ISSUE STATEMENT

To retain nuclear energy as an important electricity generation option in a carbon-constrained future, nuclear power must overcome critical challenges in capital cost, natural uranium resource utilization, waste disposal, and proliferation while maintaining its current safety and reliability record. Overcoming these challenges will require “advanced fuel cycles.” In the next few years, important research and development planning decisions must be made in order to have real nuclear technology options available at the time and scale needed to make a difference. These decisions (or lack thereof) will necessarily have long-term implications for the nuclear industry with respect to the evolution of the nuclear fuel cycle, i.e., what types of reactors and nuclear fuels can be deployed, the time frame over which these technologies can be commercialized, how commercial spent nuclear fuel can be managed, and what methods are available for disposing used fuel and other high level waste.

DRIVERS

Economics and Sustainability

Continued and expanded use of nuclear power may be predicated on improved economics and sustainability. These developments may require evolution of the present nuclear fuel cycle to provide a more flexible framework that can adapt to changes in technology and national policy. The technical and economic conditions for breakthrough of these advanced technologies are challenging, as they encompass not only reactors, but also dedicated reprocessing, fuel fabrication, and waste disposal facilities. Their competitiveness may be anticipated on paper, but it will eventually have to be proven by experience prior to wide-spread implementation by the nuclear industry.

Policy Uncertainty

In the United States, fuel cycle policies remain unclear following the demise of the Global Nuclear Energy Partnership (which focused national R&D priorities on actinide burning in advanced reactors for non-proliferation objectives) and the termination of the Yucca Mountain repository program. These developments mean that commercial used nuclear fuel in the United States can, with few exceptions, only be stored at the reactor sites where it was generated. This dilemma is shared by EPRI’s members outside the United States without national centralized storage or waste disposal facilities. The “Blue Ribbon Commission on America’s Nuclear Future (BRC)” established by the United States Secretary of Energy, completed its review of policies for managing the back end of the nuclear fuel cycle, including all alternatives for the storage, processing, and disposal of civilian and defense used nuclear fuel, high-level waste, and materials derived from nuclear activities. The Commission’s findings and recommendations were published in January 2012. These recommendations focused primarily on used fuel storage, transportation, and disposal issues, particularly with regard to institutional and legal arrangements, and included limited direction on fuel cycle RD&D. The predominant theme emerging from the BRC and other influential studies is one of “preserving options.” However, it is EPRI’s view that in order to truly keep fuel cycle options open for the future, those options need to be identified and defined early, and supporting RD&D efforts must be pursued on an appropriate timeline.

Advanced Technologies

Many different fuel cycle options have been considered. Some of them represent dramatic changes compared to the light- or heavy-water reactor systems with which the nuclear industry is currently familiar. What works on paper, however, does not necessarily work on an industrial scale in the context of efficient power generation. The impact of complex fuel cycles on power operation is generally lacking in existing analyses, which typically focus on natural uranium utilization, waste minimization, and non-proliferation. Therefore, the path toward economic implementation of advanced technologies by the nuclear operators requires careful consideration.

RESULTS IMPLEMENTATION

Success will ultimately be measured in terms of the extent to which ideas from EPRI and its membership inform the RD&D programs pursued by governments and other relevant entities in the United States and abroad. On behalf of EPRI’s membership, EPRI is positioning itself as a collaborative thought center for advanced fuel cycle modeling and analysis, enabling and enhancing productive discussion, interaction and collaboration among government, academia, and industry. EPRI is also leading and supporting the evolution of key model and assessment tools through the establishment of (or leadership in existing) user groups.

EPRI is not, nor should be, in a position to lead global efforts to develop a closed fuel cycle; the lion’s share of the R&D will be borne by governments or private industry. The use of EPRI tools will identify technology gaps, risk trade-offs, and
implementation issues to inform decision-makers about benefits and drawbacks of proposed advanced fuel cycle scenarios. EPRI will work closely with organizations such as the U.S. Department of Energy to provide input to the R&D plans for these organizations such that their plans result in realistic and economic options for the nuclear industry. EPRI has initiated an annual workshop series on nuclear fuel cycle RD&D assessment with a view to making this a leading venue for information exchange and collaboration among key international stakeholders.

**PROJECT PLAN**

Key EPRI capabilities emerging from advanced fuel cycle RD&D will provide the following for the nuclear industry:

1. A reasoned, transparent, traceable basis for evaluating fuel cycle options that have the potential for future deployment. Identification of the required steps for transitioning from light- or heavy-water reactor technologies to advanced fuel cycles through the deployment of new technologies will be documented.

2. The capacity to independently evaluate the benefits and drawbacks of fuel cycle options over time in terms of economics and material and energy flows.

3. Independent assessment of impact on human health and on the environment arising from nuclear fuel cycle options and scenarios.

4. A straightforward metric for evaluating the nonproliferation and security risks associated with fuel cycle options.

EPRI is delivering these capabilities through a suite of assessment tools based on a platform of software, simplified relationships, and a structured decision-making framework. EPRI is pursuing phased development of this nuclear fuel cycle assessment toolkit with an emphasis on flexibility and adaptability to anticipate the evolution of technology, policy, and the needs of EPRI members. The core theme of project execution is collaboration with the intent of leveraging the resources and expertise of other entities, notably the U.S. Department of Energy, the national laboratories, key utilities and technology vendors. EPRI will retain responsibility for maintenance and use of the toolkit, which is expected to evolve based on end-use member experience.

EPRI is now targeting application of its Decision Framework, related tools, and expertise developed under this roadmap to assess the full set of Generation IV reactor technologies (and supporting nuclear fuel cycle technologies) to develop and prioritize a set of desirable technology attributes from a utility perspective to inform deployment-focused nuclear RD&D planning to ensure utilities (and society) have real nuclear energy options if and when they are needed at the scale needed for continued access to safe, reliable, affordable electricity via a flexible, resilient, and interconnected power system.

**RISKS**

**Risk**
The long-term strategic nature of this program may render it less attractive relative to projects with shorter time horizons and payoffs.

**Mitigation**
EPRI will engage decision-making and decision-informing entities at the highest levels to demonstrate the value and relevance of EPRI work in the international community pursuing RD&D for commercialization of advanced fuel cycle and reactor technologies.

**Risk**
Given the relatively modest resources available to EPRI for its work program and the enormity of the task at hand, failure of EPRI to maintain and strengthen its collaborative ties with key partners, such as the U.S. DOE and industrial and national R&D organizations, could limit the relevance and effectiveness of the EPRI contribution for the benefit of the nuclear utilities.

**Mitigation**
EPRI will continue its independent, high-quality fuel cycle assessments to maintain its technical credibility and standing among peer organizations. One of the most important products of this work is the development of in-house and contractor expertise, which can be drawn upon by EPRI and its members to evaluate government and industry RD&D proposals and technically inform the public debate of such efforts. Maintaining this expertise is expected to require a lower funding commitment than is needed to support the current program of assessment tool development. In light of the funding level required to conduct technology development and demonstration, on the order of 10's to 100's of millions of dollars annually, EPRI provides the potential for very high degree of leverage for its research investment.
## 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>
</tr>
</thead>
</table>
| 0        | Original Issue: August 2011  
Roadmap Owner: John Kessler |
| 1        | Revision Issued: December 2011  
Roadmap Owner: Andrew Sowder  
Changes: Addition of explanatory text to second Mitigation statement under Risk section. |
| 2        | Revision Issued: August 2012  
Roadmap Owner: Andrew Sowder  
Changes: Update of section on Policy Uncertainty to reflect completion of Blue Ribbon Commission study and ongoing policy uncertainty in the U.S. Added reference to the establishment of an EPRI nuclear fuel cycle assessment workshop series. |
| 3        | Revision Issued: December 2012  
Roadmap Owner: Andrew Sowder  
Changes: Minor updates to Results Implementation section to reflect progress from planning to implementation of project. Major revisions to roadmap completed for greater clarity and simplification. Key modifications include truncating timeframe to 2030, eliminating cross connection indicators, introduction of new nomenclature for recurring events (open circle with capital letter), and elimination of less significant “swim lanes.” Minor revisions to roadmap to reflect internal (i.e., project) and external developments, including new, delayed, or completed deliverables, changes in projected timelines for activities, and anticipated changes in funding status for certain elements. |
| 4        | Revision Issued: August 2013  
Roadmap Owner: Andrew Sowder  
| 5        | Revision Issued: August 2014  
Roadmap Owner: Andrew Sowder  
Changes: Major changes to roadmap for clarity (through simplification) and to reflect better defined products from and end-states for the work. Several swimlanes were combined and references to key external activities and entities were substantially reduced to focus on primary players and emphasize key areas of interest. |