July 7, 2016

MEMORANDUM TO: Michael E. Mayfield, Director
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Office of New Reactors

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SUBJECT: SUMMARY OF JUNE 7-8, 2016, DEPARTMENT OF ENERGY AND NUCLEAR REGULATORY COMMISSION CO-HOSTED WORKSHOP ON ADVANCED NON-LIGHT WATER REACTORS

The Department of Energy (DOE) and Nuclear Regulatory Commission (NRC) hosted a two day workshop on advanced non-light water reactors (non-LWRs) and advanced fuel qualification on June 7-8, 2016. The workshop included senior officials from DOE and NRC along with speakers, panelists, and participants from industry, the national laboratories, academia, and other non-government organizations. Participants continued the initiative begun during the September 2015 workshop (summary available at Agencywide Documents Access and Managament System (ADAMS) Accession No. ML15265A165) to explore options for increased efficiency, from both a technical and regulatory perspective, for safely developing and deploying advanced non-LWRs. DOE and NRC provided updates on recent non-LWR activities and strategies while speakers, panelists, and participants discussed processes, identified challenges, and proposed near- and long-term improvements associated with advanced non-LWR fuel development and qualification.

I. Opening Remarks and Objectives of Workshop

Craig Welling, Deputy Director, Office of Advanced Reactor Technologies, DOE welcomed the participants and encouraged active participation in the workshop. Dr. John Kelly, Deputy Assistant Secretary, Nuclear Reactor Technologies, DOE also welcomed participants and recognized that enthusiasm for advanced non-LWRs has greatly accelerated over the past two years. The September 2015 DOE-NRC workshop, the November 2015 White House summit on advanced nuclear technologies, and establishment of stakeholder advanced reactor working groups all demonstrated increasing interest in advanced non-LWRs. Building upon this interest, DOE had announced its Gateway for Accelerated Innovation in Nuclear (GAIN) initiative to improve access to national laboratory research libraries, laboratory facilities, and technical resources to accelerate development of advanced non-LWRs. The GAIN initiative also will provide small business support in the form of vouchersfor laboratory support. Initial voucher award selections have been

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announced. In March 2016, DOE completed its Advanced Test/Demonstration Reactor (AT/DR) planning study. The study began at the direction of Congress, involved a diverse team of national laboratory experts, included feedback from industry stakeholders, and incorporated input from DOE's Nuclear Energy Advisory Committee. DOE has also recently released cost-share awards to X-Energy and Southern Company Services for the development of two advanced reactor concepts (pebble bed gas-cooled reactor and molten chloride fast reactor, respectively). While these awards do not reflect a down-selection of concepts, they are a promising step for increased industry engagement. The DOE also released its Vision and Strategy Document for Advanced Reactors. The draft document is available at: http://energy.gov/ne/downloads/draft-vision-and-strategy-development-and-deployment-advanced-reactors. Dr. Kelly also recognized the progress DOE and NRC have made on advanced reactor general design criteria. In terms of advanced fuel for non-LWRs, Dr. Kelly stated that fuel qualification is a long term effort. As such, DOE, NRC, and stakeholders must work together early on to identify requirements and fuel development plans.

Dr. Jennifer Uhle, Director, Office of New Reactors, NRC expressed her appreciation for the large attendance at the workshop. Recent congressional activities have demonstrated the need for NRC to support the safe development and deployment of non-LWR. Dr. Uhle emphasized continued collaborative work between DOE and NRC while maintaining independent roles (i.e., DOE promotes advanced reactor research and development while NRC ensures safe, secure, and environmentally acceptable deployment). The NRC has also released its draft vision and strategy for safe, effective, and efficient non-LWR mission readiness for public comment (ADAMS Accession Number ML16139A812). Dr. Uhle stressed that advanced fuels will be a critical component in licensing non-LWR designs. She stated that nuclear fuel safety drives all safety requirements for nuclear energy production, and some of the proposed new fuel designs differ dramatically as compared to the LWR operating fleet. As such, advanced fuel qualification will require rigorous experimental and analytical study. Early industry input on the fuel qualification will aid in streamlining the process and minimizing unnecessary regulatory burden.

II. NRC Remarks on the Development and Deployment of Advanced Non-Light Water Reactor Technologies

Stephen Burns, Chairman, NRC provided keynote remarks on motivations, challenges, and opportunities for non-LWR licensing. Chairman Burns referenced the development of 10 CFR Part 52 rules in 1989 and subsequent certification of the Westinghouse AP1000 design referenced for Vogtle and V.C. Summer combined licenses as past examples of NRC's responsiveness to the challenges put before it within the safety context it regulates. NRC, DOE, and industry all have unique roles in developing non-LWRs. Despite the differences, strong support for cooperation exists now within mandated responsibilities. A non-LWR application could theoretically be licensed using existing processes and exemptions. This could admittedly take a substantial amount of time with current staffing and funding. New fuel designs could also take one to two decades for testing and qualification. As such, NRC is looking at a multipart strategy for licensing non-LWRs. DOE and NRC plan to hold a Commission meeting in late June 2016; to discuss items of interest between DOE and NRC, including non-LWRs. NRC's FY17 budget requested $5M in non-

fee recoverable activities for non-LWRs such as: stakeholder outreach, gap analysis of current regulatory guidance, completing advanced reactor design criteria, developing an incremental regulatory design review process, observing international design review processes, working with DOE to support the GAIN initiative, and endorsing industry codes and standards. Chairman Burns stressed that NRC is ready to work with potential applicants. He indicated that to improve processes, it is important that industry keep the NRC informed of its progress. Chairman Burns concluded by stating that safety can be achieved while allowing innovation.

III. Visions and Strategies for Advanced Reactor Development

Dr. John Kelly, DOE presented on DOE's recent Vision and Strategy for Advanced Reactors. Evolving carbon reduction policies in the U.S. (e.g., Executive Orders, Climate Action Plan) have pointed to a need for the U.S. to generate 80% of its electricity from clean energy sources by 2035. To meet this goal, recent studies project thata nearly tenfold increase in renewables and a doubling in nuclear are needed by 2035. Advanced LWRs, small modular reactors (SMRs), and Generation IV non-LWRs will need to play a substantial role to meet future nuclear needs as current plants reach the end of license extensions. The DOE's recent Vision and Strategy for Advanced Reactors builds on six strategic objectives to meet the following vision and goal: the vision is that by 2050, advanced non-LWRs will provide a significant and growing component of the nuclear energy mix; the goal is that by early 2030s, at least two advanced non-LWR concepts have reached maturity and demonstration, and have completed NRC licensing reviews to allow construction. To meet the vision and goal, the first strategic objective looks at enhancing innovation infrastructure and improving methods and capabilities at national laboratories. Major activities include: knowledge management, restarting the Transient Reactor Test Facility (TREAT), and implementing GAIN. The second objective looks at retiring technical risk by soliciting industry input on research and development (R&D) needs and launching technology-centered working groups for liquid-metal fast reactors, high temperature gas-cooled reactors, and molten salt reactors. The third objective explores fuel cycle pathways such as tristructural-isotropic (TRISO) fuel development, separations and enrichments technologies, and addressing the back end of the fuel cycle. The fourth objective focuses on assisting NRC in the development of an advanced reactor regulatory framework. The fifth objective looks to maximize effectiveness of public and private sector investments through working groups and financial incentives. The sixth objective focuses on developing the future nuclear energy workforce with continued support of the DOE's Nuclear Energy University Program.

Dr. Jennifer Uhle, NRC, discussed the NRC's vision and strategy for non-LWRs. She stated that the Atomic Energy Commission, NRC's predecessor, reviewed and licensed non-LWRs in the past (e.g., Fermi 1, Peach Bottom 1, and Fort Saint Vrain) and that the NRC could theoretically review and license a non-LWR today. The recent construction permit process for licensing SHINE (a medical isotope production facility) showed how interim staff guidance was used in the regulatory process. Using the current regulatory framework to license non-LWRs, though achievable, may not be efficient. The NRC's vision is to serve as a trusted, independent, transparent, and effective nuclear regulator with openness and clarity. The NRC's plan includes three strategic objectives: enhancing technical readiness, optimizing regulatory readiness, and optimizing communications. These objectives will be achieved by implementing

near-term (0-5 years), mid-term (5-10 years), and long-term (10+ years) strategies. Near-term strategies include acquiring/developing sufficient knowledge, technical skills, and capacity to perform non-LWR regulatory reviews; acquiring/developing sufficient computer codes and tools; establishing flexible risk-informed and performance-based review processes within the bounds of current regulations; developing conceptual design assessments and staged review processes; identifying and resolving technology-inclusive policy issues; and developing and implementing a structured, integrated communications strategy. Mid-term strategies include resolving technology specific issues impacting regulatory reviews; continuing to develop technical skills and capacity to perform non-LWR reviews (including test or prototype reactors); and developing a new non-LWR framework, with rulemaking, if necessary. Long-term strategies would focus on finalizing a new non-LWR framework. Specific implementation action plans (detailed tasks, cost estimates, work durations, etc.) are targeted to be developed by September 2016 for near-term goals and by February 2017 for mid-term goals. Notional NRC timelines for non-LWR reviews support DOE's goal of having at least two non-LWR technologies ready for construction by the early 2030s.

Following the session, participants had several questions. John Kelly was asked how DOE would receive funding for a demonstration reactor. Dr. Kelly responded that history has shown there are ways to get funding if there is strong interest in a major project. Dr. Kelly was also asked about DOE's subsequent efforts based on the AT/DR study. Dr. Kelly responded that technology specific working groups would be formed to help with the process along with utility involvement. Jennifer Uhle was asked if the proposed staged licensing review process could increase delays and risk. Dr. Uhle responded that while a staged-review process could take longer than if a complete application was initially submitted, the NRC will try to be as flexible as possible, and that the process would still allow applicants to submit everything at once. If an application is submitted in stages, a final integrated review step will be needed once the entire application has been submitted. Dr. Uhle was also asked whether the NRC would independently develop their own non-LWR codes. She indicated that she did not envision the NRC developing their own codes from scratch. However, Dr. Uhle responded that it may be more difficult to review another code versus running NRC codes because an independent analysis by the NRC is needed to make a finding. But the NRC should do it in a uniform way. Dr. Uhle was asked what advantages Part 50 would offer for potential applicants. Dr. Uhle responded that, for those applicants with a site/owner identified, advantages for a less complete design can be submitted, construction could be completed earlier, with fewer design details needed initially; However, a risk of the first-of-a-kind applicant's schedule being longer and not receiving an operating license may exist.

IV. Utility Perspective on Development and Regulatory Support for Advanced Reactors

Stephen Kuczynski, Chief Executive Officer, Southern Nuclear Company provided a utility perspective on advanced reactor regulatory development. His remarks were based on broadening nuclear support, broader funding, and licensing reviews and approvals. Mr. Kuczynski focused on leadership, motivations for cooperation among a diverse group of stakeholders, and significant challenges utilities may face. He stated that leadership has many definitions including the ability to influence the way people think and behave. To lead, one must establish trust, relationships, and communicate in both directions. In terms of motivation for cooperation, stakeholders believe in public safety, protecting the environment, and meeting

challenges. Southern Company expresses a strong interest in innovation as seen in the recent AP1000 licensing and construction at Vogtle. Southern also recognizes that SMRs can be potential game changers in the near term. In terms of industry challenges, the question remains whether or not nuclear utilities will be ready to meet future carbon reduction goals. Mr. Kuczynski stated that individuals need to step forward, lead, and persevere. Every nuclear source has something to offer including SMRs, AP1000s, and non-LWRs, which can provide even greater characteristics in terms of safety, efficiency, and flexibility. Utilities and markets are not stagnant. Mr. Kuczynski referenced the changing markets among coal, oil, and natural gas as examples As such, advanced reactor stakeholders need to address challenges as a group today to be fully prepared for the future. Excellence should be built in from the very start for all concepts. Stakeholders must also promote the benefits of nuclear energy's minimal environmental footprint. While good work has taken place for licensing reactors, more needs to be done in terms of leadership and process development. Mr. Kuczynski advocated greater NRC transparency and noted that industry and fuel designers need to know the threshold for an adequate review. Today's tools are better, but the requirements aren't clear. Mr. Kuczynski also stressed the need to build demonstration reactors by 2025, improve advanced reactor economics, and solidify a coalition of owner-operators. Strong public-private partnership was also recommended to support the transition from millions to billions of dollars necessary to deploy advanced reactors. Mr. Kuczynski concluded by reiterating the need for strong legislation, diverse groups working together, and leadership.

V. Recent DOE Initiatives

Thomas O'Connor, Director, Advanced Reactor Technologies, DOE began the session with an update on the DOE's AT/DR study. Congress provided $7M to DOE in FY15 to conduct the study to provide transparent and defensible suggestions for a potential advanced test/demonstration reactor. Per the study, demonstration reactors would allow for technology validation at either engineering, performance, or commercial demonstration levels. A test reactor would support irradiations for component and fuel qualification. The study framework was developed by a team consisting of technical experts from Argonne, Idaho (INL), and Oak Ridge National Laboratories with the NEAC providing study advice and recommendations on which reactors best serve the strategic objectives. Laboratory teams conducted technical readiness assessments, developed point reactor designs, and developed study criteria and metrics. An independent and diverse panel of laboratory, industry, and other government agency experts then independently evaluated the point designs against the criteria and metrics. The lab team submitted the draft final results of the study in March 2016. The study yielded the following demonstration reactor results based on potential mission needs (in addition to the fundamental requirement to produce electricity): modular high temperature gas reactor for process heat applications, sodium fast reactor for actinide management, and fluoride high temperature reactor and/or lead fast reactor for a small scale demonstration for future design development. For an irradiation test reactor, the study concluded that a sodium fast reactor would provide the greatest potential benefit and sufficient fast neutrons for irradiation and qualification capabilities. The study estimated a cost and schedule of $4B and 13-15 years for design, licensing and construction for mature designs and $2-4B and 20 years for less mature designs. The Class 50 licensing path would be pursued for mature technologies with the possibility of using the Class 104c licensing path for the lower maturity reactors and the irradiation test reactor. The NEAC Nuclear Reactor Technology Subcommittee reviewed the results and will present their conclusions in June 2016.

Brian Robinson, Program Manager, Office of Advanced Reactor Technologies, DOE presented on the Department's recent Advanced Reactor Concepts (ARC)-15 awards between industry and DOE. DOE used a Technical Review Panel (TRP) process in 2012 and 2014 to solicit R&D needs from industry. The TRP process led to four ARC-13 and five ARC-14 awards to explore advanced reactor components. The ARC-15 process broadened the scope beyond advanced reactor components and offered $12.5M (with a potential for multi-year funding) for the further development of two performance based advanced reactor concepts. The ARC-15 awards should not be interpreted as an advanced reactor design down-selection by DOE. A Merit Review Board reviewed applications based on technical merit (safety, operations, and economics), furtherance of the reactor concept, viable planning, team capabilities and experience, and industry cost share. The ARC-15 merit review process selected X-Energy's Xe-100 (pebble bed high temperature gas reactor concept) and Southern Company Services Molten Chloride Fast Reactor as the awardees. DOE is finalizing the contracts now after initial kickoff meetings in February 2016. Next steps include developing milestones to track progress and a technical review schedule to determine whether to continue funding for the next period.

Kemal Pasamehtemoglu, Associate Lab Director, INL presented on the GAIN initiative launched during the November 2015 White House Summit on Advanced Reactors. The GAIN initiative's major objectives include: maintaining global leadership (DOE), enabling global industrial leadership (vendors/suppliers), assisting in optimized use of nuclear energy domestically within the clean energy portfolio (utilities), and rapid and cost effective advanced reactor development towards market readiness (public-private partnerships). GAIN is not a program of its own, but is instead a consolidation and access mechanism to DOE capabilities and expertise. GAIN looks to change the traditional sequential reactor deployment strategy to a faster and more integrated progression to meet advanced reactor demonstration goals by the 2030s. Rapid and cost effective retirement of technical risks will help avoid the traditional large leaps in funding required currently to deploy new reactors. GAIN remains in the development phase in FY16 with further execution planned for FY17. GAIN is expected to be in full execution phase in FY18. Over the next few months, GAIN will host several technology-specific workshops to collect data, identify R&D gaps, and prioritize vendor/investor R&D needs.

William Corwin, Materials Engineer, Office of Advanced Reactor Technologies, DOE discussed ongoing work related to the American Society of Mechanical Engineers (ASME) Code Section III Division 5 for advanced reactor high temperature materials. Different organizations have various functions in qualifying materials. ASME provides rules and in-service inspection criteria, owner/operators provide inputs, DOE develops technical input for code updates, and NRC may endorse codes to facilitate licensing. Mr. Corwin stressed that the ASME Code Section III Division 5 rules have already been developed. The next steps involve further research by DOE, qualification of several advanced high temperature materials into the ASME Code Section III Division 5, and subsequent NRC endorsement. Section III has different criteria for low temperature and high temperature metallic materials. Low temperature stress criteria are independent of time while high temperature material stress criteria are time dependent. Division 5 has been specifically developed for high temperature reactors (gas, metal, and salt cooled reactors). Recent DOE work will add the code case for two high temperature metals with beneficial characteristics for advanced reactors (Alloy 617 and Alloy 709). Several issues still need to be addressed including weldments, aging and environmental issues, creep fatigue, and multi-axial loading. NRC has begun to assess the rules for endorsement. Endorsement will be important for vendors to develop their concepts.

Following the session, the participants received several questions. Thomas O'Connor was asked why the AT/DR study was completed prior to developing DOE's Vision and Strategy for Advanced Reactors. Mr. O'Connor responded that ideally the Vision and Strategy would have been completed prior to the conduct of such a study, but in this case Congress directed DOE to perform the study through the FY 2015 appropriation. Brian Robinson was asked about lessons learned from the mPower and NuScale DOE awards. Mr. Robinson responded that DOE has incorporated deliverables and a phased budget approach for the ARC-15 awards.

VI. Recent NRC Initiatives

Deborah Jackson, Deputy Director, Division of Engineering, Infrastructure, and Advanced Reactors, NRC began the session with a discussion on regulatory review options for non-LWRs. As stated earlier in the day, if an application for a non-LWR came in today, the NRC could theoretically review it using exemptions and LWR-like review processes, though this process can increase inefficiencies. Small non-LWR startup companies rely heavily on venture capitalists, potentially making current processes too large of a financial risk. There are currently five review paths after the design phase, using Part 50 or 52 for power/prototype reactors, Part 30 or Part 70 for special nuclear material (SNM) experiments, and a path for review of test facilities without SNM. In terms of the design review process, the NRC is considering two new additional steps (conceptual design assessment and staged-review) to minimize regulatory risk and provide designers with feedback throughout the review process. The conceptual design assessment would provide early design phase regulatory feedback on potential technical risks and challenges. The staged-review process would be based on submitting major portions of the non-LWR design under the Part 52 Standard Design Approval (SDA) process for safety review by the NRC.

Douglass Miller, Lead Technical Advisor, Canadian Nuclear Safety Commission (CNSC) next presented on the Canadian pre-licensing vendor design review process. The CNSC serves in a regulatory oversight role similar to NRC and recognizes the need for clarity between vendor and regulator on requirements and expectations. New technologies can have just as many uncertainties as first generation reactors. Utilities are under great cost pressures and may benefit from a more staged, discrete review process. The vendor design review process is an optional review (completely separated from licensing) offered by CNSC for vendors to determine whether their design is ready for potential deployment. Vendors must come prepared, and outcomes of the process helps the vendor have discussions with future licensees interested in their technologies. The vendor may select from three phases of review: Phase 1 (approx. 5,000 hours staff time or 1 year – determines if design shows intent of Canadian safety requirements); Phase 2 (10,000 hours or 2 years - more specific and in depth review of the design); and Phase 3 (scope and depth requested by vendor). The CNSC will consider information and designs from other countries, though if using codes and standards outside of Canada, the vendor will have to identify gaps.

Jan Mazza, Project Manager, NRC provided a status update on the Advanced Reactor Design Criteria (ARDC) initiative. The initiative began in 2013 between DOE and NRC and includes two phases. In Phase 1, DOE issued a report to NRC in December 2014 presenting a draft set of generic ARDCs and design specific general design criteria (GDCs) for modular high temperature gas-cooled reactors (mHTGRs) and sodium-cooled fast reactors (SFRs). Phase 2 is currently in progress where NRC considers the report, develops ARDCs, requests public

feedback, and issues a regulatory guide. NRC has developed generic ARDCs and custom SFR and mHTGR GDCs along with associated rationale that went out for a first public comment period on April 7, 2016. NRC also held a public meeting on May 17, 2016. NRC has also developed security design considerations in addition to the GDCs. NRC expects further engagement on mHTGR-DC 16 functional containment, mHTGR-DC 10 reactor design, ARDC 17 electric power systems, ARDC 35 Emergency Core Cooling System (ECCS), and the security design considerations. Future activities include a 45 day public comment period for security design consideration, Advisory Committee on Reactor Safeguards (ACRS) meeting on July 6, 2016, public meetings in summer/fall 2016, formal public comment period for fall 2016, and a final regulatory guide in 2017.

Steven Lynch, Project Manager, NRC presented on licensing novel technologies under the current NRC framework. Both power and non-power reactors are licensed as utilization facilities. Section 103 of the Atomic Energy Act (AEA) applies to commercial facilities while Section 104 of the AEA applies to medical therapy and R&D licenses (104a-medical therapy, 104b-early industrial and commercial facilities (obsolete), 104c-research and development). All operating research and test reactors are licensed under Section 104c of the AEA. The NRC defines a research reactor as nuclear reactor licensed under 104c for operation at 10 MW or less, and is not a testing facility. NRC has no definition for a “demonstration” reactor. Research reactors are not held to GDCs as are commercial reactors and do not require an environmental impact statement or ACRS review. A testing facility is defined as generating thermal power over 10 MW (or greater than 1 MW if it has a circulating loop through the core, liquid fuel loading or experimental facilities with the core in excess of 16 square inches in cross-section). Testing facilities require an environmental impact statement, hearing, and ACRS review. A reactor is considered commercial if more than 50% of the annual costs of owning and operating is devoted to sales of materials or electricity. Mr. Lynch used the SHINE Medical Technologies, Inc. isotope production facility construction permit application review as an example of effective licensing of a novel technology. For novel technologies, early interaction supports efficient application processing and review.

Following the session, the presenters received several questions. Deborah Jackson was asked about protection of proprietary information during the review process. Ms. Jackson responded that NRC has an extensive regulatory process to protect proprietary information in 10 CFR 2.390. Douglass Miller was asked about SMR licensing approaches in Canada. Mr. Miller responded that the CNSC has consolidated SMR requirements into a single document using a graded approach commensurate with risk. Mr. Miller was also asked if there are ongoing discussions between NRC and CNSC on pre-licensing processes. Mr. Miller responded that NRC and CNSC are having discussions on the topic. Steven Lynch was asked why Part 104b is no longer a viable option. Mr. Lynch responded that, unless brought back by law, only facilities licensed prior to 1970 were eligible for Section 104b licenses. Mr. Lynch stated that the regulations provide no obvious advantage for licensing under Section 104b over Section 104c.

VII. Panel on Recent Industry Initiatives

Jeffrey Merrifield, U.S. Nuclear Infrastructure Council (USNIC) began the panel session on industry initiatives. Merrifield commended DOE and NRC on organizing the second workshop. Mr. Merrifield stated that current licensing issues relate to processes, leadership, and NRC/DOE work force deployment. Processes must ensure adequate protection, not absolute protection. The USNIC has held several summits on advanced reactors, has seen promising interest, believes GAIN is a positive step forward, and encourages other group efforts as well. Mr. Merrifield expressed concerns over NRC and DOE advanced reactor deployment timelines and believes demonstration by 2035 is a less than ambitious goal. Continued licensing modernization efforts based on congressional direction and continued development of ARDCs to support future reactor designs (i.e. molten salt reactors) were discussed as beneficial steps. The USNIC supports NRC's FY17 $5M off-fee base request and suggests funds should be invested in a team of qualified individuals to develop a risk-informed regulatory framework. NRC should provide a no cost option for developers to understand regulatory processes and changes, and should provide clear guidance for licensing processes. USNIC supports continued steps for a pre-licensing review process similar to CNSC. Mr. Merrifield also stated that the USNIC will establish a technology owners group. Mr. Merrifield concluded by reiterating that DOE, NRC, and stakeholders should push for faster deployment of advanced reactors.

Dr. Everett Redmond, Senior Director of Fuel Cycle and Technology Policy, Nuclear Energy Institute (NEI) presented on strategic priorities for advanced reactors. Only a fraction of the current fleet may have life extensions up to 80 years. To maintain nuclear energy's nearly 20% domestic electricity share, the U.S. must pursue continued safe operation of the current fleet, develop new LWRs and SMRs, create a robust domestic and global supply chain, and develop a strategic plan for advanced non-LWR development and commercialization. NEI's primary strategic goals include one or more advanced demonstration reactors by 2025 and two or more advanced reactors deployed in 2030-2035 with a regulatory framework for efficient and predictable licensing of advanced reactors. NEI has three task forces (regulatory, technology, and legislative) to accomplish these goals. Dr. Redmond reiterated the potential inefficiencies of the existing LWR-focused framework. As such, NEI supports a technology inclusive, risk-informed, and performance-based advanced reactor regulatory framework with staged approvals. Both the Electric Power Research Institute (EPRI) and NEI will be supporting upcoming GAIN technology-focused workshops.

Dr. Andrew Sowder, Principal Technical Leader, Advanced Nuclear Technology Program, EPRI presented on industry interest for advanced Generation IV reactors. EPRI serves as a not-for-profit organization for nuclear industry research and engages all of the domestic and 80% of the worldwide nuclear programs. EPRI sees the commercial environment changing for nuclear. Grid operators are having issues with quality, stability, energy, and capacity. Uncertainties still exist for natural gas prices, price of carbon emissions, and subsidies for renewables. Because of this uncertainty, EPRI has witnessed an increased interest in advanced reactors. With plant retirements, increased demand, and potentially trillions needed in new energy infrastructure, satisfying future energy demand within projected carbon limits becomes unrealistic without nuclear. EPRI recognizes that the deployment of Generation IV reactors will rely on a healthy Generation II/III+ program and a more compelling business case. EPRI envisions having a leadership role to commercialize advanced reactors and stressed the need for a mature technology demonstration by the 2030s. EPRI has established a Technical Advisory Group

guide R&D, explore owner-operator requirements, develop technology assessment and tools, provide strategic analysis and targeted technology development, and explore product flexibility of advanced reactors (e.g., electricity, process heat, radioisotopes).

Dr. Ashley Finan, Policy Director, Nuclear Innovation Alliance (NIA) reiterated the need for a staged and more technology inclusive licensing process with test bed/demonstration platforms. The current heavily LWR-based regulatory processes would require many modifications to license a non-LWR today. The current process is also all or nothing with an unclear regulatory pathway for innovators to build prototypes or demonstrations. A staged approach with discrete stages and graduated investments would reduce regulatory risk. NIA issued a report in April 2016 on advanced reactors that recommends early stage feedback mechanisms with NRC, addressing advanced reactor policy issues, revising LWR focused requirements, completing the ARDC initiative, clarifying the advanced reactor demonstration licensing process, and working on legislative processes to exempt advanced reactor infrastructure development from fee recovery. NIA suggests continued DOE funding for competitively awarded grants for advanced reactor development and support for developing codes and standards. Industry also needs to deliver a coordinated and effective message and communicate early on with NRC.

Josh Freed, Vice President, Clean Energy Program, Third Way highlighted the strong and renewed interest in advanced nuclear. Third Way noted the need for multiple technologies to meet the carbon goal. With renewables projected to provide only 30% of carbon free energy, nuclear will have an important role. As a think tank, Third Way supports advanced nuclear through communications, building coalitions, developing policies, and dealing with legislation. To achieve advanced reactors in time to meet clean energy goals, stakeholders need to act with a sense of urgency now. Advocating that nuclear is a national priority in face of climate change can build consensus with both sides of Congress. Third Way promotes a risk-informed staged licensing process to commercialize advanced reactors. Stakeholders need to work with and inform NRC to adapt standards for advanced reactors.

VIII. DOE Remarks on the Development and Deployment of Advanced Non-Light Water Reactors

Dr. Franklin Orr, Under Secretary for Science and Energy, DOE provided closing remarks for the first day. Dr. Orr expressed his appreciation for the overwhelming attendance and reiterated DOE's strong support for the ongoing DOE-NRC workshops. Nuclear energy will play a vital role in the nation's clean energy future as indicated in recent White House summits. Recent studies indicate a need for nuclear energy to double by mid-century to meet climate goals. Discussions at the 2015 Paris Climate Conference COP21 demonstrated the need for future nuclear energy growth on a global scale as well. Current fleet life extensions, new LWRs and SMRs, and advanced non-LWRs will all be necessary to meet future energy demands. The GAIN initiative will increase access to DOE expertise and increase public-private partnerships while DOE's Vision and Strategy for Advanced Reactors will support the doubling of nuclear energy required by 2050. Dr. Orr acknowledged the financial risks faced by utilities and applauded recent efforts by DOE, NRC, and industry to lower regulatory risk. Dr. Orr concluded by thanking those in attendance and promoting fruitful discussion for the remainder of the meeting.

IX. Open Discussion – Day 1

Following Dr. Orr's remarks, an open discussion was held. Andrew Sowder was asked where EPRI stands on advanced reactor code and model development. Mr. Sowder responded that EPRI develops tools where there is a need and is developing guidance on how code developers can incorporate probabilistic risk analysis.

Ashley Finan was asked how industry plans to assist NRC in addressing advanced reactor licensing needs. Dr. Finan responded that coordinated collaboration among startups, DOE, and NRC will help push things forward. All stakeholders have to make stretch goals and work towards them.

Josh Freed was asked about how to improve advocacy for nuclear energy. Mr. Freed responded that industry and trade organizations need to advocate more strongly for nuclear energy to gain government policy support.

Jennifer Uhle was asked if licensing reforms were expected to reduce cost. Dr. Uhle responded that NuScale spent $600M so far in design development. Reviewing applications in many stages will likely add cost, and the NRC is working to improve licensing efficiency that could aid in review cost reduction.

Ashley Finan was asked about differences observed between NRC and CNSC licensing processes. Dr. Finan responded that CNSC is less prescriptive which could be better for advanced reactors, though the AEC/NRC has more experience reviewing advanced reactors than CNSC.

A comment was made regarding down-blending highly enriched uranium (HEU) to achieve the 5% to 20% enrichments required for advanced reactors. Down-blending HEU to less than 20% is the current plan in the near-term, though not sustainable for the long-term. Designers would have to explore changing fabrication facility standards to enrich above the current 5% limit.

X. Advanced Reactor Fuel Development and Qualification

Deborah Jackson, NRC provided a summary of the previous day's sessions to start the second day. Key messages from the first day included strong alignment among NRC, DOE, and industry on the need to deploy advanced reactors by 2030, development of an advanced reactor regulatory framework for near-, mid-, and long-term strategies, exploring risk-informed performance-based technology inclusive frameworks, discussing what constitutes an adequate review, resolving policy issues, harmonizing various interests of stakeholders, exploring building demonstration reactors, and maintaining communications and advocacy.

Dr. David Petti, Chief Nuclear Scientist, Nuclear Science and Technology Division, INL began the session with an overview of advanced fuel development and qualification processes. Overall, the process is independent of fuel form and consists of the following phases: selection of potential fuel candidates; lab scale concept definition and feasibility (down-select reference design); improvement and scale-up (testing and validation, confidence for final qualification); and qualification and demonstration (test large quantities of fuel rods, final qualification). Each phase can take from 5 to 7.5 years to complete and consists of fabricating irradiation capsules,

irradiation, and post irradiation examination. With regards to the DOE advanced fuel program, TRISO for high temperature reactors, metallic fuel for SFRs, and U-Mo fuel for research reactors are in the qualification and demonstration phase. Metallic transmutation fuel is in the improvement and scale-up phase, and accident tolerant fuel is still in the first two phases. Cost goes up with each phase, and DOE anticipates a final cost for TRISO qualification of $250M to $300M.

Jon Carmack, National Technical Director, INL provided an overview on fuel development for advanced reactors. Each Gen IV system has unique fuel forms: Very High Temperature Reactors - TRISO, Molten Salt Reactors – liquid fuel or TRISO, SFR – metallic, oxide, metal, or nitride, supercritical water reactor– oxide in high temp corrosion resistant with most interest in Canada, gas fast reactor – carbide in dispersion or pin SiC, lead-cooled fast reactor (LFR) metallic, nitride, oxide, carbide. DOE currently funds R&D on accident tolerant fuel, transmutation fast reactor fuel, TRISO fuel, and metallic fuel for SFRs. Previous DOE advanced fuel R&D included dispersion fuel for a variety of fast reactors, metal oxide, and nitride fuel. The main objectives for DOE's advanced fuel program are fuel cycle closure (achievement of very high burn up systems or recycling using burner systems) and actinide management. In the 1960s thorium went under nearly as much research as uranium as a fuel source. Because of significant uranium reserves, the U.S. does not pursue thorium fuels at this time.

Jeffrey Schmidt, Senior Reactor Engineer, NRC presented on current fuel system regulatory guidance for advanced reactor development. NUREG-0800, Standard Review Plan (SRP), Section 4.2 provides fuel system design review information and addresses fuel, fuel clad, reactivity control elements, and components which make up the bundle. SRP Section 4.2 is currently heavily LWR-based. In a standard process, staff reviews fuel design bases (damage mechanisms and important limiting values), descriptions and drawings, design evaluation methods, testing, inspections, and surveillance plans. The challenge lies with establishing fuel system design bases and design evaluation methods. Analytical models, operating experience, and direct experimental comparisons are used to ensure design bases are satisfied. A well-defined testing and qualification program is essential if insufficient historical data exists. Mr. Schmidt discussed NRC's high-temperature gas-cooled reactor fuel qualification from the Next Generation Nuclear Plant (NGNP). NRC staff provided feedback on the NGNP fuel qualification program with no obvious impediments identified and recommended confirmatory tests. NRC also provided SFR fuel pre-application reviews for the Sodium Advanced Fast Reactor and Power Reactor Innovative Small Module (PRISM). The reviews showed no obvious impediments and identified additional testing needs. Fuel pre-application reviews are very helpful for the NRC, especially with advanced fuels.

Kevin Ramsey, Senior Project Manager, NRC presented on fuel fabrication facility licensing processes. Fuel development costs depend on individual stakeholder's conversion, enrichment, and fabrication needs, with price increasing with each additional step. Current enrichment facilities are licensed to 5%. Many advanced reactor concepts require enrichments above 5% which would require facilities to obtain a license amendment. The fabrication facility licensing processes may require environmental reviews, public hearings, and NRC quality assurance program approval. The process can take up to 5 years, so early interaction with NRC is encouraged.

Following the session, the panelists received several questions. David Petti was asked how one can compress the fuel qualification timeline. Dr. Petti responded that the burden of proof is large today with safety testing comprising the majority of fuel qualification. This makes significantly compressing the schedule difficult under current processes. Jon Carmack was asked how much DOE data on TREAT's projected conversion from HEU to lowly enriched uranium would be available to vendors. Mr. Carmack responded that the data will be available though some may be in draft form. Jeffrey Schmidt was asked if NRC has developed specified acceptable fuel design limits for advanced reactors. Mr. Schmidt responded NRC has not at this time. Kevin Ramsey received comments on efforts required to track nuclear materials for liquid fuel forms.

XI. Industry Panel on Advanced Reactor Fuel Challenges

Dr. Kevan Weaver, Director of Technology Integration, TerraPower began the session with an overview of TerraPower's sodium fast reactor fuel testing and development program. The TerraPower concept uses a novel high burnup metallic fuel design. Past experimental metallic fuel data (i.e. EBR-II) only has limited applicability to TerraPower's high burnup fuel. As such, TerraPower's program looks to extend the metallic fuel dataset to high burnup. Primary program focus areas include gathering historic data, understanding fuel behavior under various conditions, fabrication (looking at extrusion techniques for metal fuels), in pile and out of pile testing (heavy ion irradiations for clad), and post irradiation examination. The current SRP is heavily LWR-based and only provides limited guidance. Since the United States only has limited fast flux experimental capabilities, TerraPower has worked with the Russian BOR-60 reactors for irradiations.

Dr. Eric Loewen, Chief Engineer, GE Hitachi Nuclear Energy presented on licensing and fuel qualification approaches for the PRISM fast reactor design. DOE initially supported the first PRISM advanced conceptual design in the 1980s, and the concept has undergone several modernizations. Dr. Loewen identified several steps to aid in advanced reactor licensing: complete the ARDC effort utilizing industry inputs to simplify language and remove redundancy; establish a process for advanced reactors since Part 52 is currently unworkable; and build a demonstration plant to drive certification of follow-on plants. Dr. Loewen also noted the need for agreements and exemptions early on where LWR requirements do not apply and fundamental changes to NRC processes such as training NRC staff on advanced reactor technologies ahead of time.

Clay Richardson, Project Manager, Uranium Recovery and Specialty Fuel Fabrication, BWX Technologies (BWXT) discussed ongoing TRISO fuel fabrication work for DOE. BWXT uses a NRC Category 1 licensed manufacturing facility that supplies HEU plate fuel for five U.S. research reactors and can manufacture a variety of advanced fuels. For the past ten years, BWXT has supported DOE's TRISO program by manufacturing kernels, coatings, and compacts. BWXT is currently making compacts for the next set of TRISO experiments. Mr. Richardson reiterated that fuel performance demonstration is a long process, there isn't a definitive roadmap for transitioning from experimental to commercial, and U.S. commercial sources lack material greater than 5%.

Dr. Rita Baranwal, Director of Technology Development and Application, Westinghouse emphasized the need to move fast in order to eventually deploy advanced reactors. To meet

this need, Westinghouse pursues creativity, passion for customers, and strategic execution. While Westinghouse pursues LFRs, they acknowledge challenges associated with other non-LWRs. Current regulations are geared towards LWR fuels, background science for advanced fuels is not readily available, and current public perception precludes the "try and see what happens" approach from 1950s to 1970s. The commercial climate is very risk adverse. Dr. Baranwal reiterated the 15-30 years required for novel fuel development and challenges for fabricating fuel enriched to greater than 5%. DOE funding is required for ultimate success. A fast reactor with testing loops for fuel development was suggested as well as out of pile testing facilities and leveraging the GAIN initiative. More agile and flexible testing focused on high performance products can enable commercialization.

Dr. Christina Back, Division Director, Nuclear Technologies and Materials, General Atomics presented on fuel qualification strategies for the Energy Multiplier Module gas fast reactor concept. The concept uses a 30 year fuel cycle and uranium carbide as fuel with a SiC cladding. The 30 year cycle without refuel presents the challenge of increased fuel element volatile fission product pressures due to high burn ups. Fuel performance codes must be validated for extended effects of fast flux and burnup. Dr. Back questioned whether the costs of licensing can be bounded, how much data is necessary for NRC approval, and how long a prototype first-of-a-kind would need to operate before NRC issues a commercial license. Dr. Back also reiterated the need for a staged licensing approach.

XII. Open Discussion – Day 2

Kevan Weaver was asked about the usefulness of international data for domestic fuel qualification. Dr. Weaver and the NRC responded that it depends on the quality of the data, access to testing process, and how well-defined the testing processes are.

Rita Baranwal was asked about gaining public acceptance for advanced nuclear reactors. Dr. Baranwal responded that utilities must engage customers very early on and stress that no developer plans to develop a reactor inferior to high safety standards we have today.

Jon Carmack was asked to what extent codes can help with fuel development. Mr. Carmack responded that DOE invests in advanced fuel performance modeling and simulations and sees promise in their development.

Jeffrey Schmidt was asked if liquid fuels would have to be addressed in the currently heavily LWR-based framework. Mr. Schmidt responded that NRC will communicate with DOE to see what advanced fuel designs and attributes are coming down the line to better prepare future frameworks.

Several participants also commented on molten salt cooled reactor needs. DOE currently funds solid fueled salt cooled reactor work through its university programs.

XIII. Path Forward and Closing Remarks

Deborah Jackson, NRC discussed next steps for NRC and DOE. For NRC, next steps include completing the NRC vision and strategy for advanced reactors, issuing a draft guide for ARDCs and posting draft security design considerations for public comment, developing processes for

staged licensing review and conceptual design assessments, and drafting prototype guidance. For DOE, next steps include completing the DOE Vision and Strategy for Advanced Reactors, developing technology specific working groups through GAIN, completing the Advanced Test/Demonstration Reactor study, and continuing to pursue endorsement of ASME Code Section III Division 5. Ms. Jackson stated that the NRC and DOE are working to schedule the next workshop Suggestions for the next workshop topics will be considered based on participant feedback.

Jennifer Uhle, NRC thanked the presenters and participants for their attendance. Dr. Uhle reiterated that NRC can be flexible. Non-LWR applications can come in under a design certification approach and rulemaking can be completed (e.g., AP1000 and Economic Simplified Boiling Water Reactor). Dr. Uhle emphasized the need for stakeholders to collaborate and propose appropriate requirements to NRC early on in the pre-application process.

John Kelly, DOE also thanked presenters and participants. DOE's Vision and Strategy for Advanced Reactors is achievable. The step by step approach used by DOE to deploy advanced LWRs can work for advanced non-LWRs. Stakeholders need to build upon past experiences to effectively qualify advanced fuels. Activities like GAIN can help build the public private partnership. Dr. Kelly concluded by expressing DOE's strong interest in continuing to work with NRC and stakeholders to advance non-LWRs.

The meeting agenda and a list of meeting attendees are included in Enclosures 1 and 2, respectively. All of the presentations for this workshop are available on the NRC's public web site at: http://www.nrc.gov/public-involve/conference-symposia/adv-rx-non-lwr-ws/2016/presentations.html. The agenda for the workshop is similarly available on the NRC's public web site at: http://www.nrc.gov/docs/ML1614/ML16147A011.pdf.

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SUBJECT: SUMMARY OF JUNE 7-8, 2016, DEPARTMENT OF ENERGY AND NUCLEAR REGULATORY COMMISSION CO-HOSTED WORKSHOP ON ADVANCED NON-LIGHT WATER REACTORS

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AGENDA
DOE-NRC WORKSHOP ON ADVANCED NON-LIGHT WATER REACTORS
JUNE 7-8, 2016
BETHESDA NORTH MARRIOTT HOTEL AND CONFERENCE CENTER

Tuesday, June 7, 2016		
Time	**Topic**	**Speaker**
8:30 am	Welcome and Logistics	*DOE (C. Welling)*
8:35 am	Opening remarks and objectives of the workshop	*DOE (J. Kelly)* *NRC (J. Uhle)*
8:55 am	Remarks on the development and deployment of advanced non-LWR reactor technologies (e.g., motivations, interest, challenges, opportunities)	*NRC (Chairman S. Burns)*
9:15 am	Strategies for Advanced non-LWR Development and Deployment • DOE Vision and Strategy for Development and Deployment of Advanced Reactors • NRC Vision and Strategy: Safely Achieving Effective and Efficient Non-Light Water Reactor Mission Readiness	*DOE (J. Kelly)* *NRC(J. Uhle)*
10:20 am	***Break***	
10:40 am	Utility Perspective on Development and Regulatory Support for Advanced Reactors	*Southern Company (S. Kuczynski)*
11:00 am	Recent DOE Initiatives • Test/Demonstration Reactor Planning Study • Advanced Reactor Funding Opportunity Announcement (FOA) Selection Results • Gateway for Accelerated Innovation in Nuclear (GAIN) • ASME Section III Division 5	*DOE (T. O'Connor)* *DOE (B. Robinson)* *INL (K. Pasamehmetoglu)* *DOE(B. Corwin)*
12:00 pm	***Lunch***	
1:15 pm	Recent NRC Initiatives • Regulatory Review Process Options for Advanced Non-Light Water Reactor Designs • CNSC Pre-Licensing Vendor Design Review Process • Advanced Non-Light Water Reactor Design Criteria • Licensing Novel Technologies under Existing Regulatory Framework	*NRC (D. Jackson)* *CNSC (D. Miller)* *NRC (J. Mazza)* *NRC (S. Lynch)*
2:30 pm	***Break***	

ENCLOSURE 1

2:45 pm	Industry Initiatives Panel • NEI Advanced Reactor Working Group • EPRI Gen IV Technical Advisory Group • NIC Advanced Reactors • Nuclear Innovation Alliance • Third Way	*NEI (E. Redmond)* *EPRI (A. Sowder)* *NIC (J. Merrifield)* *NIA (A. Finan)* *Third Way (J. Freed)*
4:00 pm	Remarks on the development and deployment of advanced non-LWR reactor technologies (e.g., motivations, interest, challenges, opportunities)	*DOE (Under Secretary Dr. F. Orr)*
4:20 pm	Open Discussion (including select answers to RIC advanced fuel related questions)	*All*
5:00 pm	Adjourn	

Wednesday, June 8, 2016		
Time	**Topic**	**Speaker**
8:30 am	Opening remarks and summary of Day 1 activities	*NRC (D. Jackson)*
8:35 am	Advanced Reactor Fuel Development and Qualification • Anticipated fuel types of advanced reactor concepts and known state of development. Example timeline for new fuel development and testing • Past and ongoing efforts in fuel development (EBR II, TRISO) • Current regulatory guidance on fuel system design • Fuel fabrication facility licensing	*INL (J. Carmack)* *INL (D. Petti)* *NRC (J. Schmidt)* *NRC (K. Ramsey)*
10:00 am	***Break***	
10:15 am	Advanced Reactor Fuel Challenges Industry Panel • Potential challenges associated with using current regulatory framework • Industry efforts to address issues and challenges on licensing of concepts for new fuel designs • Industry approaches on fuel development and schedule	*TerraPower (K. Weaver)* *GE (E. Loewen)* *BWXT(C. Richardson)* *Westinghouse (R. Baranwal)* *GA (T. Back)*
11:30 am	Open Discussion	*All*
12:00 pm	Summary and Path Forward • Specific actions, desired outcomes, parties involved, timetable	*DOE (C. Welling)* *NRC (D. Jackson)*

	• Potential topics for subsequent workshop(s)	
12:30 pm	Closing Remarks	*DOE (J. Kelly)* *NRC (J. Uhle)*
1:00 pm	Adjourn	

ATTENDANCE LIST
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JUNE 7-8, 2016

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Abdulla	Ahmed	UC San Diego
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Adams Jr	Alexander	USNRC
Afzali	Amir	Southern Company
Ahn	Alan	GABI
Alemayehu	Bemnet	NRDC
Alfred	Nicholas	Pegasus Group
Ali	Irfan	Innovation Reform
Allen	Todd	Third Way
Austgen	Kati	Nuclear Energy Institute
Back	Christina	General Atomics
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Baker	Suzanne	Third Way
Bales	Michelle	USNRC
Ballout	Youssef	Elysium Industries
Baranwal	Rita	Westinghouse
Basu	Sudhamay	USNRC
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Blees	Tom	Science Council for Global Initiatives
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Braase	Lori	Idaho National Laboratory
Bradford	Anna	USNRC
Bresee	James	USDOE
Brown	Gilbert	UMass Lowell
Bucknor	Matthew	Argonne National Laboratory
Burns	Edward	Public
Butterfield	Ian	Pace Government Relations
Byk	Allyson	ASME
Campbell	Patricia	GE Hitachi Nuclear Energy
Caputo	Annie	U.S. Senate EPW Committee

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Cottingham	Anne	Nuclear Energy Institute
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Davis	Edward	Pegasus Group
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Diamond	David	Brookhaven National Laboratory
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El Karfi	Saadia	Global America Business Institute
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Freebairn	William	Platts Nucleonics Week
Freel	Steven	Freelance Performance
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George	Andrea	USNRC
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Kim	Lance	Southern Research
Kingston	Micah	GPS
Kinsey	Jim	Idaho National Laboratory
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Komosinski	James	Swiss Mountain Energy Consulting
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Kuczynski	Stephen	Southern Nuclear Operating Company

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Nicklas	Rick	Northrop Grumman Mission Systems
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Paterson	Andrew	Verdigris Capital / EBI
Patnaik	Anil	University of Akron
Pavlak	Alex	Future of Energy Initiative
Petti	David	Idaho National Laboratory
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Pheil	Ed	Elysium Industries
Phuong	Luc	USNRC
Pickering	Susan	Sandia National Laboratories
Piercy	Craig	American Nuclear Society
Poore	Willis	Oak Ridge National Laboratory
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Quintenz	Jeffrey	General Atomics
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Rakovan	Lance	USNRC
Ramsey	Kevin	USNRC
Rasmussen	Scott	GE Hitachi
Ray	Sheila	USNRC
Reckley	Bill	USNRC
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Richardson	Clay	BWXT
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Wheeler	Staci	NEI
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Williams	Bradley	DOE
Wolf	Donald	Advanced Reactor Concepts, LLC
Wood	Jeff	Balch & Bingham, LLP
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Wuokko	Dale	Global Energy Management Corporation
Xu	Jim	USNRC
Yang	Yaguang	USNRC
Yeshnik	Andrew	USNRC