ISSUE STATEMENT
Decommissioning of a nuclear plant encompasses the activities necessary to terminate the radioactive materials license and to release the site for other uses. In practice, this is a complex process involving careful planning and execution to satisfy requirements imposed by regulators and other stakeholders. Past experience has shown the decommissioning process takes a minimum of eight years to complete, with an average project cost greater than $685 million. Since 1972, 115 commercial power reactors have been permanently shut down in EPRI-member countries, and of these only 13 have completed decommissioning activities. Over the next 10 years, completion of decommissioning activities are anticipated for about 20 plants, while 100 plants or more are predicted to permanently shut down. By 2026 decommissioning activities may be pending at more than 180 plants, representing potential costs in the hundreds of billions of dollars. To effectively manage this demand, research and development efforts are needed in all phases of plant decommissioning to reduce schedule and costs through improvements in process efficiency. R&D efforts are specifically needed in the areas of project planning, plant decontamination and dismantlement (D&D), waste management, and performance of site radiological surveys for release.

DRIVERS

Regulatory
All regulators require completion of decommissioning within a prescribed time period, although the period differs by country and may range from “immediately” to 60 years or longer. In many countries, public pressure demands that decommissioning be completed as soon as practicable. Due to the complexity of decommissioning, most regulatory bodies worldwide require formal submittal of detailed decommissioning plans that outline all of the activities to be performed through final release of the site. Optimally, development of these plans should start three years or more prior to plant shutdown. Once the plan is approved, the level of involvement of the regulator during decommissioning may vary. However, all regulators and other external stakeholders are keenly involved in the final radiological survey for site release, a process that has historically taken three years or longer to complete.

Decommissioning Cost and Schedule
The high cost of nuclear power reactor decommissioning is driven by the complexity of working in a radiological environment, cost of radioactive waste management and disposal, and the cost of site radiological characterization and remediation. In all of these areas, the labor costs of the skilled workforce required to perform the activities is a major cost driver. Thus, technologies and methods that reduce project schedule have a nearly proportional effect on the overall project cost. Most regulators require that funds for plant decommissioning be set aside during plant operation, and the level of required funding is determined in part by experience from completed decommissioning projects. Thus, project costs affect not only plants in decommissioning but plants that are still operating.

RESULTS IMPLEMENTATION
The principal outputs from the decommissioning technology area will be implemented through: 1) guidance documents; 2) new techniques for conduct of D&D and site characterization activities; and 3) documents that review and synthesize experience. Many plants are already in the decommissioning phase, and as noted above, 10 or more plants will enter decommissioning each year for the next 20 years. Thus, to meet these needs, there is an immediate need for research results covering all phases of plant decommissioning.

Guidance Documents
- Update decommissioning pre-planning, planning and transition guidance to incorporate experience and enhance global applicability;
- Develop guidance for operating plants to facilitate decommissioning;
- Develop guidance for optimized transfer of used fuel from wet to dry storage;
- Develop guidance for management of radioactive and hazardous waste arising from decommissioning;
- Develop guidance for process control and monitoring during decommissioning;
- Develop guidance for waste management logistics; and
- Update guidance on site radiological characterization and final site surveys to incorporate experience and enhance global applicability.
Technology Development
• Develop techniques for decontamination and characterization of contaminated concrete;
• Develop automated systems for component and concrete segmentation;
• Develop dismantlement techniques for large contaminated structures;
• Develop techniques for decontamination and recycling of radioactively contaminated materials;
• Develop techniques for radiological characterization of irradiated metal;
• Develop improved techniques for the removal, characterization, treatment and management of graphite waste;
• Develop characterization and remediation techniques for radioactively contaminated subsurface soil and groundwater; and
• Develop automated systems for site radiological characterization and surveys.

DECOMMISSIONING EXPERIENCE
• Synthesize and document relevant experience from ongoing global decommissioning planning, D&D and site release activities;
• Document experience with the development and application of D&D technologies at U.S. Department of Energy sites; and
• Evaluate and document R&D and application experience for recovery and remediation activities at the Fukushima Daiichi site.

PROJECT PLAN
The development of guidance documents will be based in large part on review of both completed and planned decommissioning activities to identify best practices, but will also consider global regulatory guidance where such guidance exists. Key partners in these efforts will include U.S. and global organizations such as NEI, IAEA and NEA/OECD, as well as utilities and decommissioning and waste treatment vendors.

Development of new and enhanced technologies for decommissioning will be guided using resources such as attendance at global workshops, literature reviews and use of technology scouts. In most cases, scoping level studies will be performed to identify candidate technologies, followed by development of promising technologies and finally field deployment. Key partners in these efforts will include other EPRI programs, utilities, universities, national laboratories, the U.S. DOE, and decommissioning and waste treatment vendors.

Consistent with past practices, decommissioning experience summaries will be developed working directly with utilities and the vendors that performed the work.

RISKS
Decommissioning is a required phase in the full life cycle of a nuclear plant. As the number of nuclear plants being shut down increases, decommissioning will become a larger and larger fraction of the overall cost to the global nuclear industry. Further, decommissioning activities will require support of a larger fraction of the skilled labor force necessary to perform work at nuclear facilities. As noted above, the magnitude of the cost of decommissioning affects the operating fleet through the influence on the decommissioning funding set-aside.

In addition to economic considerations, public policy influences in most countries mandate that plant decommissioning be completed expeditiously both to repurpose the land occupied by the plants and to mitigate perceived risks. Further, both public pressures and limitations on waste disposal site capacities mandate that waste generation be minimized.

To optimize nuclear plant decommissioning, concerted efforts through technology development and enhancements can lead to process efficiency improvements. A natural outcome of these efforts will be reduced project costs, reduction in the time from plant shutdown to completion of decommissioning, and reduction in waste generation. In all cases, the commitment to nuclear and personnel safety must be maintained.

While individual decommissioning projects are not at risk if this research is not completed, the cumulative benefits to the nuclear industry for future decommissioning projects could be at risk.
RECORD OF REVISION
This record of revision will provide a high level summary of the major changes in the document and identify the Roadmap Owner.

<table>
<thead>
<tr>
<th>REVISION</th>
<th>DESCRIPTION OF CHANGE</th>
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| 0        | Original Issue: August 2014  
Roadmap Owner: Richard Reid |
| 1        | Revision Issued: December 2015  
Roadmap Owner: Rick Reid  
Changes: Update plant shutdown and decommissioning status in the Issue Statement; and revised Visio chart to reflect current R&D progress |
| 2        | Revision Issued: December 2016  
Roadmap Owner: Rick Reid  
Revision Summary: Update plant shutdown and decommissioning status in the Issue Statement; add process control and monitoring, waste management logistics, and used fuel transfer as topics for guidance; and revise Visio chart to reflect current R&D progress |
Decommissioning Technology

Utilities
- Document Experience with Key Decommissioning Activities
  - Technology Demonstration
  - Technology Deployment
  - Complete assessment of technology needs

Decommissioning Program
- Technology Development: Concrete Management, Metal Waste Characterization and Management, Automation of Reactor Internals Segmentation
- Technology Development: Automation of Site Characterization, Concrete Decontamination
- Experience Reports: Zorita RVI Segmentation, Chooz A Chemical Decontamination, Zion, Zorita
- Experience Reports: Humboldt Bay, Fukushima Dai-ichi
- DOE, NEA/OECD and Vendor Technology Evaluation
- Adaptation and Deployment of Externally Developed Technologies

Global Regulators
- NUC_FRP_02_R8 Mitigation of Fuel Failures by Foreign Material.vsd December 2016
  - Develop Regulations for Operational to Decommissioning Transition
  - Develop Site Release Criteria

NEI/IAEA
- Support Development of Operation to Decommissioning Transition Guidance
- Support Development of Site Release Criteria

Vendors
- Decontamination and Dismantlement Technology Development

DOE/OECD
- Decontamination and Dismantlement Technology Development

Legend
- Key Milestone
- Completed Milestone
- Funded Work
- Unfunded Work

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