APPENDICES

Appendix A: Work Scopes for U.S. University-led R&D Projects

Appendix B: Work Scopes for U.S. University-led IRPs

Appendix C: Work Scopes for U.S. University-, National Laboratory-, or Industry-led NSUF Access Only Projects

Appendix A: Work Scopes for U.S. University-led R&D Projects

TOPIC AREA 1 - REACTOR DEVELOPMENT AND PLANT OPTIMIZATION

NE supports existing and advanced reactor designs and technologies to enable industry to address technical challenges with maintaining the existing fleet of nuclear reactors, and to promote the development of a robust pipeline of advanced reactor designs and technologies and supply chain capabilities. Advances in reactor development, design, and testing that improve technical, cost, safety, and security issues associated with the existing commercial light water reactor fleet and advanced reactor technologies, such as small modular reactor (SMR) and microreactor designs, fast reactors using liquid metal coolants, and high temperature reactors using gas or liquid salt coolants are of interest. NE is also interested in research related to plant optimization including, but not limited to, siting, economics, construction and scheduling outcomes, reducing cost and deployment timelines, remote deployment of reactors, environmental justice and equity considerations, and secure operations, among other relevant topics.

For investigators applying to a Topic Area 1: Reactor Development and Plant Optimization work scope, incremental funding is potentially available through participation in the Department of Energy's interactions with the Organization for Economic Cooperation and Development (OECD) Nuclear Energy Agency (NEA) Nuclear Education, Skills and Technology (NEST) program. NEST ties together university research projects across multiple countries to provide students a fuller professional experience as they pursue their degree. NEST funds are provided to allow travel for students to interact with colleagues in other NEST countries in accordance with NEST program rules. Applications submitted to this work-scope do not require NEST participation. Access to NEST funds do require investigators to agree to participate in NEST. Investigators must clearly indicate in their application if they are willing to join as a NEST project or not.

NOTE: Anticipated budget requirements for NEST participation must not be included in an application submitted to this topic area. NEST funding received by successful applicants will not be included or tracked as part of the overall project budget and not subject to inclusion in project financial reporting. Additionally, participation in NEST will not be a factor considered in the review of applications.

Reactor development and plant optimization related applications should be submitted to one of the following reactor deployment categories:

RDO-1: ADVANCED REACTOR DEVELOPMENT
(FEDERAL POC – JANELLE EDDINS)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

Advanced reactor concepts have the potential to offer significant benefits, including possible lower costs, enhanced safety and security, greater resource utilization and simplified operations. NE performs research and development (R&D) to support innovative reactor concepts, including high temperature gas-cooled reactors (HTGRs), fast reactors, molten salt reactors (MSRs) and microreactors. Proposals are being sought for activities that could help reduce the technical risks associated with these designs. Proposals should clearly identify the challenge being addressed and how proposed activities will support the development, demonstration, and future deployment of advanced reactor concepts. Some potential challenges that could be addressed include, but are not limited to, advanced reactor component development and testing; transient and safety analysis; thermophysical and thermochemical properties determination of molten salts associated with Ab Initio Molecular Dynamics simulations; graphite-salt interaction studies; innovative reactor core and system design or modifications; and characterization of bypass flow for pebble bed reactors.

RDO-2: IMPROVING ECONOMIC COMPETITIVENESS
(FEDERAL POC – JASON TOKEY)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

The existing nuclear fleet continues to face economic pressures which are resulting in premature plant

TOPIC AREA 1 - REACTOR DEVELOPMENT AND PLANT OPTIMIZATION

shutdowns, and advanced reactors must prove their economic competitiveness against nascent technologies for widespread deployment to be successful. Proposals are being sought for innovative solutions to improve the economic competitiveness of existing and future nuclear power plants.

RDO-3: INTEGRATED ENERGY SYSTEMS AND INDUSTRIAL APPLICATIONS
(FEDERAL POC – JASON MARCINKOSKI)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

Nuclear reactors are an attractive technology to power multiple applications, particularly hydrogen, synthetic fuels, polymers, chemicals, minerals production, refineries, and district heating, where clean, reliable energy, or high-quality heat is needed with very high availability. Nuclear reactors offer the ability to provide heat and electricity at the location where it is needed, greatly reducing the cost to transmit/distribute energy. For commercial deployment in these areas, it is critical to consider thermal and electrical requirements for the industrial application to determine the infrastructure needed to connect the nuclear plant to the industrial application. Proposals are sought to develop reference designs for nuclear-integrated industrial systems. Proposed tasks could include, but are not limited to, chemical/industrial process models for integrating nuclear energy inputs; design of thermal, electrical, and chemical distribution and storage systems, including control system components and sensors; and innovative designs for physical protection, barriers, and nuclear and industrial plant layouts. Proposals for new reactor designs are not within scope.

RDO-4: REMOTE DEPLOYMENT/DEDICATED POWER SUPPLIES INCLUDING SITING
(FEDERAL POC – DIANA LI)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

Some advanced reactors, such as microreactors, are uniquely suited for servicing non-traditional energy markets such as off-grid communities, remote locations, military bases, and disaster relief missions. Additionally, new large electrical loads pose several challenges to the U.S. electric power grid that could potentially be addressed through use of microreactors or small advanced reactors to serve as dedicated power sources. Proposals are sought for the identification of high value opportunities for advanced reactors to service non-traditional energy markets and/or provide a dedicated supply of heat and/or electricity when compared to power sources. Areas of interest include but are not limited to, techno-economic analysis; environmental justice considerations in siting advanced nuclear projects; technical interface considerations and regulatory analysis; details on reactor type, size, variability of loads, thermal and electrical output capacity; startup and shutdown requirements under planned and unplanned conditions; site requirements such as containment, methods and capacity to transfer heat to the environment in various operating conditions, access, and physical security boundaries, operator and security staff. Proposals for new reactor designs are not within this scope.

RDO-5: IMPLEMENTATION OF ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING
(FEDERAL POC – DANIEL NICHOLS)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

Both artificial intelligence and machine learning (AI/ML) have been identified as critical tools to support optimization of a wide variety of systems pertinent to the growth and sustainability of the nuclear industry. These tools can expedite development and deployment of nuclear reactors, lower costs, and provide faster solutions to unique problems. To foster the implement of AI/ML techniques to the nuclear industry, the Office of Nuclear Energy seeks proposals that leverage these highly advantageous tools to solve problems such as, but not limited to, structural design optimization, process optimization, economic optimization, manufacturing optimization, hazard detection, and non-nominal condition monitoring. Our goal is to promote interest growth from the AI

TOPIC AREA 1 - REACTOR DEVELOPMENT AND PLANT OPTIMIZATION

community while focusing on supporting the Office of Nuclear Energy's mission.

RDO-6: OTHER REACTOR DEVELOPMENT AND PLANT OPTIMIZATION (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $1,000,000)

Proposals that are not easily categorized into one of the above sub-topic areas of Topic Area 1 (Reactor Development and Plant Optimization) should be submitted to the "other" sub-topic area.

TOPIC AREA 2 - FUEL CYCLE TECHNOLOGIES

NE develops used nuclear fuel management strategies and technologies to support meeting federal government responsibility to manage and dispose of the Nation's commercial used nuclear fuel and high-level waste and to develop sustainable fuel recycling technologies and options that improve resource utilization and energy generation, reduce waste generation, enhance safety, and limit proliferation risk. Current challenges where continued foundational research is needed, include, but are not limited to, exploiting actinide coordination chemistry and interactions at the interface, understanding structure and properties of molten salts solution, intensifying separations through selective removal of key fission product, and external forces and fields, developing real-time characterization technologies for the development of simplified materials recovery technologies. Additional challenges involve used fuel management (including storage, transportation, and disposal), proliferation risk reduction methods, and development of processes and tools to evaluate sustainable fuel cycle system and used fuel management options that can be communicated effectively to stakeholders.

Fuel cycle technology related applications should be submitted to one of the following fuel cycle technology categories:

FC-1: AQUEOUS SEPARATIONS CHEMISTRY
(FEDERAL POC – STEPHEN KUNG)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

Sustainable nuclear energy can be achieved with repeated recycling of fissile and fissionable material into advanced reactors. Currently, aqueous recycling technologies exist but are hampered by high capital and operating costs. The multiple purification cycles needed to obtain sufficiently pure products for recycling is a significant driver for the high costs involved. This topic focuses on innovative approaches that improve our fundamental understanding of aqueous separation chemistry to enable simplifying aqueous processing.

FC-2: MOLTEN SALT SEPARATIONS AND SOLUTION CHEMISTRY
(FEDERAL POC – JIM WILLIT)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

Molten salts have unique composition–dependent chemical, thermodynamic, thermophysical, and neutronic properties that make them well-suited for applications on front and back ends of fuel cycle as well as for thermal storage. These unique properties are determined by speciation and atomic level structures of the salt solution. This topic seeks proposals on innovative modeling and experimental approaches that improve our fundamental understanding of molten salt solution chemistry and properties at the atomic level to enable a broad scope of molten salt applications.

FC-3: SPENT FUEL AND WASTE DISPOSITION: DISPOSAL
(FEDERAL POC – JOHN ORCHARD)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

The mission for the Office of Spent Fuel and Waste Science and Technology is to provide a sound technical basis for the safety and security of long-term storage, transportation, and disposal of used nuclear fuel and wastes from the nuclear energy enterprise. The mission of Disposal Research is to provide a sound technical basis for assurance that the U.S. has multiple viable disposal options available when national policy is ready, identify and research generic sources of uncertainty that challenge the viability of disposal concepts, increase confidence in robustness of generic disposal concepts to reduce the impact of site-specific complexity, and develop the science

TOPIC AREA 2 - FUEL CYCLE TECHNOLOGIES

and engineering tools required to address these needs. Proposals are sought for research activities that can contribute to our knowledge in the areas of i) waste package failure modes, ii) post closure criticality, iii) radio geochemistry, iv) buffer materials, v) modeling & simulation, or vi) other areas.

FC-4: SPENT FUEL AND WASTE DISPOSITION: STORAGE & TRANSPORTATION
(FEDERAL POC – JOHN ORCHARD)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

The mission for the Office of Spent Fuel and Waste Science and Technology is to provide a sound technical basis for the safety and security of long-term storage, transportation, and disposal of used nuclear fuel and wastes from the nuclear energy enterprise. The mission of Storage and Transportation is to develop the technical bases to demonstrate used fuel integrity for extended storage periods, to ensure fuel retrievability and transportation after extended storage, and to transport high burnup fuel. Proposals are sought for research activities that can contribute to our knowledge in the areas of i) Chlorine Induced Stress Corrosion Cracking in the Canister Wall, ii) Canister Internal Environment Monitoring, iii) Fuel Cladding Degradation, iv) Stresses and Strains on Fuel Bundle Components due to Transportation or Seismic Loads, or v) other areas.

FC-5: OTHER FUEL CYCLE TECHNOLOGIES
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

Proposals that are not easily categorized into one of the above sub-topic areas of Topic Area 2 (Fuel Cycle Technologies) should be submitted to the "other" sub-topic area.

TOPIC AREA 3 - FUELS

Advancements in fuel systems, fabrication processes, cladding concepts, and evaluation techniques are important to continue progress already achieved in increasing improvement of fuel performance. NE solicits proposals that focus on LWR or advanced reactor applications that advance existing fuels concepts and enhancing performance or resilience of existing fuels including accident tolerant fuels, TRISO-particle fuels, metallic fuel, and other relevant concepts. NE also plans to support next generation LWR fuel and advanced reactor applications. All aspects of fuel design, testing, and evaluation will be considered.

Fuels related applications should be submitted to one of the following categories:

FL-1: ACCIDENT TOLERANT FUELS
(FEDERAL POC – FRANK GOLDNER)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

A key NE mission is to support the existing fleet of light water reactors (LWRs) via the Accident Tolerant Fuel (ATF) program. The ATF program activities are meant to enhance the safety and performance of existing LWRs. NE is teaming with the U.S. fuel suppliers to develop accident tolerant fuel concepts in the near term that include coated zirconium cladding and doped UO2 pellets. Longer term concepts include iron-chromium-aluminum cladding, silicon carbide composite cladding, and high uranium density fuels. Proposals are sought in areas that can contribute to enhancing LWR safety and performance including, but are not limited to: investigating if ATF concepts can enable LWR coolant CRUD reductions; investigating if ATF concepts, when coupled with fuel enriched to greater than 5% and qualified for use at higher burnup levels, can support reactor power uprates; investigating if the use of ATF concepts can be applicable to SMRs and advanced reactor applications; and investigating innovative nondestructive examination techniques for the manufacturing of silicon carbide composite cladding.

FL-2: TRISO FUELS
(FEDERAL POC – MATT HAHN)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

TRISO-particle fuel is a fuel form that has demonstrated robust safety performance for high temperature applications. Numerous U.S. companies are pursuing the use of TRISO fuel in their advanced high temperature reactor concepts. Proposals are sought for activities that enable the goal of licensing and operating nuclear reactors that utilize TRISO fuel. Potential focus areas could include, but are not limited to, a comprehensive understanding of fuel and fuel matrix properties under irradiated conditions; addressing unique challenges associated with the use of TRISO fuel in non-typical environments, such as molten salt environments and microreactor applications; and activities to evaluate or develop novel TRISO-fuel forms, including new fuel kernel compositions.

FL-3: METALLIC FUELS
(FEDERAL POC – KEN KELLAR)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

Metallic fuels for advanced reactors can operate in open or closed fuel cycles. Open cycle metallic fuel topical areas include the optimization of fuel life and energy output, as well as storability and disposability. Reactor concepts are advanced in nature regarding temperature and coolant and are usually fast spectrum. Chemically reactive or liquid bonds are to be avoided in this group due to complications with storage and disposal. Closed cycle metallic fuels topical areas include maximizing fuel burnup to support an efficient and economic fuel cycle;

TOPIC AREA 3 - FUELS

facilitating reprocessing; and geologic repository burden minimization. Fuel/clad bonding is acceptable in this group as long as it does not hinder reprocessing operations. Both fuel applications place a high priority on manufacturability, economics, safety, and resource utilization. Proposals are sought for metallic fuel modeling interests including first principles understanding, predictive capability, design streamlining, and licensing support.

FL-4: OTHER FUELS TOPICS
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

Proposals that are not easily categorized into one of the above sub-topic areas of Topic Area 3 (Fuels) should be submitted to the "other" sub-topic area.

TOPIC AREA 4 – MODELING AND SIMULATION

Science-based, verified, and validated modeling and simulation capabilities are essential for the design, implementation, and operation of nuclear energy systems. This topic areas focuses on nuclear energy related modeling and simulation projects that improve the tools and frameworks for many different modeling and simulation activities including, but not limited to: high fidelity reactor modeling, including neutronics, structural dynamics, and thermal hydraulics; multi-scale, multi-physics models for characterizing complex neutron kinetics, dynamics, microstructural, and thermomechanical phenomena; verification and validation; Uncertainty quantification; and flow modeling, among other relevant areas.

Modeling and simulation applications should be submitted to one of the following categories:

M&S-1: MULTI-SCALE MODELING
(FEDERAL POC – DAVID HENDERSON)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

Capabilities to accurately model transport phenomena, materials, fuels, and fluid behavior at lower-length scales and reliably translate the effects to the component and/or system level can significantly reduce the amount of experimentation needed to realize new technologies. Proposals should demonstrate knowledge of existing tools and methods and clearly articulate the specific capability to be developed/added and the remaining gap that will exist at completion.

M&S-2: VERIFICATION AND VALIDATION/UNCERTAINTY QUANTIFICATION
(FEDERAL POC – DAVID HENDERSON)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

Historically, nuclear technology has followed a path to product maturation that involves continuous prototyping and measurement that has provided the software validation data needed for nuclear regulatory licensing. At each prototype stage, bounding analysis for regulatory approval has relied on both conservatism and data to establish uncertainties in predicted safety parameters. Because of a lack of data, the use of modeling and simulation with a high focus on uncertainty in predicted safety parameters will be increasingly important. Higher fidelity coupled multiphysics reactor simulation has the potential to accelerate the introduction of advanced nuclear technology by reducing the need for experimental validation in many instances. Proposals are sought for the development of novel methodologies and approaches for software verification, validation, and establishment of uncertainties for high-fidelity, multiphysics coupled code systems. Novel approaches for validation and verification of single physics codes and models may also be proposed. Proposals should address the issue of establishing uncertainties for safety parameters of interest for a given technology within the framework of regulatory licensing.

M&S-3: OTHER MODELING AND SIMULATION TOPICS
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

Proposals that are not easily categorized into one of the above sub-topic areas of Topic Area 4 (Modeling and Simulation) should be submitted to the "other" sub-topic area.

TOPIC AREA 5 – INSTRUMENTATION AND CONTROLS

This topic area focuses on the research and development on sensors, instrumentation, controls and infrastructure technology that are necessary to address critical technology gaps to monitor and control both existing and advanced reactors. This topic area invites proposals that cover the development of reliable and cost-effective sensors and detectors to provide real-time, accurate and high-resolution measurements of the performance of existing and advanced reactors' cores, fuel cycle systems, and plant systems; control algorithms to enable real-time control of plant or experimentation process variables to enhance plant reliability, availability, thermal performance, and resilience; communication technologies to enable real-time transmission of sufficient data for online monitoring and advanced data analytics; machine learning and artificial intelligence capabilities to enable semi-autonomous operations and maintenance by design; and other relevant topics related to instrumentation and controls (I&C).

I&C related applications should be submitted to one of the following I&C categories:

IC-1: SENSORS AND INSTRUMENTATION
(FEDERAL POC – DANIEL NICHOLS)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

Both the existing reactor fleet and advanced reactor concepts will play a vital role in providing clean energy for the United States. To support nuclear power plants in the current and future fleet, proposals are sought that focus on the development of new, or the enhancement of existing sensor technologies. Sensor technologies focused on the existing reactor fleet should address needs which help extend the plant operable lifetime and provide additionally capabilities to increase safety, reliability, and operational efficiency. Technologies for advanced reactor concepts should tailor efforts towards accommodating the unique qualities of the future fleet such as smaller form factor, increased operating temperatures, and working fluid compatibility. Applicants to this scope should identify the type of instrumentation to be developed, or enhanced, and should specify the relevant reactor conditions for which their technology is applicable; radiation tolerance, temperature tolerance, pressure tolerance, and working fluid compatibility (if applicable). Applicants may propose new sensor concepts or leverage existing technologies with the intent to enhance capabilities. Proposals are encouraged to include development and demonstration of the instrumentation system, with data acquisition, under relevant conditions.

IC-2: ADVANCED CONTROL SYSTEMS
(FEDERAL POC – DANIEL NICHOLS)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

The development of semi-autonomous operations has been proposed to reduce costs for the next generation of nuclear reactors. To investigate and ultimately facilitate this capability, advancements are needed to enable semi-autonomous operation, fault-tolerant control systems, load-following, and load balancing of multi-unit nuclear power plants. Two necessary and important considerations for these control systems will be the coupling of digital twin assets and incorporating robust cybersecurity into the design. Proposals are sought for novel control system approaches, designs and component innovations which enable semi-autonomous operation for advanced reactor concepts.

IC-3: ADVANCED NUCLEAR CYBERSECURITY
(FEDERAL POC – REBECCA ONUSCHAK)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

Cybersecurity of nuclear power plants is a rapidly evolving field, as the existing fleet seeks cost-effective means of managing advanced threats through advanced technologies under development which require unique I&C cybersecurity solutions. Examples of novel technologies and use cases under consideration include

TOPIC AREA 5 – INSTRUMENTATION AND CONTROLS

- the use of machine learning, digital twins, and other advanced data analytics tools to support design, maintenance and/or operations;
- the use of advanced cybersecurity analytics tools for attack detection and/or response; remote and/or autonomous operations;
- the use of advanced manufacturing tools or techniques that rely on data analytics for quality assurance and/or regulatory acceptance of nuclear plant components;
- integration of electric and non-electric power applications at the same power plant (e.g. hydrogen production, process heat); and
- the use of wireless sensors and/or controls in-plant for safety- or security-related functions.

Applicants are encouraged to offer 1) technical solutions to cybersecurity challenges associated with any advanced technologies or use cases, whether or not listed here; or 2) solutions to improve the economics and/or effectiveness of cybersecurity management in the existing fleet. While cybersecurity may also be important as a consideration or feature in other technical areas, the intent for this topic is to offer solutions to cybersecurity challenges specifically.

IC-4: OTHER I&C TOPICS
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

Proposals that are not easily categorized into one of the above sub-topic areas of Topic Area 5 (I&C) should be submitted to the "other" sub-topic area.

TOPIC AREA 6 – LICENSING AND SAFETY

There is a continued need for enhancing understanding of licensing and safety requirements as they apply to the safe and secure operations of reactors and all fuel cycle related facilities. This area focuses on better understanding nuclear reactor and recycling plant safety and safeguards margins, physical security system response, and materials accountancy system response using risk-informed frameworks, probabilistic risk assessment, the reliability of passive systems and components, and the integration with materials accountancy and physical protection measures. This includes advancement of modeling and simulation capabilities to develop, verify and validate next-generation safety systems codes. This topic covers additional aspects of licensing and safety including flexible plant design, operations, cyber security, physical security and material control and accountancy, plant automation and modernization, human/machine interface challenges, among other relevant topics.

Licensing and safety related applications should be submitted to one of the following categories:

LS-1: RISK INFORMED SYSTEMS ANALYSIS/PROBABILISTIC RISK ASSESSMENT (FEDERAL POC – BILL WALSH) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $1,000,000)

The use of probabilistic risk assessment (PRA) serves as a fundamental element of nuclear plant operations. However, application of legacy tools and methods have demonstrated that complexity, high modeling resource requirement, and lengthy analysis times are limiting the potential application of this technology. Proposals are sought to enhance the applicability, usability and efficiency of PRA tools or other innovative risk assessment methodologies. Major areas of concern are quantification speed and memory limitations to process large PRA models, Human Reliability Analysis (HRA) dependency analysis, and quantification and result output from the combined hazard PRA models where external hazards are included in a single model (i.e., internal flood, fire, seismic, high winds PRA models).

LS-2: SAFETY IMPLICATIONS OF UTILIZING PROCESS HEAT (FEDERAL POC – JASON MARCINKOSKI) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $1,000,000)

Using thermal and electrical energy from nuclear reactors for industrial process heat can decarbonize industrial processes with a reliable energy source at a low cost. Additionally, economic pressure arising from decreased natural gas cost combined with an increase in renewable-energy capacity on the power grid, has raised interest in exploring high-value off-grid applications of nuclear energy with reduced transmission costs. To expand the use of clean, reliable nuclear energy for decarbonizing industrial processes, the Office of Nuclear Energy is evaluating the feasibility of directly using energy from a nuclear power plant (NPP) for use in off-grid industrial processes to include: physical placement of chemical plants with existing LWRs; colocation of advanced reactors at industrial sites; and regulatory research and review for licensing and permitting. The feasibility of installing a modification to an existing nuclear plant, or installing a system in an advanced nuclear plant, to export heat to an industrial facility will rely, in part, on the performance of a safety analysis that demonstrates conformance with Nuclear Regulatory Commission (NRC) regulations. Proposals are being sought to evaluate the safety implications of utilizing heat from both existing NPPs and future advanced NPPs for industrial applications. This work will involve developing requirements for mutual protection from industrial and nuclear plant hazards, engineering of conceptual systems to address the requirements as a basis for safety analysis, and assessments of the impacts of both nuclear and industrial system maintenance and operations on the integrated nuclear-industrial system.

LS-3: ADVANCED REACTORS AND FUEL CYCLE FACILITIES MATERIALS ACCOUNTANCY, CONTROL, AND PHYSICAL PROTECTION (FEDERAL POCS – SAVANNAH FITZWATER & TANSEL SELEKLER)

TOPIC AREA 6 – LICENSING AND SAFETY

(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

Advanced nuclear reactors, including small modular reactors and microreactors, and associated fuel cycle facilities, face challenges in meeting domestic Materials Control and Accountability (MC&A) and physical protection system (PPS) requirements while still maintaining cost-effectiveness. Proposals are sought for new and novel approaches to improve the efficiency of process monitoring, to develop new MC&A methods and tools for advanced reactors, and fuel fabrication and recycling processes (e.g., salt synthesis, TRISO fuel fabrication, and electrochemical recycling), physical protection, or potential cross over areas between reactors and fuels.

LS-4: ADVANCED REACTOR LICENSING TOPICS
(FEDERAL POC – JANELLE EDDINS)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

Successful licensing of advanced reactors will require establishment of an advanced reactor regulatory framework, including the R&D necessary to establish the associated licensing technical requirements. Proposals are sought for activities that address technology specific gaps in licensing technical requirements for advanced reactors and reduce the regulatory risks associated with those designs.

LS-5: OTHER LICENSING AND SAFETY TOPICS
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

Proposals that are not easily categorized into one of the above sub-topic areas of Topic Area 6 (Licensing and Safety) should be submitted to the "other" sub-topic area.

TOPIC AREA 7 – ADVANCED NUCLEAR MATERIALS

Identification, investigation, and research and development of revolutionary technologies in crosscutting materials science areas have the potential for radical improvement in reactor or fuel cycle performance, safety, and economics. This topical area invites applications that cover key materials science topics to better understand core and structural materials, advanced materials manufacturing techniques, qualifications and/or testing of existing materials, new classes of materials not yet developed for nuclear reactors, fuel recycle, environmental effects, thermal effect, and irradiation effects, among other relevant areas including materials to efficiently immobilize fission products and off-gas capture species.

Advanced Nuclear Materials applications should be submitted into one of the following materials science categories:

NM-1: LWR CORE OR STRUCTURAL MATERIALS
(FEDERAL POC – SUE LESICA)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

Understanding materials degradation in the current fleet of reactors is vital to their continued operation. Proposals are sought to further understand and predict environmentally assisted fatigue of LWR core or structural materials, a damage mechanism that may limit extended operation of the LWR fleet.

NM-2: ADVANCED REACTOR CORE OR STRUCTURAL MATERIALS
(FEDERAL POC – SUE LESICA)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

Ensuring a pipeline of qualified materials to facilitate the economical deployment and efficient operation of advanced reactors is vital to the Department's decarbonization goals. Proposals are sought to develop a fundamental understanding of the damage mechanisms of creep-fatigue and their interactions in the advanced reactor environment, at both microstructural and structural mechanics levels. This understanding can be leveraged to utilize materials developed in other industries or to design new material systems for code qualification. This would be a significant improvement over the current approach of relying on time-consuming and extensive test programs to determine the adequacy of the creep-fatigue performance of a structural material.

NM-3: ADVANCED MANUFACTURING TECHNOLOGIES
(FEDERAL POC – DIRK CAIRNS-GALLIMORE)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

This effort seeks to transform materials, processing, and fabrication techniques to significantly change the nuclear manufacturing cost curve. This includes but is not limited to the state of practice of processing and fabrication of composites and concrete, metals, joining and repair, as well as emerging capabilities developed within the advanced manufacturing enterprise for components, sub-systems, systems, and structures.

NM-4: MATERIAL FOR FUEL RECYCLING APPLICATIONS
(FEDERAL POC – KIMBERLY GRAY)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

Advanced Waste Form Materials and Sorbent Materials for Off-gas Capture. Developing materials for fission product immobilization and sorbent materials for capturing off gas chemical species generated through the reprocessing of used nuclear fuel.

TOPIC AREA 7 – ADVANCED NUCLEAR MATERIALS

NM-5: OTHER ADVANCED NUCLEAR MATERIALS TOPICS
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $1,000,000)

Proposals that are not easily categorized into one of the above sub-topic areas of Topic Area 7 (Advanced Nuclear Materials) should be submitted to the "other" sub-topic area.

STRATEGIC NEEDS BLUE SKY

Maintaining fundamental skills and knowledge in key nuclear engineering topics is important to maintain and establish research excellence and expertise. Sub-topic areas are intentionally broad to allow for flexibility in response. A response should address innovative research in the identified area and could include any aspect (experiments, modeling, etc.) that is necessary to accomplish the proposed scope.

SN-1: THERMAL HYDRAULICS AND HEAT TRANSFER
(FEDERAL POC – JENNA PAYNE)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $500,000)

SN-2: REACTOR PHYSICS
(FEDERAL POC – JENNA PAYNE)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $500,000)

SN-3: NUCLEAR CHEMISTRY
(FEDERAL POC – JENNA PAYNE)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $500,000)

Appendix B: Work Scopes for U.S. University-led IRPs

INTEGRATED RESEARCH PROJECTS

IRP-1: GRAND CHALLENGE IRP – ACCELERATING REACTOR DEPLOYMENT (FEDERAL POC – BRIAN ROBINSON) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $3,000,000)

NE's goal of demonstrating several advanced reactor types within this decade resulting in advanced reactor deployment in the 2030s, is a core aspect of addressing U.S. clean energy climate change goals. One of the primary challenges is reducing overall capital and operating and maintenance (O&M) costs while also de-risking the technologies for more rapid adoption by industry. NE solicits applications for this scope that take a holistic, multi-disciplinary approach to reactor deployment considerations for specific reactor technologies. Applications can cover a wide variety of topics including innovative component, instrumentation, and fuel handling systems; design optimization including integrated systems or reducing the size of the core or number of components; technologies to reduce the cost and schedule for construction; and siting infrastructure considerations for remote applications and transition from fossil generation sources, including environmental justice considerations. Proposals that suggest innovative ideas for cost reduction or shortening the deployment timeline by developing a holistic, multi-faceted approach, including a focus on key technical needs areas, like nuclear economics, accelerated testing, and reactor/plant design expertise, are desired.

For investigators applying to this work scope, incremental funding is potentially available through participation in the Department of Energy's interactions with the Organization for Economic Cooperation and Development (OECD) Nuclear Energy Agency (NEA) Nuclear Education, Skills and Technology (NEST) program. NEST ties together university research projects across multiple countries to provide students a fuller professional experience as they pursue their degree. NEST funds are provided to allow travel for students to interact with colleagues in other NEST countries in accordance with NEST program rules. Applications submitted to this work-scope do not require NEST participation. Access to NEST funds do require investigators to agree to participate in NEST. Investigators must clearly indicate in their application if they are willing to join as a NEST project or not.

NOTE: Anticipated budget requirements for NEST participation must not be included in an application submitted to this work scope. NEST funding received by successful applicants will not be included or tracked as part of the overall project budget and not subject to inclusion in project financial reporting. Additionally, participation in NEST will not be a factor considered in the review of applications.

IRP -2: GRAND CHALLENGE RESEARCH AND DEVELOPMENT AT MINORITY SERVING INSTITUTIONS (MSI) (FEDERAL POC – JENNA PAYNE) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $1,500,000)

NE's mission is to advance nuclear energy science and technology to meet U.S. energy, environmental, and economic needs. Toward this mission, NE has identified goals to address challenges in the nuclear energy sector, to help realize the potential of advanced technology, and to leverage the unique role of the government in spurring innovation:

1. Enable continued operation of existing U.S. nuclear reactors
2. Enable deployment of advanced nuclear reactors
3. Develop advanced nuclear fuel cycles and spent nuclear fuel management options

This opportunity is restricted to MSI lead institutions, including historically black colleges and universities (HBCUs), tribally controlled colleges and universities, (TCCUs), Asian American and Native American Pacific Islander-serving institution (AANAPISI) and Hispanic-serving institutions (HSIs), as defined in Title III and Title V of the Higher Education Act. This scope solicits applications that address one or more NE mission related technical areas that advance nuclear engineering research and development at MSI institutions.

INTEGRATED RESEARCH PROJECTS
NE is allowing a flexible framework for consortia construction and recognizes several viable and effective models including partnering in a multi-MSI consortia style model, partnering with national laboratories, other institutions of higher education, or industry collaborators. This scope is intended to develop nuclear expertise and capabilities at Minority Serving Institutions. Therefore, 80% of the total budget request should directly support lead or collaborating partners that are MSIs. Other institutions of higher education, national laboratories, or industry may participate in a supporting capacity at no more than 20% of total budget in composite. Applications should focus on addressing an important NE mission related topic area with a particular focus on broad student involvement and capacity building to support the next-generation workforce in nuclear energy.

Appendix C: Work Scopes for U.S. University-, National Laboratory-, or Industry-led NSUF Access Only Projects

NUCLEAR SCIENCE USER FACILITIES (NSUF) ACCESS ONLY

Applicants interested in utilizing Nuclear Science User Facilities (NSUF) capabilities only should submit "access only" applications under this sub-topic areas. Applications under the NSUF-1 work scope must support the Department of Energy Office of Nuclear Energy's mission. Capabilities available through the NSUF can be found on the website at NSUF.inl.gov.

Experiments with x-ray synchrotron radiation may be proposed. The NSUF has access to beam time at the X-ray Powder Diffraction beamline at the National Synchrotron Light Source II (NSLS-II), as well as, starting in October 2024, the HEXM and other beamlines at the Advanced Photon Source (APS).

NOTE: Access to NSUF capabilities will require agreement and final signature to the User Agreement (copy provided in Part IX, Appendix E). The terms and conditions of the User Agreement are non-negotiable, and failure to accept the terms and conditions of the User Agreement will terminate processing and review of the application. To ensure compliance throughout the application review process, applicants must indicate in the Letter of Intent (LOI) and full application submission that the User Agreement has been read, understood, and the terms and conditions are accepted. Further, submission of a pre-application and a full application indicates the applicant will comply with and agree to the terms and conditions of the User Agreement. Upon award of an NSUF supported project, the User Agreement must be signed before activities will begin on the project. Failure to sign the non-negotiable User Agreement within 30 days of receipt of the User Agreement may result in cancellation of an awarded project.

NSUF-1.1: CORE AND STRUCTURAL MATERIALS AND NUCLEAR FUEL BEHAVIOR AND ADVANCED NUCLEAR FUEL DEVELOPMENT
(FEDERAL POC – MELISSA BATES)
(ELIGIBLE TO LEAD: UNIVERSITY, NATIONAL LABORATORY, OR INDUSTRY)
(UP TO 7 YEARS)
(NSUF READINESS REQUIREMENTS APPLY)

This NSUF element is focused on fundamental understanding of irradiation effects in core and structural materials and the behavior of nuclear fuels (including cladding) in reactor and research into advanced nuclear fuels and improving the performance of current fuels. For the core and structural materials aspect of the work-scope, areas of interest include material aging and degradation mechanisms (e.g., creep, fatigue, embrittlement, void swelling, fracture toughness, IASCC processes and mitigation, and corrosion), testing alternate and/or radiation resistant materials for application in current and future fission reactors, and materials from alternate or advanced manufacturing techniques (including welding and joining). For the nuclear fuels aspect of the work-scope, areas of interest include the fundamental physics and chemistry of nuclear fuels and other radioactive materials, irradiation and thermal effects on microstructure development and the effects on, for example, thermophysical and thermomechanical properties as well as chemical interactions. Proposed projects may involve research in the areas of fuels and materials irradiation performance and combined effects of irradiation and environment on fuels and materials. Advanced fuel types extend to fast spectrum transmutation systems, coated particle fuels for high-temperature reactor systems, robust fuels for light water reactors including accident tolerant fuels, and fuel for small modular, micro-, and other advanced reactor concepts. Activities can be aimed at irradiation experiments (neutron steady state or transient, ion, and gamma) and post irradiation examination that investigate fundamental aspects of fuel performance such as radiation damage, amorphization, fuel restructuring, species diffusion and migration, and fission product behavior. Separate effects testing focused on validation of specific modeling and simulation issues is encouraged. Proposals that advocate duplicating previous or on-going NSUF supported irradiation studies will not be considered. A complete list of NSUF awards made under CINR funding opportunities can be found under the R&D flag on the website NEUP.inl.gov. Projects whose relevancy is based solely or primarily on fusion energy needs will not be considered. Applications coupling experimental methods with modeling and simulation are strongly encouraged.

NSUF-1.2: HIGH PERFORMANCE COMPUTING AT IDAHO NATIONAL LABORATORY
(FEDERAL POC – MELISSA BATES)
(ELIGIBLE TO LEAD: UNIVERSITY, NATIONAL LABORATORY, AND INDUSTRY)
(LIMITED TO 3 YEARS)
(NSUF READINESS REQUIREMENTS APPLY)

The Nuclear Science User Facilities (NSUF) High-Performance Computing (HPC) resources offered through Idaho National Laboratory provide scientific computing capabilities to support advanced modeling and simulation. Applications may address a wide range of research activities, including performance of materials in harsh environments (including the effects of irradiation and high temperatures), performance of existing light water and advanced nuclear reactors, and multiscale multi-physics analysis of nuclear fuel performance.
Current HPC capabilities include:

Sawtooth: INL's newest supercomputer operates with a LINPACK rating of 5.6 petaflops and is ranked #37 on the November 2019 TOP500 list. The HPE SGI 8600 system comprises 99,792 cores with 403 TB of memory. The system also includes dedicated GPU capability with 108 NVIDIA V100 GPUs.
Lemhi: A Dell 6420-based system operating on an OmniPath fat tree network. It contains 20,160 cores and 94 total terabytes of memory. Lemhi is rated at 1 petaflop and ranked #427 on the November 2018 TOP500 list.
Hoodoo: A Lambda Hyperplane deep learning distributed memory system with 44 NVIDIA A100 tensor core GPUs and 7.2 TB of total memory.
Storage: 3 Petabytes of disk storage including a WORM (Write-once read-many) filesystem for use in multi-year archiving of data.

HPC support includes access to INL HPC systems, assistance with system login and running code, high performance visualization, data archiving, basic HPC training, and software support and expertise as requested. Software includes an assortment of tools in the areas of: Computer Aided Engineering, Chemistry, Code Development, Data Manipulation, Math, MPI, Neutronics and Transport, Numerical Libraries, Programming, and Visualization. Access to HPC resources through this FOA does not provide licenses to software. INL MOOSE-based tools are available subject to license approval. Use of DOE-developed software from the NEAMS programs is encouraged.