Nuclear Energy System Cost Modeling

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Abstract

The U.S. Department of Energy's Fuel Cycle Technologies (FCT) Program is preparing to perform an evaluation of the full range of possible Nuclear Energy Systems (NES) in 2013. These include all practical combinations of fuels and transmuters (reactors and sub-critical systems) in single and multi-tier combinations of burners and breeders with no, partial, and full recycle. As part of this evaluation, Levelized Electricity Unit Cost (LEUC) ranges for each representative system will be calculated. To facilitate the cost analyses, the 2009 Advanced Fuel Cycle Cost Basis Report is being amended to provide up-to-date cost data for each step in the fuel cycle, and a new analysis tool, NE-COST, has been developed. This paper explains the innovative "Island" approach used by NE-COST to streamline and simplify the economic analysis effort and provides examples of LEUC costs generated.

The Island approach treats each transmuter (or target burner) and the associated fuel cycle facilities as a separate analysis module, allowing reuse of modules that appear frequently in the NES options list. For example, a number of options to be screened will include a once-through uranium oxide (UOX) fueled light water reactor (LWR). The UOX LWR may be standalone, or may be the first stage in a multi-stage system. Using the Island approach, the UOX LWR only needs to be modeled once and the module can then be reused on subsequent fuel cycles.

NE-COST models the unit operations and life cycle costs associated with each step of the fuel cycle on each island. This includes three front-end options for supplying feedstock to fuel fabrication (mining/enrichment, reprocessing of used fuel from another island, and/or reprocessing of this island's used fuel), along with the transmuter and back-end storage/disposal. Results of each island are combined based on the fractional energy generated by each islands in an equilibrium system.

The cost analyses use the probability distributions of key parameters and employs Monte Carlo sampling to arrive at an island's cost probability density function (PDF). When comparing two NES to determine delta cost, strongly correlated parameters can be cancelled out so that only the differences in the systems contribute to the relative cost PDFs. For example, one comparative analysis presented in the paper is a single stage LWR-UOX system versus a two-stage LWR-UOX to LWR-MOX system. In this case, the first stage of both systems is the same (but with different fractional energy generation), while the second stage of the UOX to MOX system uses the same type transmuter but the fuel type and feedstock sources are different. In this case, the cost difference between systems is driven by only the fuel cycle differences of the MOX stage.