessing, Fuel Fabrication, and Repository Facilities[1] Historically closed fuel cycles have had separately-sited SNF storage facilities, reprocessing facilities, fuel fabrication facilities, and the repository. These facilities can be collocated and integrated into a single facility at the repository site *if the repository site is chosen before a closed fuel cycle is implemented*. In addition to less transportation, this closed fuel cycle option can result in cost savings, reductions in risks, improved repository performance (waste forms with low waste loadings [less radiation damage and wider waste form choices], isotopic dilution for some solubility-limited waste forms, etc.), and termination of long-term repository safeguards requirements. While a repository has a few hundred jobs, an integrated backend facility would have thousands of high-paying jobs and thus increase the benefits and attractions for a community and a state to accept a repository.

Closed Fuel Cycle with Repository and Borehole/Saltdiver Disposal. The repository system consists of at least two facilities: a conventional repository and a borehole or equivalent disposal facility. The functional requirements are (1) safe dispose of most wastes in a conventional repository and (2) dispose of selected small-volume wastes in a facility designed with enhanced isolation capabilities. Enhanced isolation can be used for disposal of high-hazard wastes (minor actinides and certain fission products), disposal of high-heat wastes ($^{90}Sr/^{137}Cs$), or support nonproliferation policies (plutonium disposal). In many cases, the borehole could be located kilometers under a traditional repository. Borehole disposal may create the option of smaller-scale economic regional repositories for SNF and HLW.

We need to integrate fuel cycles, SNF storage, and waste management—starting with the question of long-term goals (endpoints) while recognizing policies and technologies change. Appropriate endpoints: (1) conventional repositories for the open fuel cycle with SNF retrievability to maintain options and (2) collocation and integration of back-end facilities with the repository for closed fuel cycles.

[1] C. W. Forsberg and L.R. Dole, "Collocation and Integration of Reprocessing, Fabrication, and Repository Facilities to Reduce Closed Fuel Cycle Costs and Risks," Paper 10197, *Proc. of the International Congress on the Advancement of Nuclear Power Plants*, San Diego, June 13-17, 2010