# DOE-ID NEPA CX DETERMINATION
# Idaho National Laboratory



CX Posting No.: DOE-ID-INL-16-115

**SECTION A. Project Title:** TerraPower Traveling Wave Reactor Research and Development Activities at Idaho National Laboratory

**SECTION B. Project Description and Purpose:**

The purpose of this revision is to refine and add scope to the proposed action.

This environmental checklist covers TerraPower research in developing a new Generation IV nuclear power plant based on its Traveling Wave Reactor (TWR) concept. TWRs take advantage of a “breed-and-burn” process by which fissile material is bred in situ from natural or depleted uranium (DU) to sustain power operations for decades without enrichment or reprocessing. The breed-and-burn nuclear fuel cycle minimizes reliance on enriched uranium, and would allow TerraPower to deliver an economical and sustainable energy source without increasing proliferation concerns. The Prototype Traveling Wave Reactor plant (TWR-P) is currently in the design phase.

Idaho National Laboratory (INL) conducts test pin fabrication, irradiation testing, and post-irradiation examination (PIE) activities to evaluate methods for a commercial-scale metal fuel fabrication process for manufacture of TerraPower's first TWR-P core. Research and Development (R&D) activities associated with this activity at INL include 1) purchasing and installing equipment in the Materials and Fuel Complex (MFC) Experimental Fuels Facility (EFF), building MFC-794 and the Fuels and Applied Science Building (FASB), MFC-787 to develop a process to fabricate TerraPower test pins; 2) characterize un-irradiated fuel to confirm fuel development and examine irradiation performance; 3) fabricating test pins for irradiation testing at Department of Energy (DOE) and non-DOE reactors; 4) shipping test pins to and from test reactors; and 5) performing PIE of irradiated test pins.

The following discussion details INL efforts in support of TerraPower:

**Fuel Slug Fabrication Technology Development**

<u>Alloying, Casting and Preparation</u>
To support process development, INL researched methods to alloy, cast and prepare fuel. Alloying and casting is a combined process that uses DU. Two casting systems have been designed, fabricated and installed to enable fuel billet casting efforts--one in EFF and one in Fuel Manufacturing Facility (FMF).

The EFF casting system includes an induction furnace capable of reaching temperatures of at least 1450ºC (2642ºF), melting up to approximately 3 kilograms of uranium, and casting a single fuel billet at a time. The system is comprised of induction coils, molds, power supplies, controllers, vacuum pumps, etc., and is installed in a fume hood in EFF.

Design of the FMF casting system is identical to the EFF casting system, however it is installed in the Special Nuclear Material (SNM) glovebox in the FMF south workroom.

The following discussion details the casting systems:

*Benchtop-scale Casting System (BCS)*
A subset of test fuel pins will be made using the prototypic Experimental Breeder Reactor-II (EBR-II)/Fast Flux Test Facility (FFTF) Vacuum Induction Melting (VIM)/injection casting method. To improve the quality of the cast product, the BCS-II may need to be moved from a radiological hood to a glovebox to better control oxidation of the melt. Modification and development of a process to alloy and cast fuel slugs that replicates the historic EBR-II/FFTF casting method will be evaluated.

*Engineering-scale Casting System (ECS)*
An engineering-scale casting system (ECS) will be designed and installed at MFC. Equipment will be manufactured and installed at MFC. Pre-operational inspections and testing, followed by casting experiments aimed at developing a fuel fabrication process will also be performed.

*Reusable Mold/Crucible Development*
Several ceramics show promise for use as coating materials applied on refractory metal and graphite substrates. Refractory metal book molds and test coupons would be fabricated; Coupons would be coated with candidate ceramic materials, and casting would be repeated under prototypic conditions to demonstrate viability of the coatings. After each casting run, the mold coating will be inspected for coating integrity. The castings will continue until coating failure (e.g., cracking, delamination, chemical interaction with fuel melt, etc.) or up to a number that demonstrates adequate reusability. After the final casting, molds and coupons will be destructively examined. Representative sections will be mounted and characterized using optical microscopy and Energy Dispersive X-ray Spectroscopy (EDS) or Electron Probe Micro-Analyzer (EPMA). Coated and uncoated graphite molds/coupons may be evaluated in a similar fashion for a baseline comparison. Development of crucible coatings could be conducted based on the initial viability study of the mold.

<u>Fuel Slug Characterization</u>
Fuel slugs will be characterized to verify the manufacturing process meets target specification.

**Fuel Pin Fabrication Development**:

Fuel fabrication experiments will be performed develop a suitable fabrication process. Experiments will be designed to address the following key features of the process and product:

- Uranium Oxidation
- Fuel Diameter
- Fuel Straightness
- Fuel Surface Condition
- Fuel Grain Size and Orientation.

<u>Heat Treatment Development</u>
Certain fabrication methods impart a preferred orientation in the fuel microstructure. An effective heat treatment for fuel that will give fine, equiaxial grains will be developed. A range of heat treatments on surrogate fuel of varying texture will be performed to identify and select a preferred process. Confirmatory testing and characterization will also be performed on prototypic fuel slug forms.

Baseline fuel microstructure will be characterized before heat treating, at intermediate processing points, and after the full heat treatment. The primary characterization of interest includes the grain size (via optical microscopy or scanning electron microscope [SEM]) and texture (via x-ray diffraction [XRD] or Electron Backscatter Diffraction [EBSD]). The necessary analytical techniques to conduct this task will be developed.

<u>Fuel Pin Fabrication Development</u>
The capability to bond metallic fuel, perform end cap welding, and wire wrapping to support fabrication of fuel pins will be developed. Equipment fabrication, procurement, and installation in EFF will occur as part of this task.

*Test Fuel Pin Fabrication*
Test fuel pins will be fabricated for irradiation to evaluate TerraPower's fuel designs. Approximately 50-100 test pins, measuring from one inch to five feet in length, will be fabricated using approximately 12 Kg of Department of Energy (DOE) highly enriched uranium (HEU) of varying enrichments. DOE will own and have responsibility for the HEU and test fuel pins at all times.

*Ship Unirradiated Test Fuel Pins to Test Reactor*
Unirradiated test fuel pins will be shipped from MFC for irradiation. Irradiation is currently planned to be performed in the BOR-60 reactor in Dimitrovgrad, Ulyanovsk region, 433510, Russia. Shipping containers that are compliant with Department of Transportation (DOT) and/or International Atomic Energy Agency (IAEA) or other international regulations are needed for the shipments. Appropriate shipping containers will be evaluated, procured or leased, and licenses, certifications, etc., may be modified as necessary to enable shipping of the test fuel pins to the test reactor. Ports considered for shipping will be limited to those analyzed in the FRR EIS and ROD (DOE/EIS-0218).

*Ship and Receive Irradiated Test Fuel Pins*
Test fuel pins will be shipped from the test reactor back to MFC after irradiation. Return shipping may require up to 20 shipments. Testing is currently planned for the BOR-60 reactor in Russia. Shipping containers that are compliant with DOT and/or IAEA or other international regulations are needed for the shipments. Appropriate shipping containers for the shipments will be evaluated and procured or leased and licenses, certifications, etc., will be modified as necessary to enable shipping of the irradiated test fuel pins from the test reactor to MFC.

*Post-Irradiation Examination of Irradiated Test Fuel Pins*
Irradiated test fuel pins will undergo post-irradiation examination (PIE) at various MFC facilities including the Hot Fuel Examination Facility (HFEF), Analytical Laboratory (AL), Electron Microscopy Laboratory (EML), and the Irradiated Materials Characterization Laboratory (IMCL). PIE will include various typical non-destructive and destructive examinations. These activities are consistent with the current missions of these facilities.

<u>Metallic Fuel Bonding</u>
Fuel pins will employ a fuel and sodium (Na) bond. The Na-bonding process development may occur at the EFF or TerraPower facility. If the latter, process procedures, requirements and specifications will be transferred to INL, and equipment will be installed, inspected and tested in EFF. Verification testing (and subsequent inspection) with DU to verify the Na-bonding process would also occur. Inspection could include radiography, eddy-current testing, ultrasonic testing, and destructive evaluation (e.g., clad stripping). With successful verification testing, the process will be considered ready for fuel pin fabrication.

<u>End Cap Welding</u>
End cap welding equipment will be installed in an inert glovebox or enclosure in EFF, and pre-operational inspections and testing of equipment will be performed. Operating procedures will also be developed. The process will be considered ready for fuel pin fabrication upon successful verification testing.

<u>Wire Wrapping</u>
Fabrication, procurement, and installation of all required equipment in EFF to enable wire wrapping of fuel pins will be performed.

**Advanced Fuel Fabrication Development**
General methods, tooling, equipment set points, materials, and process parameters necessary to manufacture TerraPower's advanced fuel forms will be evaluated. Specific areas of manufacturing development include those identified in the following subtasks:

- Billet alloying & casting: Depleted uranium fuel billets will be prepared to support extrusion process development using INL's vacuum induction melting (VIM) and gravity casting system, and a suitable alloying and casting technique will be developed.

- Billet machining & preheating: An inspection technique and a preparation method consisting of sectioning, facing, turning, grinding, and other machining operations to create fuel billets with required geometry will be developed. Prior to extrusion, billets are preheated to extrusion temperature. Appropriate billet preheat materials and methods and any associated tooling will also be identified

- Extrusion: Extrusion experiments will be performed to establish and define the fabrication process for advanced fuel slug forms.

- Post-extrusion Straightening / Drawing / Sectioning / Cleaning / Gun Drilling: Post-extrusion straightening, drawing, sectioning, gun drilling and cleaning methods will be developed.

- Fuel Slug Heat Treatment: An effective heat treatment for advanced fuel forms, preferably anneal and quench, will be identified. The heat treatment parameters and experimental matrix, duration of heating at specified temperatures, quenching medium, number of quench cycles, and annealing conditions will also be defined by performing a range of heat treatments on extruded fuel to identify and select the optimum process.

  The necessary analytical techniques to conduct characterization of baseline fuel microstructure before heat-treating, at intermediate processing points, and after the full heat treatment via optical microscopy or SEM, and texture via X-Ray Diffraction (XRD) will be developed.

- Advanced fuel pin loading and bonding: Advanced fuel forms require new techniques for loading and bonding fuel to the cladding, therefore, a variety of loading and bonding techniques will be evaluated.

- Characterization: Characterization of billets and the extruded fuel slugs will provide verification that the manufacturing process meets target specification for the advanced fuel forms. Proposed examinations include visual, dimensional, chemistry, metallography, density, surface finish, and hardness.

  For optical metallography of billet and fuel slug samples, the unique capabilities of the Y-12 National Security Complex may be needed. Samples will be packaged and shipped Y-12.

**Storage and Disposition of Irradiated Test Fuel Pin Segments and PIE Remnants**:
After PIE, the irradiated test pin segments and PIE remnants will be stored with other similar DOE-owned irradiated materials and experiments at MFC, most likely in the HFEF or the Radioactive Scrap and Waste Facility (RSWF) in accordance with DOE's Programmatic SNF Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs FEIS and ROD (DOE/EIS-0203, 1995) and supplemental analyses (DOE/EIS-0203-SA-01 and DOE/EIS-0203-SA-02) and the Amended Record of Decision (February 1996). Ultimate disposal of the irradiated test pin segments and PIE remnants will be along with similar DOE-owned irradiated materials and experiments currently at MFC. Irradiated sample debris and secondary waste could total as much as 20-30 Kg.

Packaging, repackaging, transportation, receiving, and storing used nuclear fuel and research and development for used nuclear fuel management is covered by DOE's Programmatic Spent Nuclear Fuel (SNF) Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement and Record of Decision (DOE/EIS-0203, 1995) and supplemental analyses (DOE/EIS-0203-SA-01 and DOE/EIS-0203-SA-02) and the Amended Record of Decision (February 1996). The analysis includes those impacts related to transportation to, storage of, and research and development related to used nuclear fuel at the INL (see Tables 3.1 of the SNF Record of Decision (May 30, 1995) and Table 1.1 of the Amended Record of Decision [February 1996]. The EIS limits the number of shipments to the INL, and the proposed activities would fall within the limits of the EIS.

Furthermore, the Final Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel (FRR EIS DOE/EIS-0218) (DOE 1996), DOE developed and implemented a systematic process for selecting ports of entry for spent nuclear fuel. Information needed to evaluate ports and port activities, and the potential environmental impacts (incident-free and accidents) associated with the receipt of foreign research reactor spent nuclear fuel from vessels were collected and evaluated. In the Final FRR EIS, DOE considered the environmental consequences associated with shipment of foreign research reactor SNF on the oceans and along representative rail and highway transportation routes between United States ports of entry and the interim spent fuel management sites at the Savannah River Site and the INL. The analysis in the EIS is based primarily on the number of individual elements of foreign research reactor spent nuclear fuel that could be accepted, and when appropriate, also uses mass of heavy metal and volume. The amount of foreign research reactor SNF that could be accepted under the analysis in the EIS is approximately 19.2 MTHM, with a volume of approximately 110 m3 (4,100 ft3), representing approximately 22,700 individual spent nuclear fuel elements (DOE/EIS-0218 p. 2-6).

In 2004, DOE revised the FRR ROD to allow acceptance of eligible SNF until May 12, 2016, for irradiation of eligible fuel, and until May 12, 2019, for fuel acceptance. Presently, DOE has received 22 shipments at the INL of non-aluminum clad foreign research reactor

SNF from the east coast. Assuming the most conservative scenario, which consists of completing only 107 east coast shipments as identified in the FRR EIS, DOE can still complete 85 additional shipments of foreign research reactor SNF from the east coast. Based on current planning, DOE anticipates less than 20 additional shipments of FRR non-aluminum SNF before the Foreign Research Reactor Program expires in 2019. When combined with the 20 shipments included in the proposed action, DOE would still be able to complete 45 additional shipments after all anticipated FRR shipments are complete. Project activities, as described below in this EC for shipping and receiving 50-100 test pins to and from the Russian reactor in up to 20 shipments, are within the range of activities and quantities of foreign research reactor SNF analyzed in the FRR EIS (DOE/EIS-0218), revised RODs, and supplemental analyses. Implementation of the proposed action would not cause the overall total quantity of FRR SNF projected to be received under the FRR SNF Acceptance Program to exceed the estimates in the FRR SNF EIS.

The potential for transportation accidents has already been analyzed in the SNF EIS (Section 5.1.5 and Appendix I-5 through I-10) and in the FRR EIS (Sections 4.2.1 and 4.2.2).

## SECTION C. Environmental Aspects or Potential Sources of Impact:

### Air Emissions

The total greenhouse gas emissions for the shipments, along with those already received, would be approximately 96.6 tons.

Radiological emissions and emissions from chemical use would be generated.

### Generating and Managing Waste

Industrial Waste Generation and Management: Project activities would likely result in the generation of small amounts of industrial waste.

Hazardous/Radioactive Material or Waste Handling and Transportation: Project personnel will work with Waste Generator Services (WGS) to properly package and transport regulated, hazardous or radioactive material or waste according to laboratory procedures.

Low-Level Waste Generation: Personal Protective Equipment (PPE) and towels used for cleaning and polishing are estimated at ~0.056 m3 per week.

TRU Waste: Irradiated sample debris and PIE waste are expected to generate TRU waste and mixed TRU waste. Irradiated sample debris and secondary waste could total as much as 20-30 kg. Project personnel would work with WGS to characterize and properly dispose of all waste.

### Releasing Contaminants

All chemicals utilized by the project would be managed in accordance with laboratory procedures.

### Using, Reusing, and Conserving Natural Resources

All materials would be reused and recycled where economically practicable. All applicable waste would be diverted from disposal in the landfill where conditions allow.

## SECTION D. Determine Recommended Level of Environmental Review, Identify Reference(s), and State Justification:

Identify the applicable categorical exclusion from 10 Code of Federal Regulation (CFR) 1021, Appendix B, give the appropriate justification, and the approval date.

For Categorical Exclusions (CXs), the proposed action must not: (1) threaten a violation of applicable statutory, regulatory, or permit requirements for environmental, safety, and health, or similar requirements of Department of Energy (DOE) or Executive Orders; (2) require siting and construction or major expansion of waste storage, disposal, recovery, or treatment or facilities; (3) disturb hazardous substances, pollutants, contaminants, or Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)-excluded petroleum and natural gas products that pre-exist in the environment such that there would be uncontrolled or unpermitted releases; (4) have the potential to cause significant impacts on environmentally sensitive resources (see 10 CFR 1021). In addition, no extraordinary circumstances related to the proposal exist that would affect the significance of the action. In addition, the action is not “connected” to other action actions (40 CFR 1508.25(a)(1) and is not related to other actions with individually insignificant but cumulatively significant impacts (40 CFR 1608.27(b)(7)).

**References:** Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement and Record of Decision (DOE/EIS-0203, 1995) and supplemental analyses (DOE/EIS-0203-SA-01 and DOE/EIS-0203-SA-02) and the Amended Record of Decision (1996).

Final Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel and Record of Decision (DOE/EIS-0218, 1996) and supplemental analyses (DOE/EIS-0218-SA-01, DOE/EIS-0218-SA-02, DOE/EIS-0218-SA-03, and DOE/EIS-0218-SA-04) and the Revised Record of Decision (2004).

**Justification:** The proposed R&D activities are consistent with CX B3.6 "Siting, construction, modification, operation, and decommissioning of facilities for small-scale research and development projects; conventional laboratory operations (such as preparation of chemical standards and sample analysis); small-scale pilot projects (generally less than 2 years) frequently conducted to verify a concept before demonstration actions, provided that construction or modification would be within or contiguous to a previously disturbed area (where active utilities and currently used roads are readily accessible). Not included in this category are demonstration actions, meaning actions that are undertaken at a scale to show whether a technology would be viable on a larger scale and suitable for commercial deployment."

For the research and development activities on the INL Site, similar activities—e.g. test specimen fabrication and post irradiation examinations (PIE)—have been conducted at the INL Site for years, and those operations have been managed safely. The primary mission of the Material and Fuels Complex at the INL is to conduct both fabrication and PIE. These activities are a part of the laboratory's conventional operations for a wide variety of public and private clients. As part of this work, waste disposal paths have been identified and are available for all potential waste streams resulting from this project. Further, this project constitutes neither a significant addition to nor unique change from current or historical operating conditions at the INL. As a result, overall waste generation and air emissions estimates for the INL are not anticipated to change.

Although the project is a conventional R&D activity for the INL under B3.6, the DOE-ID NCO considered existing analysis to ensure that all aspects of the project were covered. The NCO examined the analyses in the Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement (1995 PSNF EIS) and the Final Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel (FRR EIS) and their associated supplement analyses and their respective Records of Decision when considering the potential impacts associated with transportation of the irradiated test specimens and transportation in the global commons.

While the research test specimens are not spent nuclear fuel, they are similar in environmental hazards, except the test specimens contain less radiological material than a normal spent nuclear fuel shipment. Therefore, the potential environmental impact of transportation of the test specimens can be conservatively estimated to be equal to or less than a spent nuclear fuel shipment. In Appendix I of the 1995 PSNF EIS, DOE presented a summary of the estimated transportation impacts of 170 shipments of Foreign Research Reactor (FRR) SNF to the INL Site (Table I-2 and Table I-8). The FRR EIS contained the environmental impacts of transporting 162 shipments of non-aluminum clad SNF and included marine transport, port of entry operations, and ground transportation (Sections 4.2.1, 4.2.2, 4.2.3 and Appendix E). The potential for transportation accidents to the INL was analyzed sufficiently in the 1995 PSNF EIS (Section 5.1.5 and Appendix I-5 through I-10) and in the FRR EIS (Sections 4.2.1 through 4.2.2).

Finally the NCO noted that in the record of decision for the 1995 PSNF EIS, DOE determined and stated "the evaluated potential impacts resulting from all alternatives were found to present no significant risk to potentially affected populations." Based on DOE's statement for the entire DOE SNF program, the NCO determined the proposed action would not have the potential for significant impact or have any unique or unknown risks.

Based on the scope of the project and the existing analyses that DOE has conducted, the DOE-ID NCO concluded that this activity falls within categorical exclusion B3.6, and no additional NEPA reviews are necessary at the present time.

Is the project funded by the American Recovery and Reinvestment Act of 2009 (Recovery Act) ☐ Yes ☒ No

Approved by Jack Depperschmidt, DOE-ID NEPA Compliance Officer on: 11/16/2016