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Advanced Reactors Spent Fuel & Waste Science and Technology Program

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Changing the World's Energy Future

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Advanced Reactor Spent Fuel and Waste Science and Technology Program - 24317

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ABSTRACT

Due to increased interest in advanced reactor deployment for potential new fuel cycles, the Spent Fuel and Waste Science and Technology (SFWST) program has begun to evaluate the possible implications of long-term management and final disposition of spent nuclear fuel (SNF) generated by potential advanced reactors. Safely managing and dispositioning of this potential SNF, along with any other associated radioactive wastes, is the primary focus of this initial preliminary assessment. The present paper summarizes three primary tasks that the SFWST program is currently executing (or collaborating on)—tasks related to the back end of the nuclear fuel cycle (BENFC) for potential advanced reactors.

1. Advanced Reactor SNF and Waste Streams: Strategies for the BENFC

This set of activities defines a high-level strategy for systematically approaching, identifying, and closing R&D gaps/issues associated with long-term management and final disposition of advanced reactor SNF and other possible advanced reactor waste streams. This task involves summarizing various advanced reactor concepts and the SNF and other waste forms they are likely to produce, then identifying previous experience pertaining to similar waste materials (e.g., experience related to Department of Energy [DOE]-managed SNF whose characteristics closely align with those of the potential advanced reactor SNF). This enables the identification of technical R&D gaps that exist between our detailed understanding of safe storage, transportation, and disposal techniques for the existing light-water reactor (LWR) SNF fuel cycle and the potential advanced reactor fuel cycles.

2. Characterization and Packaging Options for Advanced Reactor SNF

This set of activities is aimed at evaluating the characteristics and packaging options for advanced reactor SNF forms, which are categorized into three types: (1) tristructural isotropic (TRISO), (2) metallic, and (3) fuel salt. Focus is placed on TRISO and metallic SNF, as well as on other waste streams from such advanced reactors, due to the near-term anticipated demonstrations of the Xe-100 and Natrium advanced reactors. Preliminary information on the spent fuel salt discharged from molten-salt reactors (MSRs) is examined to provide a baseline for future efforts. All calculations and assumptions in this work were based on publicly available information.

These activities enabled calculation or estimation of the following characteristics in support of the preliminary assessment SNF volume and mass, radiation/activity levels over time, thermal conditions over time, potential radionuclide source terms, chemical interactions and evolutions, disposal inventories, and waste form lifetimes. Based on those characteristics, calculations were performed to determine the applicability of existing canister designs. These evaluations included geometric (e.g., dimension, volume) and mass/weight considerations, known operational approaches and loading procedures, physical and chemical considerations/conditions for storage environments, and as-loaded radiation, thermal, and criticality analyses to identify constraints on storage, transportation, and disposal.

3. Back-End Management of Advanced Reactors (BEMAR)

DOE Office of Spent Fuel and Waste Disposition members chair an integrated project team to evaluate the feasibility and potential of managing waste forms generated by advanced reactors. This integrated project team, called the Back-End Management of Advanced Reactors (BEMAR), includes DOE staff from a range of organizations within the Office of Nuclear Fuel Cycle and Supply Chain, Office of Reactor Fleet and Advanced Reactor Deployment, Office of Clean Energy Demonstrations, and Office of Assistant General Counsel for Civilian Nuclear Programs. It also includes national laboratory technical staff within the Spent Fuel and Waste Disposition Program (NE-81 and NE-82). BEMAR works directly with advanced reactor developers to procure information on the (often proprietary) characteristics of SNF and other waste forms. These characteristics aid in determining the feasibility of storage, transportation, and disposal of advanced reactor SNF. BEMAR is also tasked with developing rough-order-of-magnitude cost estimates for the waste management system for advanced reactor SNF. To accomplish these tasks, BEMAR is implementing a systems engineering approach.

INTRODUCTION

Over the past decade, interest in advanced nuclear reactors has increased, and new advanced reactors that utilize different fuel forms are expected to become operational by 2030. As new fuel cycles and reactor concepts are designed and developed, new challenges arise in regard to managing the spent nuclear fuel (SNF) being generated. Effective SNF management is paramount to a functioning fuel cycle, and to maintaining public trust in nuclear energy.

In 2018, Congress passed the Nuclear Energy Innovation Capabilities Act of 2017 (Public Law 115-248), enabling both private and public institutions to conduct civilian R&D regarding advanced nuclear energy technologies in order to expand the theoretical and practical understanding of nuclear physics, chemistry, and materials science.

In its fiscal year 2020 budget, Congress appropriated $230 million to launch the Advanced Reactor Demonstration Program (ARDP) which provided funding to advanced reactors of various designs and levels of maturity [1]. The Bipartisan Infrastructure Law then increased funding for ARDP by nearly $2.5 billion via a cooperative agreement to fund one large demonstration reactor from X-energy and one from TerraPower [2]. Even though the ARDP awardees vary in terms of reactor concept, technological maturity, and anticipated scope, they represent only a fraction of the many advanced reactor concepts and designs being pursued around the world. Figure 1 shows the different ARDP award winners.

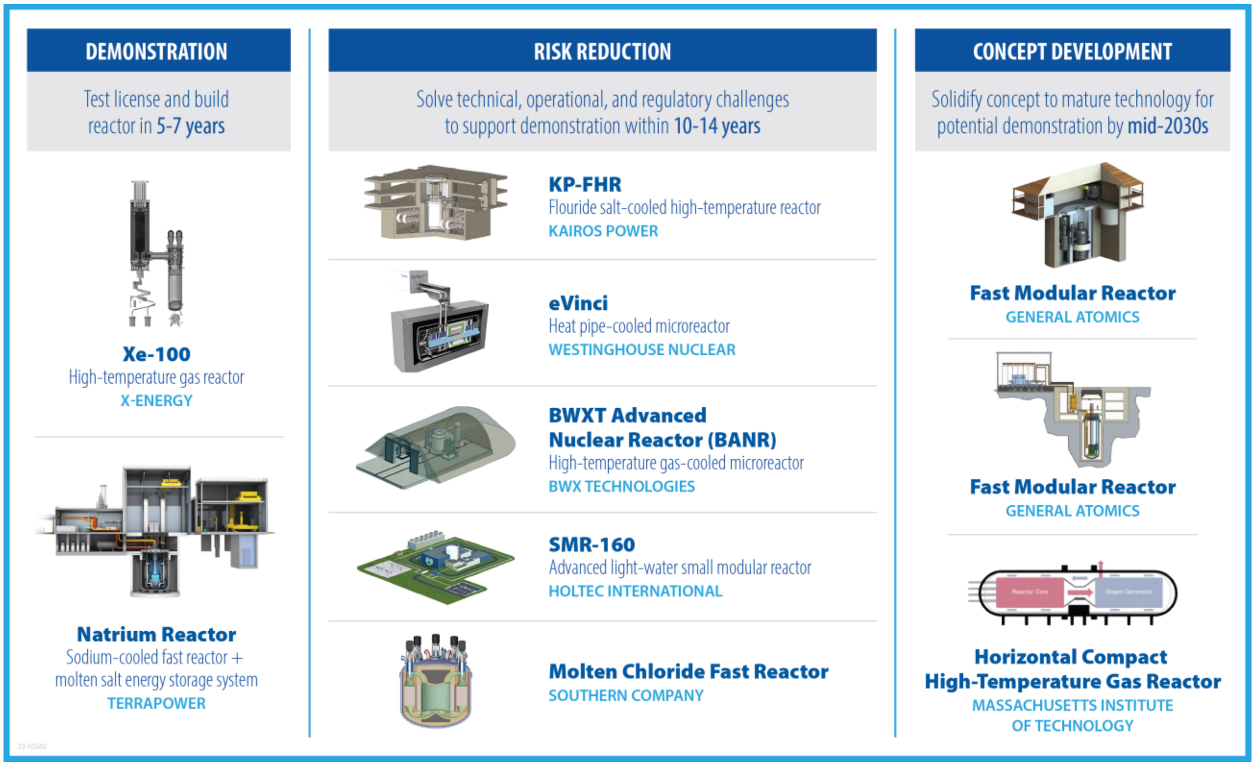

Figure 1. ARDP award winners.

The National Reactor Innovation Center and the Gateway for Accelerated Innovation in Nuclear, both headquartered at Idaho National Laboratory, actively support the construction and demonstration of advanced reactors. These programs provide commercial vendors with the facilities and research staff for performing the R&D necessary to clear all technical, regulatory, and financial hurdles preventing innovative advanced nuclear technologies from moving forward. However, the primary goals of these programs do not include understanding the post-discharge management of SNF and other waste streams.

To close the knowledge gaps that exist in managing waste streams from advanced reactor technologies, the Office of Spent Fuel and Waste Science and Technology (SFWST) sponsored a study by the National Academies of Sciences, Engineering, and Medicine for evaluating the merits and viability of different nuclear fuel cycles, emphasizing the back end of the nuclear fuel cycle (BENFC) [3]. In addition to this funded effort, SFWST is evaluating, via the following three primary tasks, the feasibility of long-term storage, transportation, and eventual disposition of advanced reactor SNF:

1. Advanced Reactor SNF and Waste Streams: Strategies for the BENFC
2. Characterization and Packaging Options for Advanced Reactor SNF
3. Back-End Management of Advanced Reactors (BEMAR).

The present paper serves to summarize these three primary tasks that the SFWST Program is executing (or collaborating on) in regard to the BENFC of potential advanced reactors.

ADVANCED REACTOR SNF AND WASTE STREAMS: STRATEGIES FOR THE BENFC

This task is detailed in "Advanced Reactors Spent Fuel and Waste Streams Disposition Strategies" which identifies gaps and outlines areas in which further research would contribute to a well-defined disposition pathway for potential advanced reactor SNF and associated additional waste streams. Through doing so, a high-level strategy was generated via the following actions:

- Survey the range of advanced reactor SNF and associated waste streams in order to classify advanced reactor fuels and waste into groups.
- Collate and evaluate previous experience pertaining to existing analogous SNF.
- Identify technical gaps related to storage, transportation, and disposal of advanced reactor SNF and other waste forms.

After surveying the wide range of advanced reactor designs, the associated waste streams were categorized under four primary fuel types: tristructural isotropic (TRISO) fuel, metallic fuel, molten salt reactor (MSR) fuel salt, and accident-tolerant fuel (ATF) from light-water reactors (LWRs). In addition to the SNF stemming from these advanced reactors, other products such as low- and high-level waste were also examined. After identifying potential waste streams, legacy fuels with characteristics similar to those of advanced reactor fuels were identified to garner experience in the area of SNF management.

The United States has experience in managing the waste streams from several reactors that utilized exotic fuels similar to those envisioned for advanced reactors. Coated particle fuel (a TRISO variant) contained in a graphitic matrix was used to power the Peach Bottom Unit 1 and Fort Saint Vrain reactors. The N-Reactor at the Hanford Site produced a significant amount of metallic fuel, whereas Experimental Breeder Reactor (EBR)-II at Idaho National Laboratory incorporated sodium between the fuel and the cladding, creating a distinctive metallic SNF sub-type: sodium-bonded SNF. Previous experience with MSR operations is limited to the MSR Experiment (MSRE), which operated from June 1965 to December 1969 before being permanently shut down. The MSRE was a graphite-moderated, liquid-fueled reactor that used a fuel formed by dissolving UF_4 fuel in a carrier salt composed of a mixture of LiF, BeF_2, and ZrF_4 [5]. Both TRISO and metallic SNF have been stored and transported, and were included by reference in the license application for the previous repository concept. However, very limited experience has been attained in terms of effectively managing spent fuel salts.

This task identified a number of key findings, some of which are highlighted below:

- Based on a survey of reactor types, three fuel types are the most common: TRISO, metallic containing sodium, and fuel salt. Of these, literature review and analysis indicate TRISO to be the only advanced reactor fuel with a clear pathway for direct disposal, though fuel salt waste disposal may be possible in certain repository design concepts. Sodium-bonded metallic SNF were not accepted in the previous repository and will likely need to be processed and/or treated, as the metallic sodium bond reacts violently with water. This presents disposal hazards as well as potential storage and transportation issues.
- Though TRISO fuel has a clear direct disposition pathway, U.S. experience with TRISO fuel is related to prismatic TRISO from the Fort Saint Vrain reactor. Furthermore, some emerging commercial concepts employ TRISO pebbles in a pebble-bed reactor. Fuel compacts removed from the prismatic block may necessitate further analysis, especially with respect to safeguards/security and packaging/handling. TRISO from a pebble-bed MSR may also experience an ingress of salt into the graphite/coated particle matrix, potentially warranting additional investigation in this area.

- Many commercial designs plan to use high-assay low-enriched uranium (HALEU) fuel (with an enrichment of 5%–19.75%), which will generally be used to a higher burnup than traditional LWR fuels. This has implications across the BENFC in terms of SNF storage, transportation, and disposal, as higher thermal loads tend to accelerate degradation mechanisms. Notable implications for criticality safety are also associated with HALEU.
- ATFs are generally expected to be equally—or even somewhat more—robust in comparison to standard LWR fuels when placed in the disposal environment. However, ATF thermal and mechanical properties are sufficiently different to warrant further analyses, especially in regard to the impacts on storage and transportation. The extra elements added to ATFs could potentially affect the near-field geochemistry in the disposal setting. Due to the variety of ATFs, scoping studies must be conducted on a case-by-case basis to assess the BENFC.

Lastly, this work determined a strategy for systematically analyzing advanced reactor waste streams in order to ensure safe, effective SNF management. The path forward includes developing a more detailed gap and features, events, and processes analysis to guide future R&D efforts.

CHARACTERIZATION AND PACKAGING OPTIONS FOR ADVANCED REACTOR SNF

This task is detailed in the report "Storage, Transportation, and Disposal of Advanced Reactor Spent Nuclear Fuel and High-Level Waste" [6]. The scope of this task emphasizes TRISO and metallic SNF and their associated waste streams, due to the near-term anticipated demonstrations of the Xe-100 and Natrium advanced reactors. However, it also provides preliminary information on the spent fuel salts discharged from MSRs, affording a baseline upon which future efforts can build.

The specifics pertaining to SNF and other waste streams are still being determined by many commercial reactor vendors, as assumptions regarding fuel materials, burnups, and enrichments continue to evolve. The present work utilized publicly available information to ascertain general characteristics of advanced reactor waste streams in different fuel categories. It also identifies multiple reactor types that utilize each fuel type, and highlights possible differences that could affect the back-end management of SNF and other waste streams between reactors that use the same fuel type. The following characteristics were calculated or estimated: SNF volume and mass, radiation levels over time, thermal conditions over time, potential radionuclide source terms, chemical interactions and evolutions, disposal inventories, and waste form lifetimes.

Based on these estimated characteristics, calculations were performed to determine the applicability of existing canister designs. These evaluations included geometric (e.g., dimension, volume) and mass/weight considerations; known operational approaches and loading procedures; physical and chemical considerations/conditions for storage environments; as-loaded radiation, thermal, and criticality analyses to identify constraints; and the flexibility and compatibility of each cannister in order to identify disposal safety considerations. Additionally, modifications were analyzed to support extended dry storage and transportation capabilities. The selected modifications were evaluated based on criticality and/or thermal concerns. Material compatibility was also of concern, as advanced reactor fuel types differ substantially from existing LWR SNF already contained in dry storage systems.

This paper also provides a literary review and analysis of storage, transportation, and disposal evaluations and the experience gained from relevant non-LWRs that operated in the past. Finally, it provides preliminary concepts of operation for advanced reactor SNF. This includes storage, transportation, potential treatment, and disposal activities from both a micro and a systems-integration perspective. The following subsection provides conclusions from the analyses detailed in "Storage, Transportation, and Disposal of Advanced Reactor Spent Nuclear Fuel and High-Level Waste" [6].

TRISO Fuel

Preliminary analyses suggest that dry storage and transportation of TRISO SNF from advanced reactors can be safely performed per the current regulatory frameworks for dry storage (10 CFR 72) and transportation (10 CFR 71). Development of a database of SNF material properties and a basis for potential in-reactor and post-discharge failure rates remains an important area of R&D work for supporting system and package designs and understanding age-related degradation phenomena that could impact content configuration assumptions.

Based on the desirable characteristics of TRISO SNF, all disposal concepts are amenable to TRISO SNF, thanks to the low corrosion rates of TRISO particle coatings under both dry and wet conditions. Disposal of TRISO-based SNF was included in the disposal plan for Yucca Mountain. The safety analysis for Yucca Mountain concluded that the introduction of water would not significantly increase the reactivity of graphite in TRISO SNF [7]. This should be confirmed based on the design of new advanced reactor TRISO SNF and packaging options (e.g., disposal with or without graphite blocks), as well as on the geology and expected chemical environment (i.e., reducing or oxidizing) of any proposed repository. TRISO SNF is likely to meet long-term standards for potential disposal options, without the need for additional engineered barrier system components. However, additional research is needed to study the long-term performance and stability of TRISO SNF particles and the graphite-based compacts and block elements.

The primary challenge regarding TRISO SNF is the volume of waste generated. It is estimated that TRISO-fueled reactors will discharge 10–25 times more SNF than do LWRs per unit of power produced. This is primarily because the graphite moderator is included as part of the SNF form. Chemical or mechanical recovery of the graphite has been examined, but the level of contamination of the recovered graphite is unclear. If the activity is too high, disposition of the graphite as low-level waste will be infeasible.

Metallic Fuel

Preliminary analyses of metallic focused on SNF from TerraPower and GE-Hitachi's Natrium reactor either with internal sodium or without sodium. Both fuel types will contain HALEU; however, most design details pertaining to the Natrium Demonstration rector (Demo) are proprietary. Publicly available information [8, 9, 10] indicates that the metallic fuel assemblies will be ~470 cm long, with a maximum cross-sectional dimension of ~18.5 cm. The fuel assembly, which includes an upper handling fixture (assumed to be 31 cm long) and a lower nosepiece (assumed to be 33 cm long), is too tall to fit in most commercial storage or transport canisters; however, it would fit inside a typical pressurized-water reactor (PWR) basket space (22.7 by 22.7 cm) within a large multi-purpose canister.

To perform storage, transport, and disposal analyses, the Natrium core, assembly, and fuel pin parameters assumed by Kim [11] were employed. Kim based his assumptions on a revised PRISM/MOD-B design in order to develop a consistent set of parameters that would lead to a fuel burnup of about 150 GWd/MTU. Kim demonstrated that, 10 years after reactor discharge, the Natrium SNF would result in lower fuel mass, fuel volume, decay heat, activity, and radiotoxicity (per GWe-year) relative to a conventional PWR. These same parameters were used in the present work to perform criticality, dose rate, and thermal analyses.

The characteristics of the metallic SNF used in this evaluation do not impose any technical constraints related to the structural, thermal, or dose rate parameters for the packages considered. However, criticality could present a problem if no burnup credit is received and the basket fails to maintain effective spacing between elements. This is because of the high fissile loading contained within a metallic element. Increasing the loading density could change the results of these analyses, and thermal/dose considerations may become a larger obstacle.

Fuel failure was analyzed for a single fuel pin operated at the core's average power level. One potential cladding degradation mechanism is the fuel-cladding chemical interaction (FCCI), which produces an inner-cladding brittle zone from which a softer cladding zone extends outward. To reduce the FCCI to an acceptable level during storage, the peak cladding temperature should be set at 400°C (i.e., the Nuclear Regulatory Commission's limit for LWR SNF) until further investigation has been performed.

Storage and transport experiences and lessons learned were reviewed in regard to metallic fuel irradiated in EBR-II, the Fast Flux Test Facility, and the N-Reactor, as well as in regard to management of sodium-bonded SNF from EBR-II and FERMI 1. Experience indicates that residual coolant sodium can be removed from the cladding outer surface to an acceptable level, and a canister containing metallic fuel assemblies can likely be dried to an acceptable level via hot-vacuum drying.

However, the internal sodium bonded within cladding of the SNF is much more difficult to remove with superficial processes and could require a much more extensive treatment option. One such treatment method is termed electrometallurgical treatment (EMT) which generates a uranium product and two waste forms: a ceramic waste form and a metallic waste form. The EMT process is being used on sodium-bonded EBR-II and FFTF fuels at Idaho National Laboratory.

Fuel Salt

Preliminary analyses of the technical constraints related to the transport and dry storage of MSR SNF from advanced reactors focuses on once-through U-Pu fuel cycles. These fuel cycles correspond to the MSR concepts identified by the U.S. Nuclear Reactor Commission; however, changing the salt from chloride to fluoride or the spectrum from thermal to fast can generate significantly different results. Due to the water-soluble nature of the salts, MSR waste will likely need to be converted into a more stable waste form(s). Several waste forms were surveyed in Storage, Transportation, and Disposal of Advanced Reactor Spent Nuclear Fuel and High-Level Waste [6], with the technology readiness level ranges being listed for each, based on the available knowledge. Furthermore, a number of additional waste forms, including radioisotopes such as ^{137}Cs produced from trapped fission gases, will arise from scrubbers and filters.

Potential waste streams from in-development concepts were surveyed, but these concepts were insufficiently defined in the available materials to allow for many inferences to be made. Therefore, only scoping calculations were performed to examine how closely prototypic MSR waste approaches the design envelope of existing PWR SNF casks. The evaluated parameters included waste mass, radiation shielding, criticality, and decay heat rejection.

Cask capacity for fuel salt was found to be mostly dependent on fission product inventory, with existing casks being capable of handling the fission products generated by 750 GWd of thermal energy throughout the fuel's lifetime. For salts that have (or must be assumed to have) criticality potential, criticality safety controls may be necessary. Moderator exclusion is almost a must if burnup credit cannot be established for some salts. A likely mode of MSR operation is to add U as needed to maintain criticality under near-optimal conditions, meaning that criticality may be of no particular concern if a burnup credit formalism or fissile nuclide concentration determination is established.

It remains to be determined at what point in a waste management system the conversion from salt into one or more physiochemically stable waste forms can be accomplished. Furthermore, no consensus exists as to whether waste form conversion will be done at utility sites or a centralized facility. Quantities, rules, and heuristics are needed to credit burnup and low fissile composition for criticality. This may represent an extension of methodology at the site. Other quantities could perhaps be time averaged or determined based on something other than MTUs. Expected challenges going forward include the complexity of preparing to handle many different types of waste that may need stabilized prior to transportation. This is compounded by the fact that many of these waste forms are not fully defined. Water solubility, potential corrosion, and off-gas must all be considered prior to transporting halide wastes. Several MSR concepts include quasi-decadal primary system refurbishment, which will also need to be characterized and dealt with.

Concept of Operations

Preliminary concepts of operations were developed for TRISO, metallic, and MSR SNF, based on representative reactors that received ARDP awards. Operations were examined in the context of existing LWR SNF. Additionally, large-scale effects on an integrated waste management system were examined. One primary impact on the integrated waste management system is the volume of SNF generated. Table 1 compares the volume produced per year with the volume produced per MWe.

Table 1. Volume of waste produced, by reactor type [6].

	TRISO	Metallic	PWR	Boiling-water Reactor
Reactor Name	Xe-100	Natrium	Typical PWR	Typical boiling-water reactor
Power (MWe)	80	345	984	1002
Discharged Volume (m^3/yr)	7	1.8	9.1	10.6
Assumed Canister Volume (m^3/yr)	13	6.2	31.7	40.0
Discharged Volume (m^3/GWe)	85	5.2	9.2	10.6
Assumed Canister Volume (m^3/Gwe)	158	18	32.2	39.9

The volumes of SNF from TRISO-fueled reactors exceed those produced by LWRs (normalized to energy production), because the TRISO SNF form includes the moderator. Though not included in the comparison in Table 1 above, the volume of SNF produced by MSRs could be high, as an MSR’s coolant could be included as part of its SNF. Metallic SNF is expected to necessitate a smaller number of canisters than traditional LWR SNF. Furthermore, increasing the packaging efficiency by using neutron absorbers could further decrease the assumed canister volume for metallic SNF.

BEMAR

BEMAR is an integrated project team formed in 2022. Representatives from the DOE Office of Spent Fuel and Waste Disposition within the Office of Nuclear Energy chair a diverse collection of experts spanning several offices within the Office of Nuclear Energy, Office of General Counsel for Civilian Nuclear Programs, Office of Clean Energy Demonstrations, and include technical specialists from five national laboratories. BEMAR works directly with advanced reactor developers to assess for DOE the technical feasibility of storing, transporting, and disposing of advanced reactor SNF, based on the characteristics that the developers provide to DOE (much of which is proprietary). BEMAR is also tasked with developing rough-order-of-magnitude cost estimates for comparing the waste management system for individual advanced reactors to existing LWR management practices [12].

This task supports DOE in disposing of the nation's SNF and high-level waste—a responsibility assigned to DOE in the amended Nuclear Waste Policy Act of 1982 [13], which also prescribes various reactor licensing requirements:

> "(1) (A) The Commission shall not issue or renew a license to any person to use a utilization or production facility under the authority of section 103 or 104 of the Atomic Energy Act of 1954 (42 USC 2133,2134) unless–
>
> (B) such person has entered into a contract with the Secretary under this section; or
>
> (ii) the Secretary affirms in writing that such person is actively and in good faith negotiating with the Secretary for a contract under this section.
>
> (B) The Commission, as it deems necessary or appropriate, may require as a precondition to the issuance or renewal of a license under section 103 or 104 of the Atomic Energy Act of 1954 (42 USC 2133, 2134) that the applicant for such license shall have entered into an agreement with the Secretary for the disposal of high-level radioactive waste and spent nuclear fuel that may result from the use of such license." – Section 302 (b): (b) ADVANCE CONTRACTING REQUREMENT

The technical feasibility of different fuel forms can be assessed by implementing a systems engineering approach. While reactor and fuel characteristics may significantly deviate from one vendor to the next, the systems engineering approach creates consistency in the data received from reactor vendors, as well as in the products generated. It also affords strict information control for protecting propriety information [12].

BEMAR continues to meet with advanced reactor vendors in order to request physical characteristic, chemical composition, radionuclide inventory, and operations and waste management information. It then uses this information to assess the feasibility of SNF management practices and provide rough-order-of-magnitude cost estimates [12].

CONCLUSIONS

The SFWST program has begun to evaluate the possible implications of long-term management and final disposition of SNF generated by potential advanced reactors. Safely managing and dispositioning this potential SNF, along with any other associated radioactive waste forms, is the primary focus of this initial preliminary assessment. The SFWST program is currently executing (or collaborating on) three primary tasks related to the BENFC for potential future advanced reactors.

1. Advanced Reactor SNF and Waste Streams: Strategies for the BENFC

This set of activities defines a high-level strategy for systematically approaching, identifying, and closing R&D gaps/issues associated with long-term management and final disposition of advanced reactor SNF and other possible advanced reactor waste streams. This task involves summarizing advanced reactor concepts and the SNF and other waste forms they are likely to produce, then identifying previous experience pertaining to similar materials (e.g., experience related to DOE-managed SNF featuring characteristics closely related to those of potential advanced reactor SNF). This would enable identification of technical R&D gaps that exist between our detailed understanding of safe storage, transportation, and disposal techniques for the existing LWR SNF fuel cycle and the potential advanced reactor fuel cycles.

2. Characterization and Packaging Options for Advanced Reactor SNF

This set of activities is aimed at evaluating the characteristics and packaging options for advanced reactor SNF forms, which are categorized into three types: (1) TRISO, (2) metallic, and (3) fuel salt. Focus is placed on TRISO and metallic SNF, as well as on other waste streams from such advanced reactors, due to the near-term anticipated demonstrations of the Xe-100 and Natrium advanced reactors. Preliminary information on the spent fuel salt discharged from MSRs was examined to provide a baseline for future efforts. All calculations and assumptions in this work were based on publicly available information.

These activities enabled calculation or estimation of the following characteristics in support of the preliminary assessment: SNF volume and mass, radiation/activity levels over time, thermal conditions over time, potential radionuclide source terms, chemical interactions and evolutions, disposal inventories, and waste form lifetimes. Based on those characteristics, calculations were performed to determine the applicability of existing canister designs. These evaluations included geometric (e.g., dimension, volume) and mass/weight considerations, known operational approaches and loading procedures, physical and chemical considerations/conditions for storage environments, and as-loaded radiation, thermal, and criticality analyses to identify constraints on SNF storage, transportation, and disposal.

3. BEMAR

BEMAR, an integrated project team formed to evaluate the BENFC of advanced reactors, includes staff from a wide range of DOE offices and national laboratories. BEMAR works directly with advanced reactor developers to assess for DOE the technical feasibility of storing, transporting, and disposing of advanced reactor SNF, based on the characteristics provided by the developers. BEMAR is also tasked with developing rough-order-of-magnitude cost estimates for comparing the waste management system for individual advanced reactors to existing LWR management practices.

Both the Strategy and Characterization tasks were completed in 2023. However, new tasks related to performing a gap and features, events, and processes analysis have been identified for 2024. These tasks ensure that SFWST remains a part of a holistic approach to determining the feasibility of advanced reactors moving forward. BEMAR is continuing its mission into 2024.

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