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Advanced Nuclear Technology: Advanced Light Water Reactors Utility Requirements Document Small Modular Reactors Inclusion Summary

2014 TECHNICAL REPORT

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All or a portion of the requirements of the EPRI Nuclear Quality Assurance Program apply to this product.

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ABSTRACT

This report summarizes a project by EPRI to include requirements for small modular light water reactors (smLWR) into the EPRI Utility Requirements Document (URD) for Advanced Light Water Reactors. The project was jointly funded by EPRI and the U.S. Department of Energy (DOE). The report covers the scope and content of the URD, the process used to revise the URD to include smLWR requirements, a summary of the major changes to the URD to include smLWR, and how to use the URD as revised to achieve value on new plant projects.

Keywords
Advanced nuclear
Carbon free
Construction
New nuclear plants
Non-emitting generation
Reactor design
Small modular reactors

EXECTIVE SUMMARY

Background

A sustaining element for new nuclear plant development has been the Electric Power Research Institute (EPRI) Utility Requirements Document (URD) for Advanced Light Water Reactors. The 3500+ pages containing approximately 40,000 technical and project functional requirements in the URD constitute one of the basis documents for many of the advanced plants currently being built in the United States and internationally. When the U.S. Department of Energy (DOE) initiated efforts to enable deployment of small modular reactors (SMR) in the United States, the EPRI URD was a logical place to start. The DOE and EPRI joined together to revise the current version of the URD to include requirements for small modular light water reactors (smLWR). The project was jointly funded in equal shares with EPRI being the active agent to revise the URD to include smLWR content.

Purpose

Successful deployment of smLWR requires that they embody the safety, design, operational, and new plant project attributes that a potential owner/operator would require. This project was undertaken to identify and document those owner/operator desired attributes. An initial study concluded that most of the requirements in the URD were applicable to smLWR. Given this insight, the purpose of this project was the revision of the current URD to include additional or revised requirements unique to smLWR.

Value

The resulting Revision 13 of the EPRI URD containing smLWR requirements is of significant value to designers/manufacturers of new smLWR plants; engineering, procurement, construction (EPC) contractors of these plants; and owners/operators of the plants. Each can proceed with their scopes of responsibility working from a clearly documented common understanding of technical and project management expectations.

Benefit to the Public

The public benefits from a sound economy. A sound economy requires a reliable, cost-effective, environmentally compatible electric power supply. Successful deployment of smLWR will be a sustaining diverse non-emitting generation source for such an electric power supply. The revised URD provides a structure enabling project success, plant success, common concepts, and commercialization and deployment of smLWR.

Results of the Project

The project met its goal of detailed revision of the EPRI URD to include smLWR requirements. It caused both potential owners/operators and smLWR vendors/designers to deliberate over technical and new plant project requirements to ensure that the established requirements met the needs of the owners/operators but were also achievable by the vendors/designers.

Activity Summary

The EPRI project team reviewed in detail all 3500+ pages in the current Revision 12 of the URD containing approximately 40,000 technical and new plant project requirements. As a result, a total of 1,243 new or revised content changes of note (that is, other than editorial) were made to the current URD to create Revision 13 of the EPRI URD. This effort included not only technical experts from utilities, vendors, and engineering firms, but also industry executives who maintained oversight of the process and provided guidance on difficult and impactful topics.

Products

The final products for this project are EPRI reports 3002003129, *Advanced Nuclear Technology: Advanced Light Water Reactor Utility Requirements Document Revision 13, and 3002003130, Advanced Nuclear Technology: Advanced Light Water Reactor Utility Requirements Document (URD) Small Modular Reactors Inclusion Summary*.

The URD was created and has been developed through the last 24+ years. It represents an EPRI and industry investment in the hundreds of millions of dollars. The inclusion of smLWR into the URD has resulted in changes of note to approximately 3% of the technical and project management requirements contained in the URD. For these reasons, access to the full content of the URD itself is limited to EPRI members. This summary report is available to the DOE to be provided as they desire; it is also available for download at www.epri.com.

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1 DESCRIPTION OF THE URD

EPRI Utility Requirements Document

Following the extensive cancellations of new nuclear units and the severe downturn of new nuclear plant purchases after the Three Mile Island accident, EPRI interacted with many industry decision makers to determine what conditions and plant capabilities would allow them to consider purchasing new nuclear plants in the future. The responses revolved around regulatory certainty, plant safety and reliability, and cost-effective and timely design, construction, and operation of new nuclear plants.

EPRI assembled teams of technical experts from utilities, manufacturers, designers, and constructors who were deeply involved in the design, construction, and operation of nuclear projects during the 1970s and 1980s. EPRI also assembled a strong nuclear industry executive management team to challenge and ultimately accept the results of the technical teams. The result was the EPRI Utility Requirements Document for Advanced Light Water Reactors; Passive and Evolutionary (Active). The URD, containing tens of thousands of technical and project functional requirements, became one of the basis documents for the current AP1000, Economic Simplified Boiling Water Reactor (ESBWR), evolutionary power reactor (EPR) designs, and international variations of these designs.

The URD was then and is now a declaration of owner/operator requirements for any new nuclear plant they might purchase—large or small. It defines owner/operator expectations for organizations creating new plant designs and proposing new plant projects. This provides a potential buyer with critical content for their new nuclear plant request for proposals. It also provides criteria necessary to evaluate proposals once received. Likewise, the URD can be referenced in contracts and used as a standard to evaluate design and project performance throughout a new nuclear plant project.

The EPRI URD is a living document. It has been and will be routinely updated by EPRI to incorporate lessons learned by the industry that are important to the success of new nuclear plants. With the current revision to incorporate smLWR, the URD has been revised 13 times over 22 years. Revision 12 incorporated insights from the Fukushima accident along with many other assembled lessons learned.

The Table of Contents (TOC) of EPRI URD Revision 12 follows (the TOC for URD Revision 13 is the same):

Tier 0 – Executive Summary

Tier 1 – Policy and Top-Tier Design Requirements

Chapter 1: Overall Requirements

Tier 2 – Advanced Light Water Reactor (ALWR) Plant

Chapter 1: Overall Requirements

Chapter 1.1: Information Management System

Chapter 1, Appendix A: PRA Key Assumptions and Ground Rules

Chapter 1, Appendix B: Licensing and Regulatory Requirements and Guidance

Chapter 1, Appendix C: ALWR Cost Estimating Ground Rules

Chapter 2: Power Generation Systems

Chapter 3: Reactor Coolant System and Reactor Non-Safety Auxiliary Systems

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Chapter 11: Electric Power Systems

Chapter 12: Radioactive Waste Processing Systems

Chapter 13: Main Turbine-Generator Systems

Chapter 14: Tier 2 References

2
PROCESS TO CREATE THE SMALL MODULAR LIGHT WATER REACTORS (SMLWR) URD REVISION

Concept

During 2010 and 2011, two members of the team that wrote the original EPRI URD led an industry team that evaluated the concept of revising the current URD to include smLWR requirements. They performed a detailed review of the URD portion containing ALWR Policy and Top-Tier Requirements as a proxy for the entire URD. The team concluded, “It was recognized that the current ALWR URD provides a readily adaptable base document that has established a proven, effective approach to assemble, evaluate, and document the needed owner/operator requirements.” They identified areas requiring substantial attention as well as challenges and objectives to address concerns limiting the deployment of smLWR. This study is documented in EPRI report 1023036, *Program on Technology Innovation: Review of EPRI Advanced Light Water Reactor Utility Requirement Document to Included Small Modular Light Water Reactors*.

Guiding Principles

Based on the insights of this study, a set of guiding principles for the effort to include smLWR requirements into the EPRI URD was developed by one of the original URD team members. This set of guiding principles is included in its entirety in Appendix A of this report. The guidance set forth the 22 principles that are the core elements of the URD and modified them as needed to emphasize smLWR. It created the project team structure of a technical Core Team reporting to and being guided by an Executive Committee.

The process to be followed for identifying smLWR revisions and inclusions was established as follows:

1. Identify those existing ALWR requirements that apply directly to smLWRs. We expect that the majority of the existing requirements will apply with little or no modification.
2. Identify those existing ALWR requirements that do not apply and are not needed for smLWRs. We expect this to be a relatively small number of the overall requirements.
3. Identify those existing ALWR requirements that potentially apply to smLWRs but that require significant modification to be relevant.
4. Identify the new requirements that are needed to address the unique characteristics of smLWRs.

A significant aspect of the guiding principles is that the smLWR inclusions focus on *functional requirements*. The existing URD tended to focus on prescriptive or quantitative requirements that were built on the foundation of the many years of design, construction, and operation of the current fleet of LWRs. Because no smLWRs have been constructed or operated and few have detailed designs completed, the emphasis for inclusions would be on more qualitative *functional requirements*.

A primary assumption of smLWR inclusion into the URD is that the smLWR designers/project teams will conclude that they have achieved and/or will achieve each of the ALWR functional requirements contained in the URD. If they do not, they are to describe in detail why the requirement does not and should not apply to their design and/or project concept. If they do not comply with the stated URD requirements for any reason, the items of noncompliance are to be listed for consideration by the potential owner/operator.

Process

The URD content review and development process followed by the teams is shown in Figure 2-1. Each of the 20 URD chapters and major sections containing technical and new plant project requirements were treated through this process.

During 2012 and 2013, a separate project within EPRI accomplished a substantial review of Revision 11 of the URD to update it for recent lessons learned (that is, Fukushima and others) and to reformat it for ease of use. The resulting Revision 12 was the content that was reviewed by this process to identify and incorporate smLWR requirements.

Each chapter was reviewed line by line, requirement by requirement (all 40,000), by experts knowledgeable of and experienced with the material contained in the chapter. The subject matter experts (SME) declared each requirement to be acceptable as written for smLWR use/consideration, requiring major revision (if so, they proposed a draft revision), or requiring minor revision (if so, they proposed the revision). The SME used a project-specific writer’s guide to ensure that reviews and revisions were consistent. This was considered the *triage* portion of the review effort.

The triaged chapter was submitted to the technical Core Team three weeks prior to each scheduled face-to-face meeting for review. Five Core Team meetings were held. The Core Team was composed of 42 individuals from utilities, vendors/designers/manufactures, engineering and construction firms, consultants, and representatives from industry organizations (names of Core Team members are listed in the Acknowledgments). During the subsequent meeting, the Core Team reviewed in detail each major revision. They also scan-reviewed the minor revisions to ensure that none of these needed to be treated as major. During the review, significant discussion occurred over the concepts embodied in the proposed revisions and the wording used to address the specifics.

After Core Team review and comments, the revisions were incorporated into the chapter. During a subsequent meeting of the Core Team, the conformed chapter was reviewed with the Core Team to ensure that the final wording met Core Team expectations.

The Core Team monitored the progression of each chapter through the entire process. They maintained a listing of Project Action Items to track items needing additional attention. Topics that were complicated, impactful, and/or required Executive Committee guidance were identified for generation of a topic position paper (TPP). This allowed the Core Team to document its perspective and bases for requirements that were significant. A listing of the TPP produced during the project is included in this report as Appendix B.

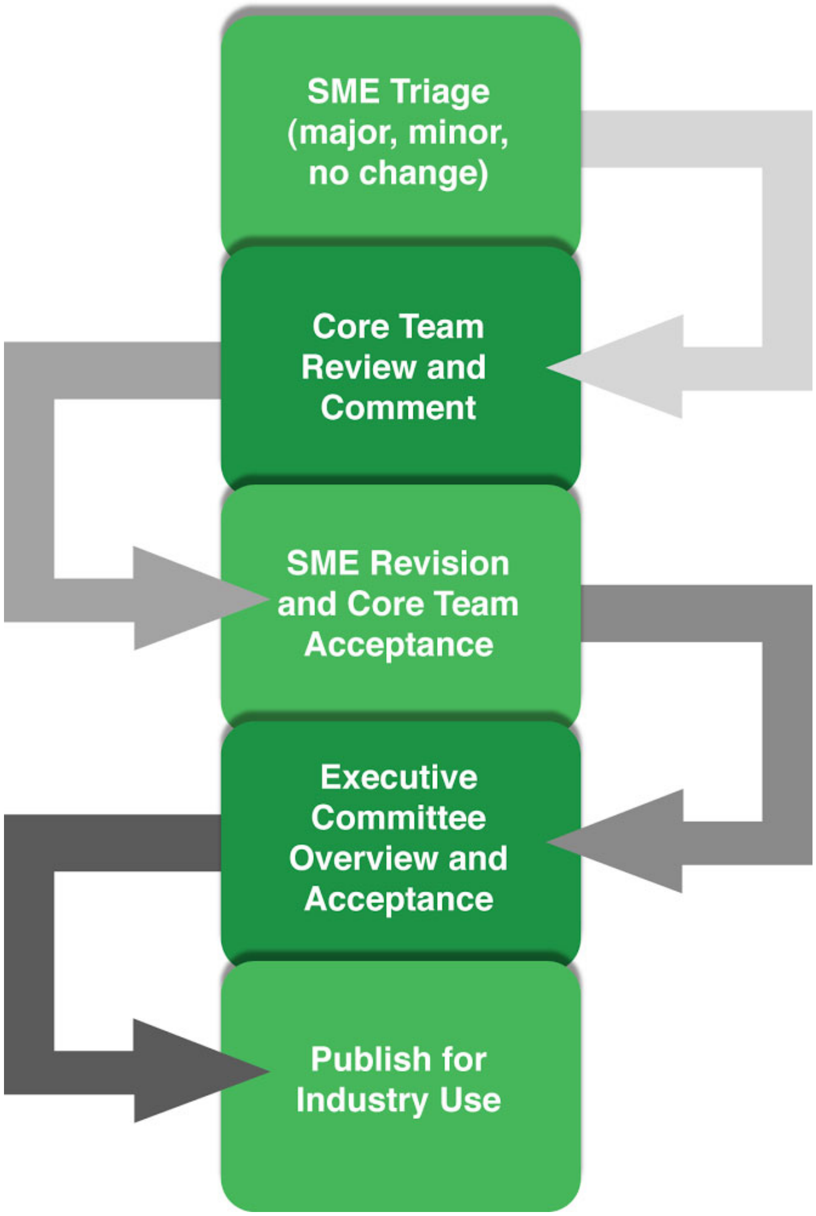

Figure 2-1
URD review process to include smLWR requirements

The Executive Committee was composed of 34 executives from utility, vendor/manufacturers, engineering and construction firms, consultants, and representatives from industry organizations (the names of Executive Committee members are listed in the Acknowledgments). With minor exceptions, there was a one-to-one correlation of organizations on the technical Core Team and the Executive Committee; that is, each executive had a corresponding Core Team member from his or her company.

Activity

The URD Revision 12 contained approximately 40,000 technical and new plant project requirements. Each of these was reviewed and commented on in a systematic, documented process. This resulted in 1,243 changes of note to the URD to include smLWR requirements. Approximately 3% of all of the requirements in the URD were revised for reasons other than editorial. The industry investment in the EPRI URD through Revision 12 has been estimated to be in the hundreds of millions of dollars. The equal sharing of the $460,000 project cost by the industry and DOE emphasizes the value each places on the work completed. The accrued value of URD Revision 13, which includes smLWR, to the industry and to the DOE effort to enable deployment of smLWR plants is substantial.

The Core Team met in session for five 2-day meetings. Each meeting involved an average of 25 people, resulting in a total of 250 person-days of fully committed Core Team participation. Each meeting involved review of triaged chapters and proposed changes, review of conformed chapters incorporating Core Team and SME final changes, and development of TPPs on issues of consequence. The Executive Committee accomplished its work through four webcasts, which included detailed review of summarized major changes to each chapter and consideration of selected TPPs to provide project guidance.

An EPRI file transfer protocol (FTP) site was established to allow Core Team and Executive Committee members easy access to chapters, TPPs, and project status monitoring material when and as generated. This provided real-time access and review opportunity for all project participants at any time.

3
DETAILED DESCRIPTION OF THE URD REVISION 13 INCLUDING SMLWR REQUIREMENTS

The URD is a large and detailed document. It includes technical requirements on many specific aspects of a nuclear plant. It also includes project management and plant operational details that are necessary for the successful design, construction, start up and continuing operation of a nuclear plant. The details of the URD are expanded below for each chapter.

The following scopes of content for each chapter are abridged. Also indicated are the number of changes of note incorporated to accomplish the inclusion of smLWR into the URD along with the primary smLWR characteristics that caused the changes. Changes of note for each chapter are summarized in Section 4 of this report.

Abridged Scope of Content for URD Revision 13

Tier 0 – Executive Summary (10 pages) – 36 changes

- Purpose of the URD
- Scope of the URD
- Listing of ALWR policies
- Summary table of top-tier design requirements

The 36 changes were summary statements related to the details discussed below for Tier 1, Chapter 1 and Tier 2, Chapter 1.

Tier 1 – Policy and Top-Tier Design Requirements

Chapter 1: Overall Requirements (56 pages) – 147 changes

- Program policy statements
  - Simplification, design margin, human factors, safety, regulatory stabilization, plant standardization, proven technology, maintainability and equipment reliability, quality assurance, economics, sabotage, and good neighbor
- Top-level design requirements
- Economic goals
- ALWR implementation

The 147 changes resulted primarily from URD inclusion of smLWR allowing shared systems, added economic goals, differences in system designs, fuel cycle length to support plant availability target, spent fuel pool capacity consistent with fuel cooling time, maneuvering and transient response, plant availability target, constructability goals, cost projections update, deployment of smLWRs, some smLWR possibly excluding large-break loss of coolant, station blackout coping of 72 hours with indefinite coping with support, smaller source term, plant availability, refueling interval 24–48 months, full-load rejection capability, spent fuel capacity based on cooling time, and construction schedule goals.

Tier 2 – Advanced Light Water Reactor (ALWR) Plant

Chapter 1: Overall Requirements (500 pages) – 54 changes

Chapter 1.1: Information Management System

Chapter 1, Appendix A: PRA Key Assumptions and Ground Rules

Chapter 1, Appendix B: Licensing and Regulatory Requirements and Guidance

Chapter 1, Appendix C: ALWR Cost Estimating Ground Rules

- Safety design
- Performance design
- Structural design
- Materials
- Reliability and availability
- Construction and constructability
- Operability and maintainability
- Quality assurance
- Licensing
- Design process
- Mechanical equipment design
- Component monitoring

The 54 changes resulted primarily from access to in-vessel components for testing, inspection, and maintenance; addressing new construction techniques; demonstrating capability of unproven technology and materials; expanded siting options; less frequent initiating events; smaller source terms and small emergency preparedness zone (EPZ); PRA differences for smLWR and lower core damage frequency (CDF) expectations; design for 60-year life; fuel cycle length and refueling sequence to support plant availability target; targets for waste generation and radiation exposure; plant availability of 95%; and use of shared systems.

Chapter 2: Power Generation Systems (162 pages) – 27 changes

- Main and extraction steam
- Feedwater and condensate
- Chemical addition
- Condensate makeup purification
- Auxiliary steam
- Backup feedwater

The 27 changes resulted primarily from some smLWR needing no backup feedwater system, requiring vendors to analyze the optimum number of feedwater heating stages, guidance and flexibility provided on the number and sizes of pumps in the condensate/feedwater systems, flexibility on the number of circulating water flow paths due to the small size of smLWR condensers.

Chapter 3: Reactor Coolant System and Reactor Non-Safety Auxiliary Systems (274 pages) – 93 changes

- Reactor coolant system
- Steam generator
- Pressurizer
- Chemical volume and control system
- Sampling system
- Reactor water cleanup system
- Passive plant reactor shutdown cooling system

The 93 changes resulted primarily from routine use of natural circulation instead of reactor coolant pumps (RCPs), planned provisions to flood the containment, smLWR performing various functions with fewer components and less piping that is, integral pressurizers and normal pressurizer spray from chemical volume and control system [CVCS]), allowing reactor coolant system (RCS) safety discharge to containment, various new integral steam generator designs, some designs not using soluble boron, and no in-containment refueling water storage tanks (IRWSTs).

Chapter 4: Reactor Systems (159 pages) – 82 changes

- Reactor vessel and internals
- Core and fuel
- Control rod drive mechanisms (CRDMs)

The 82 changes resulted primarily from refueling cavity seal applications, installation of vessel internals, neutron shielding due to less concrete, plant availability targets, and CRDMs inside of RCS boundary.

Chapter 5: Engineered Safety Systems (398 pages) – 66 changes

- Passive and active decay heat removal
- Passive and active safety injection
- Core damage prevention
- Accident mitigation
- Depressurization systems
- Emergency feedwater systems

The 66 changes resulted primarily from external flooding of the reactor vessel during RCS depressurization, some designs being able to exclude large-break loss-of-coolant accidents (LOCAs), smaller EPZs potential, reductions in rapid and large-scale core damage potential, smaller containment possibly requiring lower leak rate, use of natural circulation vs. passive safety injection (SI), and substantial containment margin.

Chapter 6: Building Design and Arrangement (202 pages) – 13 changes

- Site layout, drainage, shops, transportation
- Heating, ventilating, and air conditioning (HVAC) and radiation zones
- Primary containment
- Turbine-generator building
- Auxiliary building
- Fuel storage facility
- Technical support center
- On-site emergency response center

The 13 changes resulted primarily from below-grade structures associated with smLWRs, multiple connected units requiring simultaneous operation and startup, smLWR containment designs that are significantly different from large dry containments, most have no In-containment refueling water storage tanks.

Chapter 7: Fueling and Refueling Systems (124 pages) – 124 changes

- Fuel pools
- Cooling and cleanup of fuel pools
- Fuel handling
- Fuel storage area HVAC
- Fuel shipping and cask transfer
- Fuel receipt and inspection
- Reactor disassembly to allow fueling

The 124 changes resulted primarily from modular designs of some core concepts, underwater disassembly of portions of containment and reactor vessel components, and multiple fuel cycle options.

Chapter 8: Plant Cooling Water Systems (173 pages) – 40 changes

- Normal and emergency service water systems and equipment
- Component cooling
- Turbine building cooling
- Heat sinks
- Circulating water
- Chilled water
- Portions of fuel pool cooling

The 40 changes resulted primarily from increased sharing of cooling systems, common fuel-handling buildings among units, and alternative heat sink possibilities due to lower water demands of smaller units.

Chapter 9: Site Support Systems (188 pages) – 50 changes

- Fire protection systems
- Environmental monitoring systems
- Decontamination systems
- Compressed air and gas systems
- HVAC
- Labs

The 50 changes resulted primarily from the possibility that different process and plant facility layouts may be used by the smLWR plants to accomplish site support functions.

Chapter 10: Man-Machine Interface Systems (439 pages) – 198 changes

- Man-machine interfaces
- Operator actions
- Testability
- Maintainability
- Control station requirements
- Communications
- Data gathering and handling
- Software
- Safety and power generation systems specific to man-machine interface requirements

The 198 changes resulted primarily from maximizing the use of automation for multi-unit smLWR designs and using control room clusters requiring management of accidents/transients on one or more units while in normal operation on others.

Chapter 11: Electric Power Systems (226 pages) – 81 changes

- On-site and off-site power systems and equipment
- Medium- and low-voltage AC systems and equipment, including standby power
- DC systems and equipment
- Lighting, protection systems, grounding, cathodic protection, heat tracing, and other electrical support systems

The 81 changes resulted primarily from the smaller electrical outputs, smaller house loads, simpler designs, and shared systems of the smLWR

Chapter 12: Radioactive Waste Processing Systems (230 pages) – 57 changes

- Gaseous radioactive waste systems
- Liquid radioactive waste systems
- Solid radioactive waste systems
- On-site storage
- Mobile systems

The 57 changes resulted primarily from target liquid and solid waste generation amounts, advanced material options, mobile processing space and connections, and different layouts and system configurations.

Chapter 13: Main Turbine-Generator Systems (126 pages) – 32 changes

- Main turbine and associated systems
- Main generator and associated systems

The 32 changes resulted primarily from interchangeability of entire turbines and generators (vs. just rotors) and various potential configuration differences such as horizontal vs. vertical condensers.

Chapter 14: Tier 2 References (49 pages)

- A total of 1068 detailed references hyperlinked to the appropriate portion of the URD

4
MAJOR CHANGES TO THE URD TO INCLUDE SMLWR

As noted in Section 3 of this report, the triage process separated proposed smLWR-related URD changes into major and minor. For general discussion purposes, *minor* changes can be considered to be editorial in nature. To better understand the *major* changes (changes of note), they were further summarized to allow visibility of the specific attributes of the smLWR that drove a specific change or group of changes. These have been compiled by chapter; summaries of each chapter follow.

Executive Summary

The Executive Summary is composed of 10 (9 without references) pages of introduction, policies, and top-tier requirements. A total of 36 changes were made as a result of industry reviews and comments. The following is a brief summary of the major changes made to incorporate smLWRs into the Executive Summary of the URD:

- **Human Factors Design**. Human factors design concepts will be especially important for smLWR control rooms to allow operation of multiple units. [Section 4]
- **Proven Technology**. Noted that innovative solutions will be required for demonstrating new, unproven technology. [Section 4]
- **Factory Fabrication**. Use of factory fabrication of modules was added to the discussion of a reduced construction schedule versus previous generations of reactors. [Sections 4 and 7]
- **Size of Emergency Planning Zone**. Added top-tier requirement that core damage frequency for smLWRs should justify a smaller EPZ. [Sections 1.2.3 and 7]

Tier 1 – Policy and Top-Tier Design Requirements, Chapter 1, Overall Requirements

Chapter 1 is composed of 56 (46 without references, acronyms, and definitions) pages of technical and project requirements. A total of 147 changes were made as a result of industry reviews and comments. Following is a brief summary of the major changes made to incorporate smLWRs into Tier 1, Chapter 1 of the URD:

- **URD Expansion to Include smLWRs**. Many sections have been updated to include smLWRs. Several sections in particular were revised to specifically address expansion of the URD requirements to smLWRs or to require the designer to justify any differences. [Sections 1.1, 1.2.1, 1.2.2, 1.2.3.1, 1.2.3.3, and 2]
- **Shared Systems**. Requirement modified to note that use of shared systems may be appropriate for smLWR plants with multiple units. [Section 1.2.2]
- **Economic Goals**. Added unique economic goals for smLWRs. [Sections 2.12 and 4.2]

- **Differences in System Designs**. SmLWRs may perform design functions with systems other than those employed by traditional LWRs, or the systems they use may not include components found in traditional systems. An example is an integral reactor design that includes a pressurizer but not a pressurizer surge line. [Section 3.2.1]
- **Fuel Cycle Length**. Added that the fuel cycle length for smLWRs should support the target plant availability goal. [Section 3.2.1]
- **Spent Fuel Pool Capacity**. Added a separate spent fuel pool capacity goal for smLWRs based on required fuel cooling time. [Section 3.2.1]
- **Maneuvering and Transient Response**. Added goals for plant maneuvering and transient response for smLWRs. [Section 3.2.2]
- **Target Plant Availability**. Added a separate target plant availability goal of 95% for smLWRs. [Section 3.2.3]
- **Constructability**. Added separate plant construction schedule goals for smLWRs, which are reduced from the ALWR goals. [Section 3.3.1]
- **Cost Projections**. Complete rewrite of the cost projections section, including addition of smLWRs to the discussion. [Section 4.3]
- **Deployment of smLWRs**. Added discussion of factors favoring deployment of smLWRs in the Implementation section. [Sections 5.4.1 and 5.4.2]
- **Large-Break LOCA**. Added top-tier requirement that some smLWRs may be able to exclude a large-break loss-of-coolant accident from their design basis. [Section 7]
- **Station Blackout Coping**. Added top-tier requirement that station blackout coping for smLWRs shall be a minimum of 72 hours and indefinite with external support. [Section 7]
- **Source Term**. Added discussion that the smaller source term for a smLWR may allow for use of scenario-specific or mechanistic accident source terms. [Section 7]
- **Target Plant Availability**. Added a separate target plant availability goal of 95% for smLWRs. [Section 7]
- **Refueling Interval**. Added a separate refueling interval goal of 24–48 months for smLWRs. [Section 7]
- **Load Rejection**. Added a separate load rejection goal for smLWRs of no trip for a 100% load rejection. [Section 7]
- **Spent Fuel Pool Capacity**. Added a separate spent fuel pool capacity goal for smLWRs based on required fuel cooling time. [Section 7]
- **Constructability**. Added separate plant construction schedule goals for smLWRs, which are reduced from the ALWR goals. [Section 7]

Tier 2 – Chapter 1, Overall Requirements

Chapter 1 is composed of 500 (470 without TOC, references, and acronyms) pages of technical and project requirements. A total of 54 changes were made as a result of industry reviews and comments. Following is a brief summary of the major changes made to incorporate smLWRs into Chapter 1 of the URD:

- **Maintainability**. Added discussion that access to in-vessel components for testing, inspection, and maintenance must be considered during design. [Section 1.2]
- **Constructability/Regulatory Stabilization**. Added discussion that inexperience with new construction techniques will require the designer to balance needs of the regulator and owner. Added goal for construction duration. [Sections 1.2 and 7.2.2.2]
- **Proven Technology**. Noted that innovative solutions will be required for demonstrating new, unproven technology and materials. Qualification to be provided by a combination of experience, testing, and analysis. Potential failure mechanisms shall be addressed. [Sections 1.3, 5.2.1.1, 5.6.2, 6.2.1.4, 6.4.3, 11.2.1, 11.2.2, 11.4, 12.4.4.9, and 12.5.14]
- **Plant Siting**. Added guidance that smLWRs may be considered for sites outside the given ALWR siting envelope of design parameters. [Section 2.3.1.10]
- **Initiating Event Frequencies**. Added guidance that smLWRs modify the existing ALWR initiating event frequencies to take advantage of their advanced technologies. [Section 2.3.2.3]
- **Source Term/Size of Emergency Planning Zone**. Added discussion that smLWRs should have smaller source terms that would justify a smaller EPZ. [Section 2.5.3.3]
- **Probabilistic Risk Assessment**. Added guidance that functional sequence types for smLWRs may be different from those of ALWRs due to use of advanced technologies. Also noted that quantitative levels for smLWRs would be lower than those for ALWRs at the same distances. [Sections 2.6.4 and 2.6.6]
- **Plant Design Life**. Added guidance that while smLWRs will be designed for a 60-year life, shorter lifetimes may be appropriate for replaceable components. [Sections 3.3, 11.3.1, and 11.3.3]
- **Fuel Cycle Length**. Added statement that the fuel cycle length for smLWRs should support the target plant availability goal. [Section 3.6.1]
- **Target Values for Waste Generation**. Provided guidance for developing target values for the amount of radioactive waste expected to be generated by the design. [Section 3.7.2.1]
- **Target Values for Radiation Exposure**. Provided guidance for developing target values for the amount of radiation exposure expected to be incurred from the design. [Section 3.8]
- **Environmental Qualification of In-Vessel Components**. Added guidance regarding environmental qualification of components installed inside the reactor vessel such as in-vessel control rod drive mechanisms. [Sections 4.8.2.1 and 5.3.6]

- **Water Chemistry**. Some smLWRs may not operate under water chemistry conditions for which there is a large experience base. Added guidance that any deviations from established water chemistry guidelines must provide a technical justification. [Section 5.5.2.5]
- **Target Plant Availability**. Added a separate target plant availability goal of 95% for smLWRs. [Section 6.3.5]
- **Design Refueling Outage Length**. URD requirements for ALWRs specified that the design should enable a refueling outage to be completed in 17 days. These requirements were revised for smLWRs to provide a qualitative requirement that the design refueling outage sequence should support the plant availability goal. [Section 6.3.7]
- **Shared Systems**. Requirement modified to note that use of shared systems may be appropriate for smLWR plants with multiple units. [Section 6.4.1]
- **Increased Risk for Unproven Technology**. Added discussion that use of unproven technologies may require the designer to perform evaluations of safety advantages versus increased risk because of lack of experience with the new technology. [Section 11.4]

Tier 2 – Chapter 2, Power Generation Systems

Chapter 2 is composed of 162 (153 without TOC, references, and acronyms) pages of technical and project requirements. A total of 27 changes were made as a result of industry reviews and comments. Following is a brief summary of the major changes made to incorporate smLWRs into Chapter 2 of the URD:

- **Lack of a Backup Feedwater System**. In large passive plants, a non-safety-related backup feedwater system is used that is similar to the auxiliary feedwater system in a current generation PWR. Sections were revised to note that some smLWRs do not need a backup feedwater system. [Sections 1.3.6, 3.1.3, and 8.2.1.1]
- **Main Steam Power-Operated Relief Valves (PORVs)**. Added smLWRs to the discussion of the required number of PORVs. [Section 3.4.3.3.1]
- **Feedwater Heaters**. During development of the URD, a cost-benefit analysis was performed that established the optimum number of stages of feedwater heating. Because this analysis was performed only for large plants, the section was revised to state that for smLWRs the optimum number of feedwater heating stages must be determined by the vendor. [Sections 4.3.1.6 and 4.3.3]
- **Number of Condensate Pumps**. Section was revised to provide flexibility on the number of condensate pumps and to add guidance on the need for installed spare pumps for smLWRs. [Section 4.3.2.1.1]
- **Number of Feedwater Booster Pumps**. Section was revised to provide flexibility on the number of feedwater booster pumps. [Section 4.3.4.1.1]
- **Condenser Flow Paths**. Section was revised to provide flexibility on the number of circulating water flow paths due to the small size of smLWRs. [Section 4.4.3.1]

Tier 2 – Chapter 3, Reactor Coolant System and Reactor Non-Safety Auxiliary Systems

Chapter 3 is composed of 274 (263 without TOC, references, acronyms, and definitions) pages of technical and project requirements. A total of 93 changes were made as a result of industry reviews and comments. Following is a brief summary of the major changes made to incorporate smLWRs into Chapter 3 of the URD:

- **Natural Circulation Cooling**. Natural circulation is a practical cooling option for smLWR designs due to their low power levels; however, the existing URD provisions did not address natural circulation. Revised requirements as needed to accommodate natural circulation designs. [Sections 1.3.1, 2.3.1.2, 3.1.2.4, 3.1.3.5, 3.1.3.11, 3.2.1.4, 3.5.1, 3.5.2, and 6.1.3.4]
- **Flooded Containments**. Some smLWR designs use flooded containments. Revised wording to differentiate between planned and unplanned transfers of reactor coolant to the containment envelope. [Section 3.1.2.2]
- **Lack of PSIS**. Some smLWR designs do not include a passive safety injection system (PSIS). Revised statements to provide exceptions for such designs. [Sections 2.3.1.1 and 3.1.3.12]
- **Differences in System Designs**. SmLWRs may perform design functions with systems other than those employed by traditional LWRs, or the systems they use may not include components found in traditional systems. An example is an integral reactor design that includes a pressurizer but not a pressurizer surge line (Sections 3.3.1.1 and 3.4.3.3). Revised requirements to provide guidance or exceptions to account for these differences. [Sections 1.4, 2.2.14, 3.1.1.1, 3.1.1.2, 3.1.3, 3.1.3.1, 3.1.3.6, 3.1.3.8, 3.1.3.10, 3.1.3.13, 3.1.3.16, 3.1.3.17, 3.3.1.1, 3.3.4.1, 3.3.4.2.1, 3.4.2.9.1, 3.4.2.10, 3.4.2.11.2, 3.4.3.3, 4.1.3, 5.1.3, 5.1.3.9.1, 5.1.3.10.1, 6.1.3, 7.1.3, 8.1.3, 9.1.3, and 9.3.1.1.1]
- **Low Temperature Overpressure Protection**. Requirement changed to provide design flexibility for smLWRs in providing low-temperature overpressure protection. [Sections 3.3.2.1 and 9.1.2]
- **RCS Safety Valve Discharge**. Added allowance for RCS safety valve discharge into the containment envelope for some designs. [Section 3.4.4.5]
- **Steam Generators**. Revised requirements to account for differences in smLWR steam generator designs and first-of-a-kind design issues. [Sections 4.1.1.1, 4.1.2.6, 4.2.3.1.1, 4.3.2.1.1, 4.3.2.1.2, 4.4.1.2.1, 4.4.1.5.1, 4.4.1.8.2, and 4.6.2]
- **Soluble Boron**. Some smLWR designs do not use soluble boron for reactivity control. Added exceptions to requirements as needed. [Sections 6.2.2.1, 6.2.2.2, and 6.2.3.1]
- **Location of High-Energy Piping**. Previous URD requirements were established to minimize the amount of high-energy piping outside containment. Exceptions were added because smLWRs have smaller containments. [Sections 6.3.1.5 and 6.3.2.6]
- **Designs with no IRWST**. Some smLWR designs do not include an in-containment refueling water storage tank. Added exceptions to requirements as needed. [Sections 9.1.2, 9.1.3, and 9.2.2.1.1]

Tier 2 – Chapter 4, Reactor Systems

Chapter 4 is composed of 159 (150 without TOC, references, acronyms, and definitions) pages of technical and project requirements. A total of 82 changes were made as a result of industry reviews and comments. Following is a brief summary of the major changes made to incorporate smLWRs into Chapter 4 of the URD:

- **Refueling Cavity Seal**. Clarified how refueling cavity seal requirements apply to smLWR designs. [Sections 2.3.2.7 and 6.3.1.8]
- **Installation of Vessel Internals**. Expanded the rationale to encourage factory installation of vessel internals. [Section 3.3.1.11.1]
- **Neutron Shielding**. Revised section to note that more neutron shielding may be required in smLWRs due to the reduced amount of concrete used in many designs. [Section 6.1.3.4]
- **Target Plant Availability**. Added a separate target plant availability goal of 95% for smLWRs. [Section 7.3.1.2.2]
- **Internal Control Rod Drive Mechanisms**. Added requirements for control rod drive mechanisms mounted inside the reactor coolant pressure boundary. [Sections 6.3.1.5, 8.2.1.1, 8.2.1.3, 8.3.1.3, 8.3.4.1.1,and 8.3.4.1.2]

Tier 2 – Chapter 5, Engineered Safety Systems

Chapter 5 is composed of 398 (381 without TOC, references, acronyms, and definitions) pages of technical and project requirements. A total of 66 changes were made as a result of industry reviews and comments. Following is a brief summary of the major changes made to incorporate smLWRs into Chapter 5 of the URD:

- **External Flooding of Reactor Vessel**. Certain smLWR designs have provisions to flood the annular space between the reactor and containment. Added guidance addressing vessel corrosion. [Section 1.2.2.2]
- **Large-Break LOCA**. Added discussion that some smLWRs may be able to exclude a large-break loss-of-coolant accident from their design basis. [Section 1.2.3]
- **Size of Emergency Planning Zone**. Added discussion that due to the small size of smLWRs, a smaller EPZ may be justified. [Section 1.2.3]
- **Reduced Core Damage Potential**. Added discussion that smLWR designers may be able to demonstrate that either rapid core melting or large-scale core melting (or both) are not plausible. [Section 1.2.4.2]
- **Core Cooling Makeup Inventory**. Allowed the use of either stored inventory (IRWST) or coolant retention for providing RCS makeup. [Section 2.1.3]
- **Accident Source Term**. Revised to permit the use of either NUREG-1465 guidance or plant-specific evaluations. [Section 2.4.1.3]
- **Containment Leak Rate**. Revised to note that smaller smLWR containments may require lower leak rates even with a lower fission product inventory. [Sections 2.4.2.4 and 6.4.1.3.3]

- **Containment Combustible Gas Control**. Changed requirement from prescribing a combustible gas control system to a performance-based requirement to ensure that combustible gas concentrations are maintained below the detonation limit. [Section 2.4.2.7]
- **Passive Safety Injection System**. Revised to note that some designs recycle coolant via natural circulation and do not include a passive safety injection system. [Section 5.2.1.1]
- **Containment Performance**. Revised to indicate that smLWR containments will have substantial margin to failure. [Section 8.2.2.1.1]

Tier 2 – Chapter 6, Building Design and Arrangement

Chapter 6 is composed of 202 (192 without TOC, references, and acronyms) pages of technical and project requirements. A total of 13 changes were made as a result of industry reviews and comments. Following is a brief summary of the major changes made to incorporate smLWRs into Chapter 6 of the URD:

- **Constructability, Operability, and Maintainability**. Revised section to note that smLWRs place more emphasis on below-grade structures. [Section 1.5.1]
- **Startup Testing**. Revised section to note that smLWRs may have completed units in operation on a site while others are under construction. [Section 2.2.5]
- **Embedded Primary Systems**. Added discussion that smLWRs may have primary systems that are fully or partially embedded (that is, below-grade). [Section 3.3.2.5.2]
- **Primary Containment Structure**. Because the large dry containment structure typical of current plants will not be used for most smLWRs, guidance was added to identify the major considerations affecting the containment structure design, including access for required inspections. [Sections 4.3.4.1, 4.3.4.1.2, 4.3.4.2, and 4.3.4.3.2]
- **Designs with no IRWST**. Some smLWR designs do not include an in-containment refueling water storage tank. Added exception to requirement. [Section 4.3.4.4]

Tier 2 – Chapter 7, Fueling and Refueling Systems

Chapter 7 is composed of 124 (116 without TOC, references, acronyms, and definitions) pages of technical and project requirements. A total of 124 changes were made as a result of industry reviews and comments. Following is a brief summary of the major changes made to incorporate smLWRs into Chapter 7 of the URD:

- **Overhead Crane Capacity**. Requirements revised to reflect potentially heavier lifts than those in large plants due to the need to disassemble integrated reactor assembly components. [Sections 2.3.2.3, 2.3.2.3.1, and 2.3.2.3.3]
- **Remote Disassembly Operations**. Requirements revised to include integrated reactor assembly designs and to note that some disassembly operations may be performed underwater as opposed to current designs in which reactor vessel head detensioning is performed dry. [Sections 2.3.6.1 and 2.3.6.3]

- **Design Refueling Outage Length**. URD requirements for ALWRs specified that the design should enable a refueling outage to be completed in 17 days. These requirements were revised for smLWRs to provide a qualitative requirement that the design refueling outage sequence should support the plant availability goal. [Sections 1.5.2, 2.2.1, 2.2.1.1, 2.2.1.2, 2.2.1.3, 4.2.1, and 4.5.3]
- **Plant Arrangement/Reactor Design**. Existing requirements were based on the standard of a large dry containment and a reactor coolant system with discrete large components. These requirements were revised to allow for variations in containment and reactor designs to accommodate smLWR concepts, including continuous operation of modules that are not engaged in refueling. [multiple sections]
- **Spent Fuel Pool Capacity**. Requirements changed to allow for spent fuel pool designs that may accept fuel from more than one reactor and for pools designed to accept fuel cartridges. [Sections 1.3.1 and 2.2.5.1]
- **Disassembly of Connected Piping**. Requirement revised to provide guidance for designs with an integrated reactor inside a containment vessel, with removable piping sections connecting the reactor to the containment vessel. Guidance includes handling, cleanliness control, and inspection. [Section 2.3.1.3.4]
- **Transport of Reactor Modules**. Added new requirement to address neutron flux monitoring and cooling for smLWR designs that require movement of reactor modules loaded with fuel between the reactor vessel and the fuel storage or handling area. [Sections 2.3.2.3.4 and 2.3.4.7]

Tier 2 – Chapter 8, Plant Cooling Water Systems

Chapter 8 is composed of 173 (162 without TOC, references, acronyms, and definitions) pages of technical and project requirements. A total of 40 changes were made as a result of industry reviews and comments. Following is a brief summary of the major changes made to incorporate smLWRs into Chapter 8 of the URD.

- **Shared Systems**. Requirement modified to note that use of shared cooling water system designs may be appropriate for smLWR plants with multiple units. [Section 1.5.1]
- **Normal Power Heat Sink**. Requirement for the normal power heat sink changed to require consideration of site environmental conditions, instead of the previously prescribed wet cooling tower. [Sections 2.2.15 and 7.2.2.1.2]
- **System Configuration**. The basic configurations of cooling water systems are considered to be generally applicable to all plant designs. However, due to the variety of smLWR designs, several requirements were modified to note that system configurations may vary from the stated requirements. [Sections 1.3.1, 4.1.1, 4.1.2.4, 4.3.1.3, and 4.3.1.5]
- **Design Outage Lengths**. URD requirements for ALWRs specified that the design should enable a refueling outage to be completed in 17 days, with an additional planned 25-day annual maintenance outage. These requirements were revised to remove the prescribed maintenance outage length. A *routine planned outage* was specified instead. [Sections 6.3.4.1, 6.3.4.3, 7.2.2.3.3, and 7.2.2.3.5]

- **Makeup Water Intakes**. Requirement changed to allow for other intake designs such as collection wells instead of being limited to trash racks and traveling screens. [Section 7.2.2.1.3]
- **Spent Fuel Pool Design**. Requirement changed to allow for spent fuel pool designs that may accept fuel from more than one reactor and for pools designed to accept fuel cartridges or reactor fuel modules. [Section 9.1.1.3]
- **Containment Penetrations**. Requirement for the configuration of chilled water system containment penetrations revised to note that smLWR configurations may vary due to different containment concepts used in smLWR designs. [Section 8.3.1.1.5]

Tier 2 – Chapter 9, Site Support Systems

Chapter 9 is composed of 188 (176 without TOC, references, acronyms, and definitions) pages of technical and project requirements. A total of 50 changes were made as a result of industry reviews and comments. Following is a brief summary of the major changes made to incorporate smLWRs into Chapter 9 of the URD:

- **Differences in System Designs**. SmLWR systems may have configurations that vary from those of traditional systems. Revised requirements to provide guidance or exceptions to account for these differences. [Sections 1.5, 3.1.3, 4.1.3, 5.1.4, 6.1.3, 7.1.3, 8.1.3, 8.3, 8.4, and 9.1.3]

Tier 2 – Chapter 10, Man-Machine Interface System (M-MIS)

Chapter 10 is composed of 439 (415 without TOC, references, acronyms, and definitions) pages of technical and project requirements. A total of 198 changes were made as a result of industry reviews and comments. Following is a brief summary of the major changes made to incorporate smLWRs into Chapter 10 of the URD:

- **Operating Staff**. Requirements revised to emphasize automated controls to allow optimization of operating staff for multiple reactor sites. This is based on the lower hazards associated with smaller reactors as well as the increased safety margins inherent in passive plant designs. [Sections 1.1, 2.2.7, 3.1.3.3.4, 3.3, 3.4.1.1, 4.2.1, and 9.2.3.1]
- **Main Control Room Layout**. Requirements revised to allow additional flexibility in the design of main control room areas. Designing for multiple reactor sites and for progressive addition of units—as well as the potential for an operator to have responsibility for several workstations—will necessitate innovative control room designs. [Sections 4.2.3 and 4.9.1]
- **Neutron Flux Control**. Requirements revised to remove assignment of neutron flux control methodologies to specific reactor types (that is, soluble boron for PWRs or reactor flow rate for BWRs). Smaller core designs may allow for control methodologies that cross traditional boundaries. [Section 7.2.1.2]
- **Automatic Operation of Safety Systems**. Existing requirement stated that protection and safety systems shall "normally" operate without operator action for at least 30 minutes after actuation. Removed the "normally" to establish that 30 minutes is the minimum expectation for this requirement. [Section 8.2.3.2]

- **Local vs. Main Control Room Controls**. Requirements changed to direct that both local and main control room controls be part of the same integrated M-MIS. The degree of control and monitoring provided at each location can then be a function of the M-MIS design. This increases the ability to adapt the M-MIS as needed. [Sections 2.2.11 and 3.1.3.3.3]
- **Remote Shutdown Stations.** Requirement revised to guide the plant designer to address the possibility that remote shutdown stations may need to be staffed for multiple reactors at one time. [Section 4.9.3.4]

Tier 2 – Chapter 11, Electric Power Systems

Chapter 11 is composed of 226 (205 without TOC, references, acronyms, and definitions) pages of technical and project requirements. A total of 81 changes were made as a result of industry reviews and comments. Following is a brief summary of the major changes made to incorporate smLWRs into Chapter 11 of the URD:

- **Target Plant Availability**. Added a separate target plant availability goal of 95% for smLWRs. [Section 2.2.3]
- **Off-Site Power Circuit**. Requirements modified to provide flexibility for smLWR plants with multiple small units. Allowed for reduction in the number of unit auxiliary transformers, use of one three-phase main transformer instead of three one-phase main transformers, and elimination of an installed spare unit auxiliary transformer. [Sections 3.4.2, 3.4.3, and 3.4.6]
- **Two-Bus Arrangement**. Allowed for use of a two-bus design for medium-voltage AC non-safety distribution (vs. four-bus for passive ALWRs) if justified by analysis. [Section 4.3.2]
- **Manual Startup of On-Site Power Sources**. Requirement revised so that all on-site power sources (safety and non-safety) for all plant designs are capable of being manually started without any AC or DC electric power. [Section 5.5.1.8]

Tier 2 Chapter 12, Radioactive Waste Processing Systems

Chapter 12 is composed of 230 (215 without TOC, references, acronyms, and definitions) pages of technical and project requirements. A total of 57 changes were made as a result of industry reviews and comments. Following is a brief summary of the major changes made to incorporate smLWRs into Chapter 12 of the URD:

- **Differences in System Designs**. SmLWR systems may have configurations that vary from those of traditional systems. Revised requirements to provide guidance or exceptions to account for these differences. [Sections 1.5, 2.1.5, 3.1.3.2, 3.1.3.3, 3.1.3.4, and 4.3.1.4]
- **Target Values for Waste Generation**. Provided guidance for developing target values for the amount of radioactive waste expected to be generated by the design. [Sections 1.3.1.1 and 4.4.1.1]
- **Off-Site Waste Processing**. Added allowance for off-site processing of waste. [Section 1.4.1.2]
- **System Controls**. Removed statement that limited control of the gaseous radwaste system from the main control room to BWRs only. SmLWRs will centralize most controls. [Section 2.4.1.2.2]

- **System Capacity Requirements**. Revised Section 4.4.3.2 to replace a description of waste processing sequence with a building design requirement to provide space for storage, sorting, and loading operations. Other sections revised to emphasize similar design considerations. [Sections 4.4.3.2, 4.5.2.1.2, 4.5.3.1.6, and 4.7.4.2]
- **Mobile Treatment Option**. Revised requirement to include designing to provide necessary space and system connections to permit future use of mobile processing systems. [Sections 4.4.5.1.3.1 and 5.2.1.1]
- **Corrosion-Resistant Material**. Changed to allow the use of corrosion-resistant materials other than austenitic stainless steel to allow for advances in materials technology. Disallowed the use of surface coatings. [Sections 4.4.5.4.4.4 and 4.4.5.5.1]
- **Target Plant Availability**. Added a separate target plant availability goal of 95% for smLWRs. [Section B.1.1]
- **Design Outage Lengths**. URD requirements for ALWRs specified that the design should enable a refueling outage to be completed in 17 days. Requirements were revised to note that this is not applicable to smLWRs. [Section B.1.1]

Tier 2 – Chapter 13, Main Turbine-Generator Systems

Chapter 13 is composed of 126 (119 without TOC, references, acronyms, and definitions) pages of technical and project requirements. A total of 32 changes were made as a result of industry reviews and comments. Following is a brief summary of the major changes made to incorporate smLWRs into Chapter 13 of the URD:

- **Turbine Interchangeability**. Added guidance that for smLWRs, turbine interchangeability may include the entire turbine instead of just individual rotor assemblies. [Sections 1.5.1.17 and 3.3.1.1.1.17]
- **Differences in System Designs**. SmLWR systems may have configurations that vary from those of traditional systems. Revised requirements to provide guidance or exceptions to account for these differences. [Sections 1.4, 3.1.3, and 4.1.3]
- **Design Refueling Outage Length**. URD requirements for ALWRs specified that the design should enable a refueling outage to be completed in 17 days. These requirements were revised to note that outage durations and inspection intervals may be different for smLWRs. [Sections 2.2.3 and 2.3.8.1.3]

5
PERSPECTIVE ON USE OF THE URD INCLUDING SMLWR TO ACHIEVE VALUE

The EPRI URD including smLWR leads directly to achievable value for owner/operators of new nuclear plants and for designers, manufacturers, constructors, and project teams of new nuclear plants. Some of these value uses are described in this section and are equally valid for large and small new nuclear plants.

Before smLWR purchase:

1. Conceptual designs
   a. Existing and new entry smLWR designers/manufacturers can use the URD to create and screen initial SMR design concepts.
   b. New entry designers and groups such as universities and national laboratories can use the URD as a sounding board for evaluation of advanced SMR concepts.
2. Market-ready designs
   a. Designers/vendors/manufacturers and EPC teams can offer smLWR project packages based on the URD, knowing that they meet owner/operator requirements and expectations.

As part of the smLWR purchase process:

1. Bid package preparation
   a. The URD is an index of technical and project management topics of concern to owner/operators that can be used to ensure that a request for proposal (RFP) covers all areas of concern and interest.
   b. Frequently, compliance with the URD is included as a requirement in the RFP. The bidders are expected to declare their compliance with the URD requirements and expectations. The potential owner can gain significant insight into the design/project being proposed by the number and extent of exceptions taken to the URD.
2. Proposal preparation
   a. Reactor designers and new plant project teams can reduce their cost of responding to RFPs by performing a one-time comparison of their offering against the URD requirements. Minor adjustments to design and other project plans may eliminate the need for listed exceptions and clarifications.
   b. Displaying to potential owner/operators the degree of compliance with the URD is a good way to build confidence in your new project plan and ensure being one of the potential bidders who will receive the RFP and have the opportunity to bid the project.

3. Proposal evaluation
   a. Comparison of URD exceptions by each vendor is quicker and easier than trying to interpret each design against owner-unique RFP requirements.
   b. The structure of the URD enables the grouping of exceptions and clarifications by each bidder under specific TOC identifiers and technical topics. This allows an "apples to apples" comparison of technical and project management variations among bidders against established industry requirements and expectations.
   c. The URD requirements provide an industry standard to determine the acceptability of exceptions and clarifications proposed by a bidder.
4. Contract content
   a. The URD of record in the RFP with listed exceptions and clarifications can be a major part of primary project contracts. The years of industry experience, technical requirements, and project management insights captured in the URD in carefully structured statements will serve an owner and a supplier well over the life of a new nuclear plant project and the life of the plant.
   b. Sub-portions of the URD (for example, equipment reliability requirements) can be extracted and included in equipment procurement documents.

Post-purchase smLWR project use:

1. Project organization and management
   a. Once established by project contract documents, the URD becomes a valuable source of project requirements and expectations. These documented decisions establish the basis that allows the project to proceed more aggressively, reducing the length of the overall project schedule.
   b. The URD provides detailed and meaningful bases for the structure and scope for many of the programs, databases, and approaches needed to achieve the project and operate the units. This allows these project/plant segments to be formulated and implemented more quickly.
2. Project design reviews
   a. As project detailed design progresses, the owner/operator and the extended project team will routinely perform design reviews of structures, systems, and components. The URD is a proven source document for technical and project details against which to accomplish these design reviews.
3. Project assessment and evaluation
   a. It has been said that "you get what you inspect, not what you expect." A robust self-assessment and requirement/expectation monitoring process will greatly improve the value achieved in the new plant project and the new plant itself. The content of the URD provides a detailed set of requirements and expectations that can be grouped in small sets and routinely evaluated by individuals and/or small teams.

    b. Self-assessment (see Appendix C for definition) will drive out project issues and concerns before they become issues of note impacting project schedule, budget, and/or quality.

Other uses of the URD including smLWR:

1. Current fleet operation
    a. The URD can be used by the current fleet of operating reactors as a major source of guidance, perspective, and lessons learned when considering and detailing plant modifications.
    b. The URD is a source of performance standards and objectives that can be used for standardization across a fleet of operating reactors.

Access to the URD:
The URD in its entirety is available to members of EPRI's Nuclear Sector and/or members of EPRI's Advanced Nuclear Technology (ANT) Program. For contacts and information on memberships, see details at www.epri.com.

Future:
The EPRI Advanced Nuclear Technology Program continues to monitor small modular reactor activities. Projects on particular topics are initiated as determined by the program with input from ANT industry advisors. Several SMR-related tasks are active or under consideration. At this time, the ANT Program is reviewing how the URD might be expanded to included SMR concepts beyond smLWR.

A
GUIDING PRINCIPLES FOR INCLUSION OF SMLWR REQUIREMENTS INTO THE EPRI URD

The Development of the Small Modular Light Water Reactor Utility Requirements Document (endorsed and accepted June 2013)

Overview

The Advanced Light Water Reactor (ALWR) Utility Requirements Document (URD) is being expanded to address small, modular, light water reactors (smLWRs). The URD is a set of comprehensive requirements for ALWRs initially developed in the 1980s in a utility-driven effort managed by the Electric Power Research Institute (EPRI) and co-sponsored with the Department of Energy (DOE). The URD is based on construction and operating experience of the current LWR fleet. The URD scope is broad; it includes requirements ranging from safety system design to electrical systems to the busbar and building design and layout. The URD has been an invaluable, global resource for new and experienced nuclear plant owners in preparing bid specifications and reviewing responses to bids. Plants designed in accordance with the URD ensure that the owner/operator will have a nuclear power plant that is safe, economic, reliable, operable, and maintainable. The new work expands the URD methodology to include the smLWRs currently under development and those designs to follow.

Background and Guiding Principles

The URD is founded on the fundamental principle that all new designs should take into account the almost 60 years of construction and operating experience from the current fleet of light water reactors. The requirements—developed by experienced utility personnel, technical experts, plant designers, and engineers—required the approval of the knowledgeable and experienced senior utility executives of the Utility Steering Committee (USC). This imprimatur provided by the USC gave the URD the required weight to interact effectively with the regulators and the nuclear plant designers and constructors. The requirements are based on a broad set of guiding principles. The guiding principles are provided as follows, with the unique aspects relative to smLWRs noted in *italics*.

- Promote stable regulations, which are needed to ensure safety and increase confidence in the viability and practicality of smLWRs for both owner/operators and the investment community.
- Provide design requirements for full plant scope to foster standardization and reduce nth-of-a-kind overall plant costs.
- Instill investor confidence to ensure investment community and stockholder support for new nuclear projects.

- Simplify designs to eliminate costly complexities found in earlier generation plants; increase reliability; and reduce capital, operations, and maintenance costs.
- Increase design margins for the benefit of the owner/operator that go beyond those required by regulations to address uncertainties.
- Select materials and components based on life-cycle versus up-front costs to improve safety and reduce operations and maintenance costs.
- Specify a minimum plant design life of 60 years with the intent of sustainable operation beyond 60 years.
- Ensure high plant reliability and availability to meet future power demands and increase confidence in revenue generation in all electric market conditions.
- Support load following with high ride-out (load rejection) capability to support efficient and effective grid operation in all market conditions.
- Use probabilistic analyses (safety and reliability) in all phases of new plant design, construction planning, and operation.
- Incorporate human factors into all aspects of the design, *which is particularly important for smLWRs with the multiple unit control stations.*
- Increase plant safety with an emphasis on accident prevention, mitigation, and recovery.
- Increase investment protection for the owner/operator to maximize asset utilization and minimize negative regulatory actions and public opinion.
- Use proven technology from within the commercial nuclear industry and beyond. *Comprehensive, robust test programs are required for any unproven technology.*
- Promote design for ease of maintenance, which reduces costs and occupational exposure through effective maintainability, inspectability, and replaceability assessments. *This is particularly true for the smLWRs in which the designs are integral and space is at a premium.*
- Adopt state-of-the-art construction approaches and 90% engineering completion before the start of construction to reduce capital and construction costs and the length of construction schedules and increase investor confidence. *The novel smLWR feature of shop fabrication and shipment of the integral primary system is critical to their successful deployment.*
- Ensure quality commensurate with safety and reliability requirements.
- Recognize that electric busbar costs must compete with those of other forms of emission-free baseload generation and be affordable to the average size electric utility. This competitiveness is required to support fuel diversity, greenhouse gas emissions reduction, investor confidence, and state economic regulatory acceptance.
- Increase resistance to sabotage and minimize security breaches through integrated plant design and physical arrangements. *The fact that most of the smLWR designs are expected to be located underground will facilitate enhanced security and sabotage resistance.*

- Be a good neighbor to the surrounding environment by minimizing radioactive and chemical releases in normal, upset, refueling, and accident conditions.
- Provide a basis for simplified off-site emergency planning, which will enhance public acceptance. *The deployment of smLWRs to replace retired coal-fired power stations in critical locations for electric grid stability requires acceptance of small nuclear plants closer to population centers.*
- Promote the use of a "life of the plant" information management system capable of collecting and maintaining knowledge from initial design through decommissioning to support configuration management, improve regulatory acceptance, support sustainable plant operation beyond initial design life, and minimize decommissioning costs.

Application of the URD Principles to Small Modular Light Water Reactors

With the increasing interest of utilities and owner/operators in smLWRs, a process similar to that used to develop the original URD is underway to expand it to encompass small reactors of less than 300 MWe. Similar to the original ALWR URD development, the new URD development work is co-sponsored by the DOE.

A key aspect of the new smLWR URD process is the creation of an Executive Steering Committee that serves a similar function as the original Utility Steering Committee. However, resource constraints—time and available funding—require a more efficient and effective process. The technical requirements that need to be added or modified to support the evolving smLWR designs will be drafted by technical working groups composed of industry subject matter experts, designers, and owner/operators. The smLWR Core Team is a senior, cross-functional technical team with experience with the URD process, reactor design and engineering, and plant operations and maintenance. The functions of the Core Team are to 1) ensure consistency, verifiability, and functionality of the draft requirements from the technical working groups and 2) prepare proposals for smLWR requirements to the Executive Steering Committee. The Executive Steering Committee has the responsibility to endorse—or require modifications by the Core Team—in order for the requirements to become part of the URD. It is expected that the Executive Steering Committee will meet at least on a semiannual basis.

The organization is shown in Figure A-1.

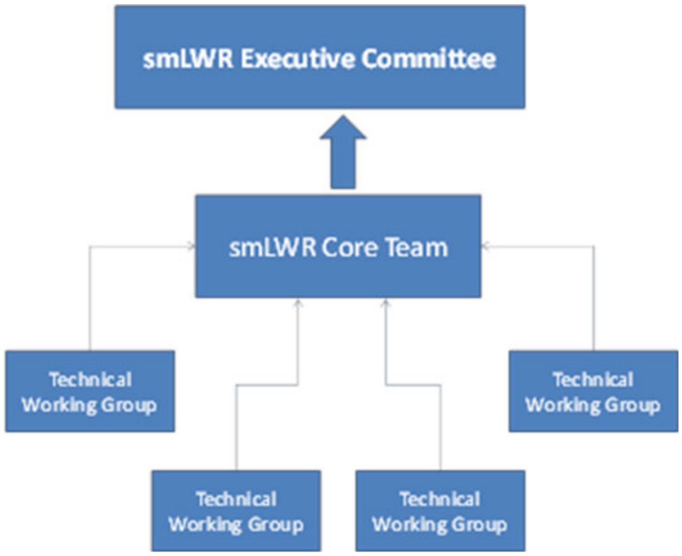

Figure A-1
Project organizational chart

Process for Developing the smLWR URD

The process to develop the smLWR URD has four steps:

1. Identify those existing ALWR requirements that apply directly to smLWRs. We expect that the majority of the existing requirements will apply with little or no modification.
2. Identify those existing ALWR requirements that do not apply and are not needed for smLWRs. We expect this to be a relatively small number of the overall requirements.
3. Identify those existing ALWR requirements that potentially apply to smLWRs but that require significant modification to be relevant.
4. Identify the completely new requirements that are needed to address the unique characteristics of smLWRs.

Technical working groups will conduct the technical work required in Steps 3 and 4 to modify existing requirements and develop new ones. The approach used for the new or significantly modified requirements will be somewhat different from the approach used for the original URD requirements. The new approach and rationale are provided next.

The owner/operator requirements for smLWRs comprise sets of performance-based, risk-informed requirements for the smLWR design, component manufacturing, plant construction, operation, and maintenance to ensure that the as-built nuclear plants meet the desired levels of safety, reliability, and economic performance. Previous URD revisions had similar goals but provided prescriptive requirements with accompanying rationales for the requirement. Such an approach was appropriate for the time (1980s and 1990s) because a significant amount of operating experience (good and bad) was available, and the new evolutionary and passive ALWR plant designs were quite similar to those in service. The smLWRs are very different from the operating reactors, and the design certified ALWRs as well as those ALWRs undergoing design certification. There is no smLWR construction and operating experience on which to base requirements. Times have changed with the increased use of probabilistic safety and reliability models in nuclear plants. The move to performance-based, risk-informed requirements is analogous to the U.S. Nuclear Regulatory Commission's (NRC's) transition from compliance-based regulations to more risk-informed regulations.

The smLWR requirements will address only those new, or significantly modified, requirements deemed by the owner/operators to be critical to the achievement of the desired safety, reliability, and economic targets. The safety targets will exceed those required by the NRC to protect the health and safety of the public to further protect the major asset investment of the owner/operator. Each smLWR requirement will quantify the level of performance required, similar to the rationale provided in the current URD. Wherever possible, an acceptable means to achieve the requirement will be provided. The acceptable means provide a field-proven way to meet the requirement, but they do not limit the designer from using alternative, but effective, methods that may result in improved economics, safety, and reliability. Existing URD requirements will be used as acceptable means where appropriate.

The smLWR requirement is compared to the traditional ALWR requirements in Table A-1.

Table A-1
Traditional vs. smLWR requirements

Application	Mandatory	Supporting
smLWR	Quantitative performance standard	Basis and acceptable means, if available
ALWR	Prescriptive requirement	Rationale for requirement

Features of the URD

The purpose of the URD is to present a clear, complete statement of utility requirements for their next generation of nuclear plants. The current URD consists of a comprehensive set of design requirements for future LWRs. The requirements are grounded in proven technology of the almost 60 years of commercial U.S. and international LWR experience. Furthermore, the URD builds on this LWR knowledge base, addressing design and operational issues that originally existed in the current generation of plants while incorporating optimized features from industry R&D that ensure a simple, robust, more forgiving design.

The URD process provides significant value for current and future nuclear plant designs by incorporating and reflecting the many reactor-years of industry experience into a single source document. Through the use of the URD, the industry can achieve the following:

- Realize significant improvements in safety
- Promote a more stable regulatory basis, including regulatory optimization, increased margin to regulations, and resolution of state and local regulatory issues
- Promote standardization
- Reduce capital and O&M costs
- Restore investor confidence

Through DOE support, the smLWR URD will be made available to support the deployment of SMRs expected to begin by 2022 and will contribute to the advancement of our nation’s energy independence and security.

Completion of the smLWR URD

The smLWR URD will be completed by December 20, 2014.

B

TOPIC POSITION PAPER LISTING FOR SMLWR URD INCLUSION

Topic Position Paper Number	Topic Position Paper Title
1	Plant Availability Targets for smLWR Plants
2	ASME Code Boundaries for smLWR Components
3	URD Focus on Passive smLWRs Plants
4	Maintainability and Inspectability of smLWR Plants
5	Applicability of ALWR Requirements to smLWR Plants
6	Spent Fuel Pool Capacity for smLWR Plants
7	Coping Time for smLWR Plants
8	General Design Criteria 17 Compliance for smLWR Plants
9	New Requirements for smLWRs with Internal CRDMs
10	Source Term and EPZ Considerations for smLWR Plants
11	CDF Goals for smLWR Plants
12	Development of smLWR Hydrogen and Oxygen Generation and Mitigation Requirements
13	Multi-Reactor/Multi-Turbine smLWR Plant Considerations
14	Small Turbine-Generator Considerations for smLWR Plants
15	Tier 1 High-Level Definitions
16	Development of smLWR Flexible Power Operation Requirements
17	Redundant Components versus Plant Reliability Considerations for smLWR Plants
18	Potential Economic Goals for smLWRs
19	Change URD Bias from Manual Operation of Systems to a Bias Towards Automation of Systems

Topic position papers (TPPs) were created by the Core Team to document their perspective on complex issues. The papers contain the issue under consideration, the background and basis compiled to better understand the issue, and the proposed resolution that would guide the detailed changes necessary for the URD. Frequently, the related changes to the URD occurred in multiple locations. The TPPs set the framework and the direction for the detailed changes while documenting the general concept in one location.

The TPPs in their entirety are included in the introductory report of URD Revision 13 (3002003129).

C
ACRONYMS AND DEFINITIONS

Acronyms

AC	alternating current
ALWR	advanced light water reactors
ANT	EPRI Advanced Nuclear Technology Program
ASME	American Society of Mechanical Engineers
CDF	core damage frequency
CRDM	control rod drive mechanism
CVCS	chemical volume and control system
DC	direct current
DOE	United States Department of Energy
EPC	engineering, procurement, construction
EPRI	Electric Power Research Institute
EPZ	emergency preparedness zone
HVAC	heating, ventilating, and air conditioning
IRWST	in-containment refueling water storage tank
LOCA	loss-of-coolant accident
LWR	light water reactors
PRA	probabilistic risk analysis
PSIS	passive safety injection system
RCP	reactor coolant pump
RCS	reactor coolant system
RFP	request for proposal
SI	safety injection
SME	subject matter expert
smLWR	small modular light water reactors
SMR	small modular reactor

TOC	table of contents
TPP	topic position paper
URD	Utility Requirements Document
US	United States

Definitions

Industry	The commercial nuclear industry in the U.S. and worldwide participants.
Self-Assessment	The process of an organization, sub-portion of an organization, and/or an individual comparing the standards and expectations they have set for themselves against their performance. Detailed observations and data reviews are accomplished. Corrective actions are established when gaps between performance and expectations are identified.
AP1000	Advanced passive large nuclear plant designed and offered by Westinghouse Corp.
ESBWR	Advanced simplified large nuclear plant designed and offered by General Electric Corp.
EPR	Advanced evolutionary large nuclear plant designed and offered by Électricité de France and associated companies.

The Electric Power Research Institute Inc., (EPRI, www.epri.com) conducts research and development relating to the generation, delivery and use of electricity for the benefit of the public. An independent, nonprofit organization, EPRI brings together its scientists and engineers as well as experts from academia and industry to help address challenges in electricity, including reliability, efficiency, affordability, health, safety and the environment. EPRI also provides technology, policy and economic analyses to drive long-range research and development planning, and supports research in emerging technologies. EPRI's members represent approximately 90 percent of the electricity generated and delivered in the United States, and international participation extends to more than 30 countries. EPRI's principal offices and laboratories are located in Palo Alto, Calif.; Charlotte, N.C.; Knoxville, Tenn.; and Lenox, Mass.

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