THE U.S. NUCLEAR ENERGY INDUSTRY'S

Strategic Plan for Advanced Non-Light Water Reactor Development and Commercialization

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Strategic Plan for Advanced Non-Light Water Reactor Development and Commercialization

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Advanced Non-Light Water Reactors: Positioning for the Future

Long-Term Vision for Nuclear Energy

America's nuclear power plants are operating at world-class levels of safety and reliability and by the 2030s are supplying an increasing amount of carbon-free energy for electricity and industrial uses. American industry maintains a leadership role in the development, demonstration and operation of both light-water and non-light water nuclear technologies for energy production and U.S. reactor designs are recognized as the most innovative available.

Strategic Goals for Advanced Non-Light Water Reactors

1. Two or more advanced non-light water reactor designs are commercially available (ready to build) in the U.S. in the 2030-2035 timeframe.
2. Demonstrations of one or more advanced non-light water reactors occur in the U.S. by 2025.
3. A licensing framework exists to facilitate the efficient and predictable deployment of advanced technologies, provides continued international credibility to U.S. designs, and encourages continued private-sector investment.

Advanced Non-Light Water Reactors have potential as a strategic energy technology to supplement the existing light water reactor technologies that provide reliable, clean carbon-free, affordable electricity generation. In addition, the advanced reactor technologies have the potential to supply other sources of diverse energy products (e.g., process heat and hydrogen for automobiles) due to their operating characteristics.

Even at less than 1 percent annual growth in electricity demand, the U.S. Energy Information Administration forecasts a need for 287 gigawatts of new electric capacity by 2040 in the United States. This new capacity will be in addition to the capacity to be replaced as a result of age related or regulatory driven retirements. The current fleet of 99 operating light water reactors will reach 60 years of operating life between 2029 and 2055 and approximately 35% of all of the generating capacity in the United States is currently 31 to 50 years old. By 2030, a significant portion of the existing generation capacity will likely need to be replaced. Currently there are four new Westinghouse AP1000 reactors under construction in the United States and a fifth reactor, Watts Bar Unit 2, will come online in 2016. Building additional nuclear power plants at an accelerated pace will be essential to avoid an increase in carbon emissions in the next few decades.

The issue of carbon emissions brings added attention and urgency to the development and deployment of large light water reactors (LWRs), small modular light water reactors (SMRs), and advanced non-light water reactors. The 2015 International Energy Agency/Nuclear Energy Agency Technology Roadmap: Nuclear Energy calls for more than doubling installed worldwide nuclear generating capacity to 930 gigawatts, from 396 gigawatts, by 2050 in order to cut energy-related carbon emissions by half and try to meet the goal of limiting global temperature increases to just 2 degrees Celsius by the end of the century (IEA's 2-degree scenario). The IEA/NEA report also says that annual connection rates should increase to well over 20 gigawatts of nuclear generation during the coming decade to try to reach the capacity targets. Advanced reactors, with simplified designs and increased inherent safety, have the potential to facilitate a rapid growth in nuclear power and to impact the energy sector with carbon free technology beyond simply electricity generation.

The nature of energy generation, transmission and consumption is also expected to change dramatically by the middle of the century. Interest in renewable and distributed generation, trends toward lower carbon emissions, long-term supply of low-cost natural gas, and the potential for emerging energy economies that do not rely on electricity are expected to create new opportunities for energy production in the future. It is reasonable to expect that existing generation technologies will continue to improve, and new disruptive technologies that are today unknown will emerge to capitalize on these opportunities.

The commercial nuclear power industry in the U.S. is preparing to address the coming energy generation opportunities. The industry is constantly looking at new technologies to provide the desired capacity, reliability, and optionality that will meet the needs for the future. Advanced large light water technologies are commercially available now, as seen with the construction of four Westinghouse AP1000 reactors in the U.S. and the NRC certification of the General Electric ESBWR design. Small modular light water reactors are on track to provide important optionality by the mid-2020s for smaller scale deployments that are well suited for more moderate demand growth and re-powering retired fossil plants. Advanced non-light water reactors with their expected higher temperature output, alternate uses in addition to electricity generation, inherent passive safety features, and variable size (from a few MWe to 1000+ MWe) will further the innovation in the nuclear power industry and must be commercially available by the early 2030s to meet future energy needs.

Major Challenges to Advanced Reactor Development

Advanced non-light water nuclear technologies must be developed now, with a higher sense of urgency, to provide optionality for future customer needs as the energy landscape changes over the next few decades. Although dates like 2030 and 2035 seem like a far-distant future, in the world of electric power planning, they are not. Given the lead times necessary to certify a generic design, license a specific site, and fabricate and build new generating capacity, planning for that capacity must begin soon.

The uncertainties associated with designing, licensing, constructing, testing, and operating first-of-a-kind technologies present major challenges to deployment. As with any large commercial project, designing and licensing reactors is a capital-intensive proposition. While licensing conventional light water reactors is challenging and time consuming, licensing an advanced reactor is currently even more challenging because the existing regulatory framework is, understandably, “light-water centric.” The existing regulatory structure, while good at protecting the public health and safety, is not designed in a way that facilitates innovation or encourages private investment. The structure would benefit from modernization including the establishment of a more technology inclusive, risk-informed, and performance-based framework. In addition, establishing meaningful regulatory milestones through a staged regulatory process could be helpful for advanced reactor designers when securing additional funding. Such milestones, providing incremental assurance of licensability, would benefit all stakeholders as investment of human capital and financial resources could be more efficiently managed commensurate with the pace of decisions from NRC.

Due to the capital expense and long service life expected of a nuclear reactor, electric power utilities and other commercial entities may want to see a demonstration of a particular technology, prior to purchase, to prove that it is both technically suitable for the intended application and can be cost competitive. There are numerous advanced reactor technologies under consideration by the industry (e.g., molten salt liquid fueled, liquid metal coolants, high temperature gas) with different levels of maturity. For example, gas cooled reactors have been commercially deployed to a limited degree, mostly internationally, for decades. Thus, demonstrating technology, potentially at a reduced scale, may be useful in establishing baseline expectations for some of the less mature advanced reactor technologies. Ultimately, an NRC action (combined license, design certification, etc.) for a final commercial design is necessary and any demonstrations of technologies should support eventual commercialization of the advanced reactor.

Foreign governments are providing significant funding to develop advanced reactor designs with the hopes of leading in the export market. For the U.S. industry, federal government support is essential to reduce financial risk of the first movers, accelerate commercialization of advanced reactors, and maintain American competitiveness. Public private partnerships are essential to prevent erosion of U.S. leadership in the nuclear sector and to enable innovative technologies to be matured through research, testing and first-of-a-kind deployment. Federal support has made a difference in the development and deployment of advanced light water reactors and small modular reactors. The Department of Energy's (DOE) successful Nuclear Power 2010 program provided funding for large advanced light water reactor technology, resulting in the design and certification of the Westinghouse AP1000 reactors, now under construction in the United States and China, and the General Electric Economic Simplified Boiling Water Reactor (ESBWR). The 2012 DOE Licensing Technical Support cost-share program is providing necessary funding for SMR development and the January 2016 DOE advanced reactor funding awards, with up to $80 million cost-share for two companies over five years, are a good first step toward federal support of advanced reactor development. However, an expanded federal program will be required for successful advanced reactor development and commercialization. Furthermore, a variety of innovative concepts is vital to a competitive market that can meet diverse customer needs and, as such, both SMR and advanced reactor development programs should be funded.

The commercial nuclear power industry is committed to addressing the challenges to advanced reactor development.

Purpose and Organization of this Strategic Plan

The goal of this strategic plan is to provide guidance and support for advanced non-light water reactor designers/owners/operators, with a focus on deployment and the institutional factors necessary to develop the next generation of plant designs. The Advanced Reactor Strategic Plan is design-neutral and will be updated as needed.

This Advanced Reactor Strategic Plan creates a roadmap of the programs and actions necessary to ensure that advanced reactors are commercially available to provide additional clean energy options to meet the environmental, economic, and energy security goals of the United States in the 2030-2035 timeframe.

The Plan:

- Sets industry goals for demonstration and commercialization of advanced reactor technologies.
- Identifies the most significant enabling conditions that must be addressed to achieve the goal.
- Assigns actions and responsibilities to the appropriate organizations to develop and implement the various parts of the strategic plan.
- Fosters joint, coordinated efforts between governments at all levels, industry (including entrepreneurs, startups and the supply chain), and the financial community to enhance implementation of the Plan and ensure sharing of resources where appropriate.

The Plan is structured as a series of building blocks. Taken together, these building blocks form the foundation on which the successful development of advanced reactors can occur. Each building block represents a major area that requires focused and coordinated attention and includes an action plan, with a list of organizations responsible for implementing parts of the building block and providing input and assistance.

The Strategic Plan includes the following seven building blocks:

1. Communicating and advocating the potential strategic benefits of advanced non-light water reactors and the need for successful development.
2. Ensuring an efficient and predictable regulatory framework appropriate for advanced non-light water reactors.
3. Defining generic research, design and operational requirements.
4. Broadening federal and state government support.

5. Financing design, development and deployment.
6. Developing a fuel cycle appropriate for advanced non-light water reactors.
7. Demonstrating that advanced non-light water reactor technologies are commercially viable.

Building Block 1

Communicating and Advocating the Potential Strategic Benefits of Advanced Non-Light Water Reactors and the Need for Successful Development

Key Objectives

- Governments, industry, non-nuclear customers, and the public support and encourage the development of advanced reactors.
- Governments, industry, and the public continue to support the existing fleet of LWRs and the development/deployment of SMRs while advanced reactors are being developed.
- A strong third-party advocacy network is aligned with industry's goals and is instrumental in influencing key stakeholders.

Purpose

The industry must convey the importance of advanced reactors as part of a portfolio of clean energy options for the future that includes SMRs and current large LWRs such as the Westinghouse AP1000. Advanced reactors are not 50 years away from commercial deployment nor are they 10 years away. Decisions and investments must be made now if advanced reactors are to be available in the 2030-2035 timeframe. While this building block outlines a broad communications plan, additional communications deliverables will emerge as the industry works through various regulatory and policy issues.

Responsible Organizations

- Nuclear Energy Institute
- Advanced reactor designers
- Owner/operators

Stakeholders

- U.S. Nuclear Infrastructure Council
- Nuclear Innovation Alliance
- American Nuclear Society
- Third Way
- Other NGOs

Action Plan

1.1 Build a coalition of thought leaders to carry key industry messages.

1.2 Develop common messages for all stakeholders (e.g., advanced reactor designers, utility, and associations) including the relationship between large LWRs, SMRs, and advanced reactors.

1.3 Identify key audiences and opportunities to influence those audiences.

1.4 Ensure advanced reactor messaging is integrated into current and future industry lobbying activities.

1.5 Develop and execute a communications plan for advanced reactors.

Building Block 2

Ensuring an Efficient and Predictable Regulatory Framework Appropriate for Advanced Non-Light Water Reactors

Key Objectives

- The regulatory framework enables the certification of designs and licensing of advanced reactors and associated fuel cycle facilities in an efficient and timely manner.
- The regulatory framework facilitates reliable and cost effective construction, maintenance and operation of advanced reactors.
- Regulatory milestones are implemented to support the continued investment of capital in advanced reactor development.

Purpose

It is vital that applicants have confidence in the stability of the regulatory framework such that design approvals and licenses can be obtained in a predictable and cost-effective manner. The current regulatory regime is light water reactor centric and there is significant uncertainty over its usefulness to certify an advanced reactor design or license an advanced reactor in an efficient and timely manner. A technology inclusive risk-informed and performance-based regulatory framework that also provides an option for a staged regulatory process, with appropriate milestones, would increase the confidence of project stakeholders as the project progresses.

Responsible Organizations

- Nuclear Energy Institute

Stakeholders

- Owner/operators
- Advanced reactor designers
- Electric Power Research Institute
- U.S. Nuclear Infrastructure Council
- Nuclear Innovation Alliance
- Standards organizations

- Gateway for Accelerated Innovation in Nuclear

Action Plan

2.1 Define timelines for industry's plans to demonstrate and commercialize advanced reactors, and identify the need-by dates for regulatory framework enhancements.

2.2 Modernize the current light water reactor centric regulatory framework to be as technology inclusive, risk-informed, and performance-based, as appropriate, to support efficient and timely regulatory reviews.

2.3 Identify and work to establish a staged regulatory process that will provide meaningful milestones based on NRC actions/decisions and will increase confidence and reduce risks for project stakeholders.

2.4 Identify and work to resolve generic regulatory policy issues that must be addressed to facilitate efficient NRC technical and safety reviews of advanced reactors (e.g., need for containment function versus a containment structure).

2.5 Engage with and leverage the DOE and NRC effort to define Design Criteria for advanced reactors.

2.6 Identify and work to ensure that NRC has the resources necessary to modernize the regulatory framework for advanced reactors.

2.7 Determine the role of/need for prototype, test, and demonstration reactors for commercialization of advanced reactors.

2.8 Develop an industry consensus on the use of NRC research and test reactor licensing process for demonstration reactors.

2.9 Develop a program to assist advanced reactor designers in navigating the regulatory process and identify areas of common interest that should be addressed generically.

2.10 Engage with and leverage the SMR Working Group activities to address regulatory issues that also affect advanced reactors (e.g., emergency preparedness, source term, physical security).

2.11 Leverage international advanced reactor regulatory efforts and programs to support the domestic efforts.

Building Block 3

Defining Generic Research, Design and Operational Requirements

Key Objectives

- Research to support commercialization has been identified and is being addressed.
- A comprehensive set of user criteria/expectations for the performance of advanced reactor demonstration and commercial advanced reactors is identified.
- New and innovative applications for the use of nuclear energy based on the possibilities created through advanced generation technologies are identified.

Purpose

Advanced reactor technologies are at different levels of maturity and some will require additional research, development, and demonstration before commercialization. A well-focused research effort will be essential to commercializing the technology in a timely manner. Since advanced reactors have the potential to provide services beyond electricity generation and have different operating characteristics relative to light-water reactor designs, the desired owner/operator attributes may be different than for light water reactor technologies.

Responsible Organizations

- Electric Power Research Institute
- Gateway for Accelerated Innovation in Nuclear

Stakeholders

- Department of Energy
- Advanced reactor designers
- Owner/operators
- Standards organizations, e.g., ANS, ASME
- Nuclear Energy Institute

Action Plan

3.1 Identify and document owner/operator desired attributes for advanced non-light water reactor safety, design, construction and operation. Attributes identified contribute to optimizing advanced design features, and design standardization. These attributes may differ for a demonstration machine or the final commercial product.

- Owner/operator requirements document for non-light water demonstration reactors and programs
- Owner/operator requirements document for commercial non-light water reactors

3.2 Identify research gaps that must be addressed to support licensing and commercialization, e.g., material code cases, material control and accounting (MC&A) requirements for liquid fuel machines. Prioritize the most significant gaps to address either generically or on a technology centered basis.

3.3 Identify facilities for carrying out the necessary research for demonstrating reactor technologies, including national laboratories, private facilities, and international partners. Assess the advantages of each, e.g., research capabilities, environmental considerations, geographic location.

3.4 Identify gaps in the capabilities of domestic research facilities.

3.5 Identify the opportunities for future energy generation and the potential roles that advanced reactors can serve.

3.6 Leverage international advanced reactor research efforts.

Building Block 4

Broadening Federal and State Government Support

Key Objectives

- Federal and state policymakers implement policies and programs that support and encourage the development of advanced reactors (e.g., financial support, access to national lab resources).
- There is strong bipartisan support for the development of advanced reactors.
- The role of the federal and state governments in demonstrating advanced reactor technologies is defined.

Purpose

Advanced reactors enjoy increasing bipartisan support, but federal and state policymakers have not yet implemented policies that strongly support the development of advanced reactors. The industry must undertake a campaign to persuade federal officials to support the development of advanced reactors. This federal-level campaign would include Congress, the administration and various government agencies.

Responsible Organizations

- Nuclear Energy Institute

Stakeholders

- Advanced reactor designers
- Owner/operators
- Department of Energy
- Electric Power Research Institute
- US Nuclear Infrastructure Council
- Nuclear Innovation Alliance
- American Nuclear Society
- Third Way
- Other NGOs

Action Plan

4.1 Develop an industry vision for a pathway to commercialization of advanced reactors, including demonstration where appropriate (e.g., the role and framework for public private partnerships, funding and direction to DOE and NRC).

4.2 Identify congressional action necessary to achieve industry vision for a pathway to commercialization of advanced reactors.

4.3 Advocate with all appropriate stakeholders for desired congressional action.

4.4 Support increased funding for advanced reactor development, design certification, licensing, and commercialization without impacting funding for SMR commercialization efforts.

Building Block 5

Financing Design, Development and Deployment

Key Objectives

- A financing infrastructure, including the investment community, private investment, federal and local governments, and international sources, that can support both demonstration and commercialization of advanced reactors is in place by 2019.
- Develop energy markets that value the new energy products that advanced reactors are capable of producing.
- Energy markets appropriately value and allow full realization of the benefits of nuclear and the unique characteristics of advanced reactors.

Purpose

Innovation is essential for commercial viability and survivability of any technology. However, developing new and innovative nuclear reactor designs is a lengthy, complex and costly undertaking. Therefore, business reality dictates that a cost-shared program, with a substantial federal contribution, is essential.

Current cost estimates to complete licensing work and design finalizations for light water reactors can vary widely – anywhere between $600 million and $1 billion per design. While the cost structure for advanced reactor designs is currently less certain, it is imperative to plan to address financial challenges similar to those facing the LWR community.

Responsible Organizations

- Nuclear Energy Institute
- Advanced reactor designers

Stakeholders

- Owner/operators
- Venture capital groups/financiers
- Department of Energy

Action Plan

5.1 Identify the unique role of private capital in the development of advanced reactor designs and how best to augment or support private capital with a government program.

5.2 Define a public private partnership arrangement appropriate for advanced reactor development by privately held companies and investor owned companies.

5.3 Define the appropriate level of federal program support for advanced reactor research and development.

Building Block 6

Developing a Fuel Cycle Appropriate for Advanced Non-Light Water Reactors

Key Objectives

- The front-end of the fuel cycle (e.g., enrichment, conversion, transportation, fabrication) is capable of serving a diverse set of advanced reactor technologies.
- The back-end of the fuel cycle is capable of serving a diverse set of advanced reactor technologies.
- Fuel cycle infrastructure is in place in time to support commercial deployment of advanced reactor technologies.
- Advanced reactor technologies improve the efficiency of the nuclear fuel cycle.

Purpose

The three primary advanced reactor technologies – molten salt, liquid metal, and high temperature gas – all differ significantly from each other and from light water reactor technologies in terms of fuel type, fabrication, and used fuel management options. In regards to fuel management, some technologies may utilize separations and recycling of fissile material, online refueling and online processing of fission products. In addition, advanced technologies may utilize enrichments that are higher than currently used in the light water reactors. Since advanced reactor fuels are not commercially available in the United States, fuel qualification will pose a significant challenge. Fuel cycle issues will have to be addressed appropriately to support commercialization.

Responsible Organizations

- Electric Power Research Institute
- Nuclear Energy Institute

Stakeholders

- Advanced reactor designers
- Owner/operators
- U.S. Nuclear Infrastructure Council
- Department of Energy
- Gateway for Accelerated Innovation in Nuclear

Action Plan

6.1 Identify and address issues/challenges with fuel cycle and fuel design analysis and fuel validation including modeling and simulation.

6.2 Identify and address issues/challenges with fuel testing facilities including quality assurance.

6.3 Develop a fuel supply plan, including source for initial core and subsequent cores.

6.5 Identify and address issues/challenges associated with enrichment, conversion, transportation and fabrication of fuel with enrichments greater than 5% (e.g., cask certification plans, criticality controls, etc.).

6.6 Identify and address issues/challenges associated with back-end of the fuel cycle (e.g., on-line processing of fission products).

6.7 Develop appropriate material control and accounting capabilities applicable to advanced reactor technologies (including separations and waste management).

Building Block 7

Demonstrating that Advanced Non-Light Water Reactor Technologies are Commercially Viable

Key Objectives

- Advanced reactor technologies are demonstrated to be technically viable.
- Advanced reactor technologies are demonstrated to be cost-competitive with other forms of energy generation.
- Advanced reactors and their key components can be fabricated and constructed by a diverse and robust supply chain.

Purpose

Due to the capital expense and long service life expected of a nuclear reactor, electric power utilities and other commercial entities are unlikely to purchase a particular advanced reactor design without confirmation that the technology is commercially viable. Successful test and demonstration of the technology or specific design would provide proof of technical suitability for the intended application and cost competitiveness. It is reasonable to expect that the supply chain for advanced reactors will be largely similar to that which serves the light water reactors. However, the supply chain will need to accommodate new technologies, which may require the addition of new manufacturing processes and capabilities.

Responsible Organizations

- Advanced reactor designers
- Owner/operators
- Nuclear Energy Institute

Stakeholders

- Nuclear supply chain companies
- U.S. Nuclear Infrastructure Council
- Electric Power Research Institute
- Venture capital groups/financiers
- DOE/USG manufacturing support

Action Plan

7.1 Advanced reactor developers test and demonstrate their technology or designs in order to provide the certainty needed, by investors and potential customers, on the technical capabilities and expected costs for construction and operation.

7.2 Address policy issues related to key advanced reactor equipment, components and structures.

7.3 Establish R&D partnerships for advanced design, assembly and methods for manufacturing.

7.4 Investigate joint ownership of key component facilities as public-private partnerships among states/localities and industry – e.g., shipyards.

7.5 Industry conducts studies of relevant manufacturing techniques that improve quality and economics of advanced reactor equipment, components and structures.

7.6 Industry solicit DOE cost-share or private funding for projects demonstrating advanced manufacturing and fabrication techniques.

Conclusion

Advanced reactors must be recognized as an essential part of future U.S. energy generation. This strategic plan creates a roadmap of the programs and actions necessary to ensure that advanced reactors are available to provide a clean energy option to meet the environmental, economic, and energy security goals of the U.S in the 2030-2035 timeframe. This plan is dynamic and will be updated periodically to respond to the current state of the advanced reactor industry and the budget and political realities that affect advanced reactors.

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