ORIGEN-based Nuclear Fuel Depletion Module for Fuel Cycle Assessment

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ABSTRACT:

One of the main goals of a fuel cycle simulator tool is to enable communication with both policymakers and the public at large as to the relative impacts of fuel cycle options on metrics as diverse as economics, resource utilization, long-term waste management (including geologic repository performance), and proliferation resistance. Yet presently, most fuel cycle simulation tools developed in the U.S. rely upon extremely simplistic models for nuclear inventory evolution and tracking, typically in the form of pre-generated fuel "recipes" (containing material input and a very limited set of output isotopic compositions) for performing fuel cycle studies. Such a static approach to fuel cycle assessment greatly constrains the flexibility and capabilities of such models. For example, a scenario involving multiple reactor-based reuse cases entails several iterations of output isotopic compositions, reflecting the changing fissile quality of materials through each irradiation cycle. More complex scenarios quickly become extremely difficult if not intractable to accurately capture for approaches using static fuel recipes.

As an alternative to this approach, we propose to develop a flexible reactor analysis module (referred to as the *Nuclear Fuel Inventory Module*) for the DOE fuel cycle simulator (CYCLUS) based upon established tools for reactor fuel depletion and decay. Using the mature and experimentally validated code ORIGEN as the basis for an embedded "depletion engine," the Nuclear Fuel Inventory Module will afford greatly enhanced modeling flexibility for the fuel cycle simulator while enabling accurate evaluations of impacts from both present and future fuel cycle options, particularly for those cycles featuring reactor-based reuse.

Such an approach yields several key advantages for fuel cycle studies. In particular, the proposed module would enable evaluation of a broad space of reactor-based strategies given ORIGEN's ability to quickly calculate nuclear inventories using pre-generated reactor data libraries derived from prior 2-D neutron transport calculations. As a result, modelers can calculate extended nuclide inventories as a function of high-level parameters of interest, such as initial fuel composition, reactor type, and total fuel irradiation (i.e., burnup). This platform likewise enables accurate tracking of isotopic inventories over the large-order timescales (i.e., decades to a million years) required for impact assessments of fuel cycle options on long-term waste management metrics, making it a vital addition to the fuel cycle simulator scope.

The **core deliverables** of this project will be: 1) an ORIGEN-based Nuclear Fuel Inventory Module for CYCLUS, 2) a distributable ORIGEN depletion engine, embeddable in a variety of code frameworks, and 3) a comprehensive set of reactor data libraries (based upon modern nuclear data) for use with the proposed reactor system module for both current commercial fuel designs as well as anticipated future reactor-based reuse scenarios.